Using an Avian Radar to Supplement an Airport Wildlife Hazard Assessment

July 2012

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16. Abstract

Wildlife hazard assessments are regularly performed to support the development of wildlife hazard management plans (WHMP) for airports. Current assessments use visual observations of wildlife, with particular attention paid to birds. As a tool, avian radar systems supplement visual observations of birds on and around airports. A study was conducted to demonstrate the feasibility of using avian radar to supplement a year-long wildlife hazard assessment effort at Cedar City Regional Airport in Utah. In December 2010, avian radar was used to test its capability to supplement scheduled monthly observations. This report summarizes the supplementary information provided by avian radar and discusses the utility of avian radar application in wildlife hazard assessments.

The avian radar consistently observed more bird targets than were identified by visual observation and provided a useful data set for analyses that supported the development of the airport's WHMP.

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LIST OF ACRONYMS

AC	Advisory Circular
ASDE-X	Airport Surface Detection Equipment, Model X
CDC	Cedar City Regional Airport
CEAT	University of Illinois Center of Excellence for Airport Technology
FAA	Federal Aviation Administration
JRC	Japan Radio Corporation
LCD	Liquid crystal display
nmi	Nautical mile
WHA	Wildlife hazard assessment
WHMP	Wildlife hazard management plan
SER/AS	Svoboda Ecological Resources/Animal Solutions, Ltd.
VGA	Video graphics array

EXECUTIVE SUMMARY

Wildlife hazard assessments are regularly performed to support the development of wildlife hazard management plans (WHMP) for airports. Current assessments use visual observations of wildlife, with particular attention paid to birds. As a tool, avian radar can supplement visual observations of birds on and around airports and can provide useful data sets for analyses to support the development of WHMPs. A test of avian radar was conducted to demonstrate its usefulness as a supplement to a scheduled monthly observation that was part of a year-long wildlife hazard assessment at Cedar City Regional Airport in Utah. The avian radar consistently observed more bird targets than were identified by visual observation and provided a useful data set for analyses that supported the development of the airport's WHMP.

INTRODUCTION

WILDLIFE HAZARD ASSESSMENT.

Wildlife hazard management has been a key part of airport safety programs for many years. Balancing the land-use requirements for safe airport operations with the increasing presence of hazardous wildlife species is a challenge for airport operators. Most airports have undeveloped parcels of land designed as open spaces to provide extra levels of aircraft safety by providing unobstructed areas. However, those areas can present hazards to aircraft if they attract wildlife to enter critical aircraft operating areas, such as arrival and departure airspace. The critical first step in managing wildlife hazards at airports is performing a wildlife hazard assessment (WHA).

Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5200-33B [1] requires consideration of wildlife attractants within 10,000 feet of the airport and recommends consideration of wildlife attractants to 5 statute miles beyond the airport if the attractant can cause hazardous wildlife movement into or across approach or departure airspace. Additionally, CertAlert No. 9-10, 2009 [2], reminds airport operators of their obligation under Title 14 Code of Federal Regulations (CFR) Part 139 [3] to have a qualified airport wildlife biologist conduct a WHA after a "triggering event" is experienced on or near the airport. 14 CFR 139.337(b) [3] defines a triggering event as an event in which:

1. an air carrier experiences multiple wildlife strikes.

2. an air carrier experiences substantial damage from striking wildlife.

3. an air carrier experiences an engine ingestion of wildlife.

4. wildlife of a size, or in numbers, capable of causing an event described in 1through 3 above is observed to have access to any airport flight pattern or aircraft movement area.

Beyond an analysis of the specific triggering event, the WHA requires the following components:

- identification of the wildlife species observed and their numbers, locations, local movements, and daily and seasonal occurrences

- identification and location of features on and near the airport that attract wildlife

- a description of wildlife hazards to air carrier operations

- recommended actions for reducing identified wildlife hazards to the air carrier

The existing methods used in WHAs depend primarily on visual observation of wildlife hazards, with particular attention paid to birds. A visual observation program is generally based on standard ornithological observation procedures in which observations are made regularly over a 12-month period to record expected seasonal changes in wildlife presence, behavior, and movement. The actual methods used may vary based on professional judgment, but the most common approach is the point-count method. As stated by Johnson [4]:

> "Point counts are used to sample bird populations for estimating densities in local areas, determining trends in populations over regional areas, assessing habitat preferences and other scientific and population monitoring purposes."

Visual surveys provide the critical species information that is the foundation for a WHA. These visual observations are usually limited to daytime periods, although the use of thermal imaging technology can extend observations to periods of darkness when visual observation is not possible.

<u>AVIAN RADAR TECHNOLOGY</u>.

Radar technology has been used in ornithology since the late 1930s, when radar users recognized that the unidentified targets in these early radars were birds. The potential for using radar to understand and manage wildlife hazards at civil airports has long been recognized. Since 2000, a research program assessing the performance of avian radars has been ongoing at the University of Illinois Center of Excellence for Airport Technology (CEAT). This research is part of a cooperative agreement with the FAA William Hughes Technical Center Airport Safety Technology Section. Avian radar provides the opportunity to detect and track birds at any time of the day or night and can be a useful addition to any visual observational program. Because avian radar makes it possible to characterize bird movement in daylight and in darkness, the use of avian radar in a WHA provides an opportunity to supplement standard visual observations, providing a better assessment of hazards. Avian radar also provides movement information at greater ranges than visual methods. With 360° coverage, avian radar provides a means to comprehensively assess bird presence and movement on and around an airport in ways that are difficult, if not impossible, for visual observers.

The primary areas where avian radar supplements existing methods for a WHA include:

- improvement in situational awareness
- capability for dawn/dusk and nighttime observation
- event characterization
- improved assessment of the total numbers of birds associated with observed movements

<u>SITUATIONAL AWARENESS</u>. Avian radars improve situational awareness because the radar presents, on a single screen, a summary of activity surrounding the radar location to ranges that are beyond the capability of visual observation. In addition, using postprocessing or advanced processing that enables target tracking, avian radar can develop a comprehensive picture of bird movement on and around the airport. Radar records also allow time-specific and forensic analyses that provide the opportunity to relate activity locations to attractants or other managed landscape characteristics. However, avian radar does not provide definitive identification of bird targets, and species identification is a critical issue in a WHA. Thus, avian radar provides a valuable supplement that, when combined with a comprehensive visual assessment, will support

management recommendations with information about movement dynamics of birds on and around the airport.

DAWN/DUSK AND NIGHTTIME OBSERVATION. When assessing the general hazards associated with bird/aircraft collisions, avian radar provides information on bird presence and movement during periods of lighting change and at night. For example, according to Dolbeer [5], bird strikes are seven times more likely to occur at night than during daytime hours in migration seasons. Avian radar effectively senses birds at all times and in all lighting conditions; although, depending on radio frequency characteristics, detections can be attenuated during rainfall.

EVENT CHARACTERIZATION. Because avian radar provides a time-sequenced record of bird movement, radar data are particularly useful to identify short-lived or irregular events . For example, assembly and dispersal of birds in roosts is known to occur at dawn and dusk. The changing lighting conditions present a challenge to observers, and the movement may be short-lived. Thus, timed observations may miss an event that produces a high hazard. Avian radar provides a continuous record; and when that record is reviewed, it is possible to identify events, determine event relationships to the airport, and focus management on addressing the cause of the event, such as roost formation, in management plans.

IMPROVED ASSESSMENT OF THE TOTAL NUMBER OF BIRDS. Avian radar also provides a comprehensive sense of the total number of birds on and around the airport. Because visual observations are line-of-sight, developing a fully comprehensive sense of bird numbers is difficult: activities occur in all quadrants, at a range of altitudes, and at ranges that are impossible to view visually. Although it is possible to use binoculars or spotting scopes, the magnification power limits the range-of-discrimination. An experienced ornithologist can certainly see larger birds and flocks at ranges of 1 to 3 miles, but species confirmation is limited to ranges of less than 1 mile. Although avian radar does not provide definitive species associations with detected targets, the radar easily scans to ranges beyond 3 miles and provides a good estimate of the total number of bird targets in a 360° coverage area.

The acquisition cost for avian radar can range from less than $1000 for low-power units to an avian radar system that costs several hundred thousand dollars. The lowest-cost radars are typically developed for small boats and have limited power and resolution. For this study, a marine radar system suitable for larger watercraft was selected for the sensor unit. This portable radar system was self-contained, with internal processing that produces a video graphics array (VGA) raster-based image displayed on a liquid crystal display (LCD) computer screen. The VGA output from the radar was split, and the VGA2USB was used to make digital recordings on a laptop computer. Using this operational approach, it was possible to use the radar for real-time analysis and to record radar images for postprocessing. When mounted in a utility trailer with generator power and the video and computer equipment, the total acquisition cost for the system was less than $25,000.

CEDAR CITY REGIONAL AIRPORT.

To assess the utility of avian radar as a supplement to a WHA, CEAT deployed a portable avian radar to Cedar City, UT, to be part of a WHA at Cedar City Regional Airport (CDC). The radar was operated simultaneously with the planned visual observations during the December 2010 field campaign, which was conducted for CDC by Svoboda Ecological Resources/Animal Solutions, Ltd. (SER/AS).

Cedar City and the airport are located in the Cedar Valley in Iron County, Utah, in the southwestern extension of the Basin and Range, Colorado Plateau Extension (figure 1). The airport has a primary runway, Runway 2/20, and a secondary crossing runway, Runway 8/26 (figure 2). The primary runway is 8653 ft (2637 m) long at an elevation of 5622 ft (1714 m). Cedar Valley is an extinct lake bed with higher elevation landforms to the west. The topography around the airport is relatively flat with land use dominated by agricultural (green) and developed (beige) areas (figure 3).

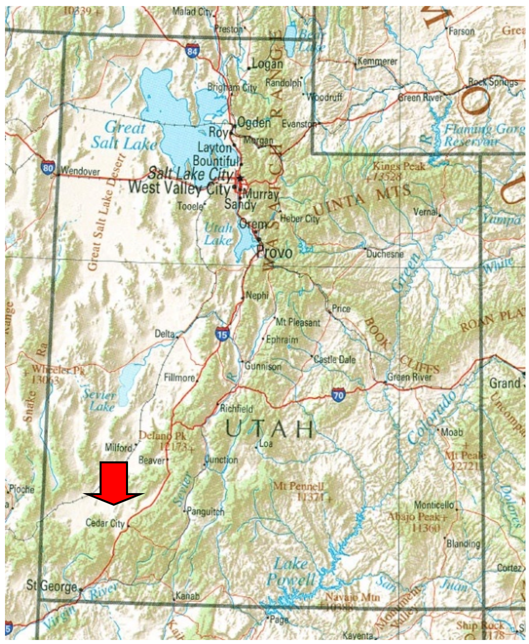
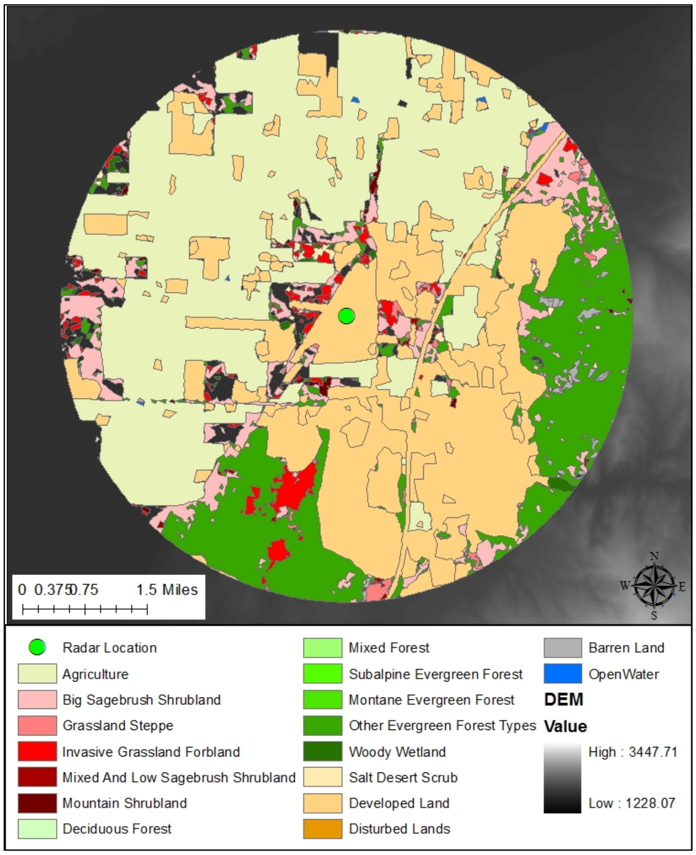


Figure 1. Map of Utah With Cedar City Indicated

Figure 2. Oblique Northward View of CDC With Avian Radar Location Identified



(Note: Digital elevation model (DEM) values are in meters.)

Figure 3. Land Use Surrounding CDC With Radar Location Indicated

METHODS AND MATERIALS

The use of avian radar at CDC was intended to supplement the WHA; therefore, radar operations at CDC were coordinated with the WHA designed by SER/AS. Avian radar was used during one of the WHA field campaigns in December 2010. The location of the radar unit was coordinated with CDC personnel and provided partial coverage of sites selected by SER/AS for point-count locations.

The radar used for this study was an X-band marine radar. X-Band radars have been deployed at several civil airports as part of the FAA's overall performance assessment activities. In December 2006, an X-Band bird radar was collocated with Airport Surface Detection Equipment Model X (ASDE-X) surveillance systems at Will Rogers World Airport in Oklahoma City, OK. Testing conducted at that time in coordination with the FAA's Spectrum Engineering Services office demonstrated that there was no interference between the X-Band bird radar and ASDE-X equipment. This commercial off-the-shelf model is typically used on ships; however, the radar unit used at CDC was specifically designated by the manufacturer for operation on land. The radar unit consists of a scanner/antenna, the radar processor, a control keyboard and mouse, and a computer monitor. The radar processor produces a video output that is displayed on a typical computer monitor. For the study, CEAT modified the connection between the radar processor and the computer monitor by splitting the video signal and directing the video data to a laptop computer that was used as a recording device. The unit used standard radar-processing architecture that displayed detections as bright spots on the computer monitor. The display can be set to retain detection "spots" for a set time period. In this "Trails" mode, sequential detections produce a target with a trail. For the study, trail length was controlled by defining a trail mode time period, typically 30 seconds to 2 minutes. This produced trails that supported heading and speed estimations. Analyzing target trails assisted in identified which targets were bird targets and enabled the heading and speed estimations, which could be used to relate target behavior to possible species. Because video recordings could be played back at different speeds, it was possible to quantify target characteristics and, with time synchronization, to determine bird presence and movement dynamics during the time periods when WHA observations were made.

Using a time synchronization approach, the CEAT study developed bird target counts around observation locations during the same time periods as visual observations. It was not possible to exactly correlate the times of WHA visual observations with radar data. However, it was possible to select averaging periods for counts based on radar data that were consistent with the times that WHA observations were made. This method provided an estimate of radar-observed targets for time intervals that could be compared to the 5- and 20-minute time periods of WHA visual observations.

THE WHA METHODS.

The WHA began at CDC in June 2010, with field observations initiated in July 2010. The assessment design, developed by SER/AS, incorporated visual and thermal observations. In general, observations at a location required the observer, using binoculars or a night vision scope, to look up and around 360° for at least 5 minutes. Systematic, 5-minute-long point-count observations were made at all locations, and 20-minute-long flyway/runway surveys were made at some locations. All hazardous wildlife within the search area of each location was recorded. Data collected included species; animal location; behavior; direction of travel; potential attractants; interactions with other animals/habitats; and habitat use by date, time, and weather conditions.

Six different wildlife assessment survey methods were used:

- Systematic surveys
- Flyway/runway
- Spotlight
- Small-mammal trapping
- Photomonitoring
- Opportunistic methods

Although the objective of each survey method varied, they all shared the same general function of identifying hazardous wildlife or their potential attractants. The surveys used location-appropriate observation procedures. The following sections describe each method used in the assessment.

<u>SYSTEMATIC SURVEYS</u>. Systematic surveys using point-count methods were conducted once per month, requiring several days to complete a full campaign of multiple surveys of all observation locations. For each campaign, up to 13 locations, representing key habitats on and around the airport (figure 4), were observed using a randomized point-count approach. Observations were made for 5- to 20-minute periods at each location, and wildlife activity observed within a 500-ft (152-m) radius was recorded. Small, nonflocking birds (e.g., songbirds) were recorded, but emphasis was placed on those bird species or groups known to be hazardous to airport operations, as described in table 1 of FAA AC 150/5200-33B [1].

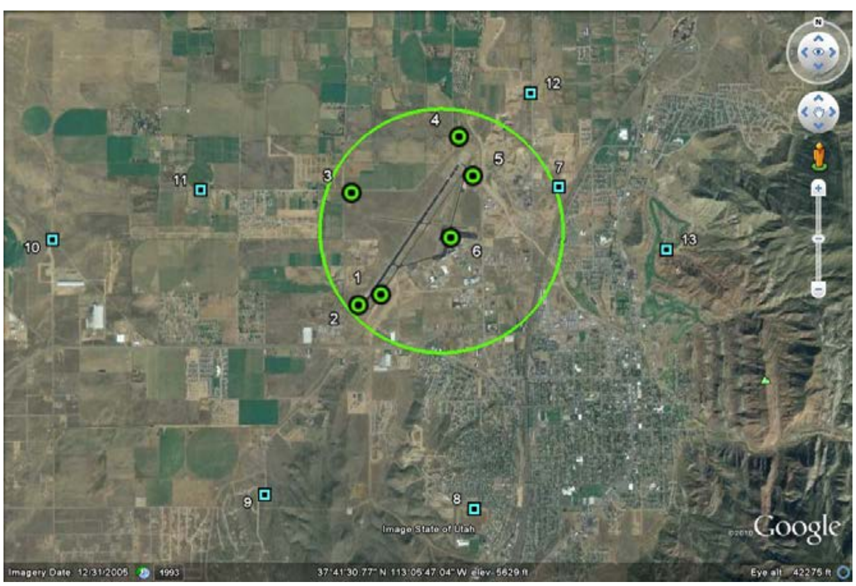


Figure 4. Point-Count Locations Used in Systematic Surveys With a 1-Nautical Mile Circle From the Radar Indicated

FLYWAY/RUNWAY SURVEYS. Runway counts were performed twice weekly at locations 2, 3, and 5. The objective of these surveys was to identify species that were a direct hazard to aircraft during takeoff and landing. Three locations with good vantage points of Runways 2/20 and 8/26 were surveyed for 20-minute periods.

SPOTLIGHT/NIGHT SURVEYS. Spotlight surveys or other nighttime survey methods, such as forward-looking infrared, were conducted one night per month in September, November, and June. The intent of these surveys was to document nocturnal wildlife activity during peak activity periods. The surveys consisted of driving a standard route around the airfield and recording species counts, locations, and behaviors.

SMALL-MAMMAL TRAPPING. Small-mammal trapping was used to determine the extent that hazardous wildlife attractants were present, thus supporting prey-based management recommendations.

PHOTOMONITORING. Photomonitoring, the use of still and video cameras, was conducted at each site at least once per season to document plant communities and habitat quality and to verify that images from aerial photography were consistent with actual ground conditions.

OPPORTUNISTIC OBSERVATIONS. Whenever hazardous wildlife was observed, observations were recorded.

AVIAN RADAR METHODS.

Avian radar studies were conducted by CEAT in coordination with the SER/AS WHA. Avian radar observations were made during the December 2010 assessment campaign at CDC. A Japan Radio Corporation (JRC) NKE-600D1T, 25-kW X-band radar was used. The radar was placed within the CDC boundary on the helicopter landing pad between Runway 20/20 and the eastern-most taxiway, south of Runway 8/26 (figure 2) on December 2, 2010, and was operated until December 4, 2010. This site produced minimal radar clutter over the airfield and provided coverage to the west of the radar location and over the arrival/departure areas of the runways. The avian radar was operated so that radar records were available for several time periods that coincided with the point-count observations conducted by SER/AS. In addition to these time periods, avian radar records were made at dawn/dusk, at night, and at other times to provide bird target data when visual observations were not possible. The avian radar was operated in the "Auto" mode with the following settings:

- Sea clutter—Manual with level at zero.
- Rain—Manual with level at zero.
- Interference rejection—Off.
- Radar video enhancement—Off.
- Radar video processing—Peak hold.

- Function—Off.
- Pulse length—Short pulse.
- Gain—approximately 7 on the indicator bar, can vary with site.
- Multiswitch—Trails.
- Trails—30 seconds.
- Range rings—Set as required (0.25 to 5 mi).
- Tune—Adjust for longest bar on the tune indicator.
- Bearing—Setup provided a north-up radar display aligned with true north. An internal GPS with external antenna provided position information for the radar display.
- Time—Updated to current time zone and Internet time.

The output from the avian radar was a raster-processed image displayed on an LCD computer screen. To provide the radar images for later analysis, a recording of the radar display was made. A VGA2USB Pro™ frame grabber was used to connect the radar processor video output and a laptop computer. The laptop was used to control the operation of the frame grabber, to route video files to an external hard drive, and to provide a time-stamp on the video file.

GROUND-TRUTHING. Ground-truthing is a method of target validation in which observers visually observe birds and confirm that the radar detected and tracked the birds by reviewing the target trails on the radar display. In the ground-truthing exercise, CEAT observers notified a radar operator, i.e., the person monitoring the radar display screen, when bird observations were made. Visually observed targets were then confirmed on radar displays by the radar operator. In this procedure, the display was set in a “Trails” mode so that target tracks would be evident on the display. Ground-truthing observations made it possible to directly correlate visual observations of birds and bird movement to the avian radar’s target indications and trails. This provided information from direct observations that related target trails to bird species, size, and movement characteristics. Ground-truthing exercises were opportunistic, occurring whenever visual sightings were possible and provided the basis for the characterization of targets and classification of target trails used in postprocessing.

The ground-truthing validation study was conducted from 10:00 a.m. to 12:00 p.m. on December 3, 2010. In the validation study, CEAT used a standard avian radar validation observation procedure. This procedure used a 10x power spotting scope to observe birds along a known bearing. The validation study used the following procedures:

1. A spotting scope was aligned to true north and placed approximately 10 m (33 ft) from the scanner to reduce angle differences between the radar view and the visual view.

2. Observations using the spotting scope were made along a fixed bearing for 5-minute periods. To facilitate later comparisons, an electronic bearing line on the radar display was set to conform to the visual observation bearing.

3. Observation bearings were randomly selected from 230° to 037° clockwise in areas with the least ground clutter.

4. The data recorded included observation bearings, time of day to the second, species/family/order of birds if possible, general direction of travel, and number of birds. Time stamp of the sighting was established as the bird passed the vertical center of the spotting scope.

POSTPROCESSING. Digital recordings of the radar images were used for postprocessing. In postprocessing, the images were reviewed, targets were counted, and target trails were reviewed. The replay function allowed stop-frame and replay of the file at different speeds. The same image could be reviewed several times to support comprehensive analysis. The targets were counted, and the trails provided information on heading and speed. Using this information on bird targets and movement, it was possible to count the number of targets and general movement patterns (heading and estimated speed). Target summaries were prepared from this data.

RESULTS

THE WHA VISUAL SURVEYS.

Visual surveys were conducted by SER/AS on December 1-3, 2010. One survey was conducted on December 1, 2010, and two surveys on December 2 and 3, 2010. Each survey required approximately 3 hours to complete; one survey was initiated at dawn, and another was timed to finish at dusk. During portions of the visual surveys on December 2 and 3, the avian radar was also operating. For the WHA observation times when the radar was operating, a total of 872 birds and 18 species were visually observed at all point-count locations, and 346 birds and 11 species were observed at locations 1-6 (see appendix A). Note the day-to-day variability in species and number of observed birds. Table 1 provides a summary of WHA visual observations by species and locations, made on December 1-3, 2010. The Common Raven was the most observed bird species by location (table 1) and by number (table 2). Table 3 provides a summary of WHA visual observations by number of birds, made on December 2-3, 2010, when the avian radar was also operating.

Table 1. Summary of WHA Visual Observations by Species and Location on December 1-3 2010, When Avian Radar was Also Operating

Location	Species
3	Red-Wing Blackbird
4	Bald Eagle
3	Golden Eagle
5	House Finch
4	Northern Flicker
2 and 5	American Goldfinch

Table 1. Summary of WHA Visual Observations by Species and Location on December 1-3, 2010, When Avian Radar was Also Operating (Continued)

Location	Species
3	Harrier
6	Ferruginous Hawk
1, 2, 3, 4, 5, and 6	Common Raven
2, 3, and 6	Starling
5	White-Crowned Sparrow

Table 2. Summary of WHA Visual Observations by Number of Birds on December 1-3, 2010

Location	Number of Times Birds Observed at Point-Count Locations	Total Number of Birds Observed	Number of Times Single Birds Were Observed at Point-Count Locations	Dominant Bird Species With Numbers Observed
1	8	10	6	Common Raven–2
2	18	65	5	Common Raven and Starling–10
3	35	69	24	Common Raven–11
4	13	23	9	White-Crowned Sparrow–10
5	16	71	7	Starling–30
6	6	108	3	Starling–100

Table 3. Summary of Visual Observations by Number of Birds on December 2-3, 2010, When Avian Radar was Also Operating

Location	Number of Times Birds Observed at Point-Count Locations	Total Number of Birds Observed	Number of Times Single Birds Were Observed at Point-Count Locations	Dominant Bird Species With Numbers Observed
1	3	3	3	Common Raven–3
2	16	59	5	Common Raven and Starling–10
3	7	11	5	Common Raven–2
4	4	4	2	Common Raven–2
5	8	11	5	Common Raven–2
6	3	101	1	Starling–100

AVIAN RADAR OBSERVATIONS.

The avian radar was set up and tuned to the site on the morning of December 2, 2010. Although the radar was operational, the majority of radar data that was synchronized with WHA observations was collected on December 3, 2010. In total, the radar operated for approximately 11 hours between December 2 and 3, 2010. A total of 4.5 hours of radar records were available for the times when the radar was operated during SER/AS visual surveys. Appendix B shows times and locations of all visual survey periods from December 1-3, 2010, and notes the specific periods during which the avian radar was operating. Radar observations were made on December 2, 2010, at location 2 from 10:24 a.m. to 10:26 a.m.; on December 3, 2010, at locations 1, 2, 3, 4, 5, and 6 from 07:27 a.m. to 08:27 a.m.; and on December 3, 2010, at locations 1, 2, 3, 4, 5, and 6 at 09:14 a.m. Additional recordings were made 1 hour before and 1 hour after sunrise/sunset and during a 2-hour period centered on midnight between December 2 and 3, 2010.

During the initial deployment of the avian radar, visual observations of bird movement were used to tune and develop operational procedures for radar operation and radar image recording. To identify the targets on the radar, aircraft were also tracked to verify operational status and support the observers' range estimations. An analysis of the clutter returns and target tracking was performed, which identified an area free of major clutter. It was located north and west of the radar location along a line from 047°, southwest through the radar site to 228°, and out to a radius of 1 nautical mile (nmi). This area of good radar coverage included Runway 2/20 and SER/AS survey locations 1-6, which were along Runway 2/20 and were all within 1 nmi of the radar locations. Therefore, radar images encompassing this area of good radar coverage were selected as the primary focus of postprocessing.

TARGET COUNTS. Total target counts from the radar on December 2, 2010, were 191 in the morning and 321 in the afternoon/dusk. During nighttime observations on December 2 and 3, 2010, there were 322 targets; 96 of those targets were counted over 2 hours around midnight. On December 3, 2010, there were 624 targets in the morning. To provide a relationship between WHA visual observations and radar observations, the average number of birds observed in 5 minutes of WHA observations and the number of bird targets in 5-minute periods in the radar data records were compared. Although lack of time synchronization did not support direct time period comparisons, using a 5-minute average for the radar data provided a sense of the number of bird targets present in the 5-minute periods used for the WHA visual observations. In general, the average number of targets counted in 5-minute periods using the avian radar data was 25 or more during the daytime, falling to an average of five targets at night (tables 4 and 5).

Table 4. Average Number of Targets per 5-Minute Period Observed in Radar Records Coinciding With WHA Visual Observations on December 2 and 3, 2010

Date	Times of Radar Use	Average Number of Targets/Five Minute Period
12/2/2010	10:17-10:28	47
12/2/2010	12:22-12:50	24.25
12/2/2010	16:15-17:43	24.7
12/2/2010	07:25-10:02	39

Table 5. Average Number of Targets per 5-Minute Period Observed in Radar Records for Times Including WHA Visual Observations on December 2 and 3, 2010

Date	Times of Radar Use	Average Number of Targets/Five Minute Period
12/2/2010	10:17-13:10	31.3
12/2/2010	15:34-15:52	20.0
12/2/2010	16:15-17:15	30.6
12/2/2010	17:16-18:17	23.3
12/2/2010-12/3/2010	22:59-01:00	5.3
12/3/2010	06:34-07:30	16.7
12/3/2010	07:33-10:55	38.6

Cells in grey are dusk/dawn and nighttime periods.

STATISTICS FROM RADAR TARGET ANALYSIS. Using a 5-minute interval in the analysis of the recorded radar data, 86 periods were recorded on December 2 and 3, 2010. The mean number of targets was 25.24 with a standard deviation of 15.66 (table 6). The number of targets per period ranged between 1 and 56. The total number of targets was 2171. Daytime operations were analyzed separately. There were 57 daytime periods recorded with a mean number of targets of 31.95 and a standard deviation of 12.662. The number of targets for all daytime data ranged between 3 and 56, with 1821 total targets observed. Dusk/dawn periods were also analyzed separately. Thirty-three periods of 1 hour before and 1 hour after sunrise/sunset were recorded. The mean number of targets was 33 with a standard deviation of 15.4. The number of targets ranged between 3 and 56 with a target total of 932. The radar was also operated for 2 hours around midnight, December 2 and 3, 2010. The mean number of targets was 5.33 with a standard deviation of 2.449. The number of targets ranged between 1 and 10 with a target total of 96.

Table 6. Summary Statistics for 5-Minute Periods From Radar Analysis

Category	Sample Size (n)	Mean	Standard Deviation	Minimum	Maximum	Total
All data	86	25.24	15.66	1	56	2171
All daytime data	57	31.95	12.662	3	56	1821
Daytime data with WHA	28	31.32	15.346	3	56	877
Daytime data without WHA	29	32.55	9.635	12	51	944
Darkness data	29	12.07	12.352	1	47	350
Night data (22:59-0:55)	18	5.33	2.449	1	10	96
Dawn/dusk	33	28.24	15.41515	3	56	932

The radar data for all periods of observations are summarized in figures 5 through 8, providing a time-sequenced view of target numbers.

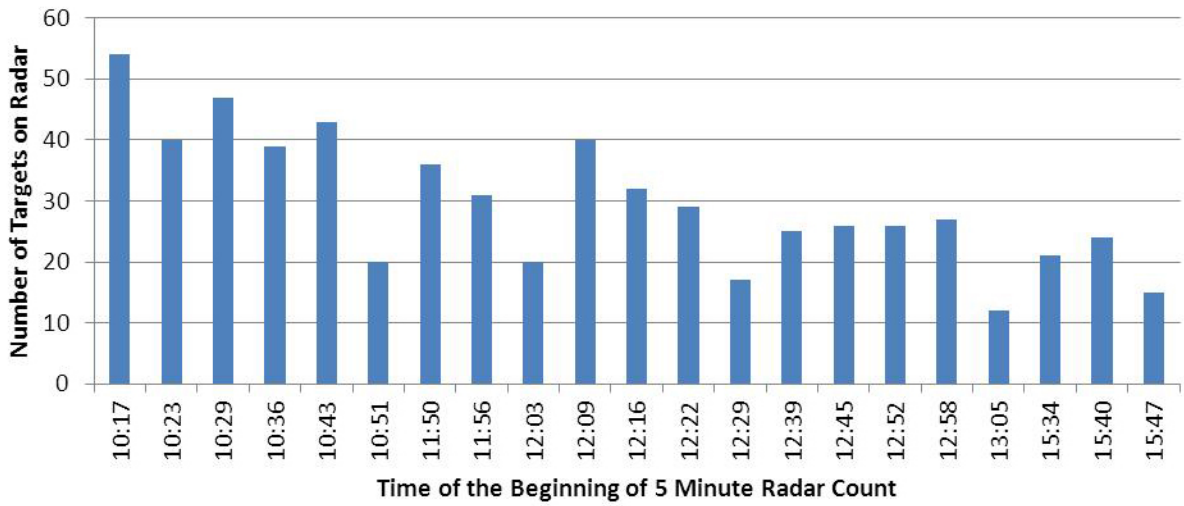


Figure 5. Number of Targets Observed During Daytime, December 2, 2010

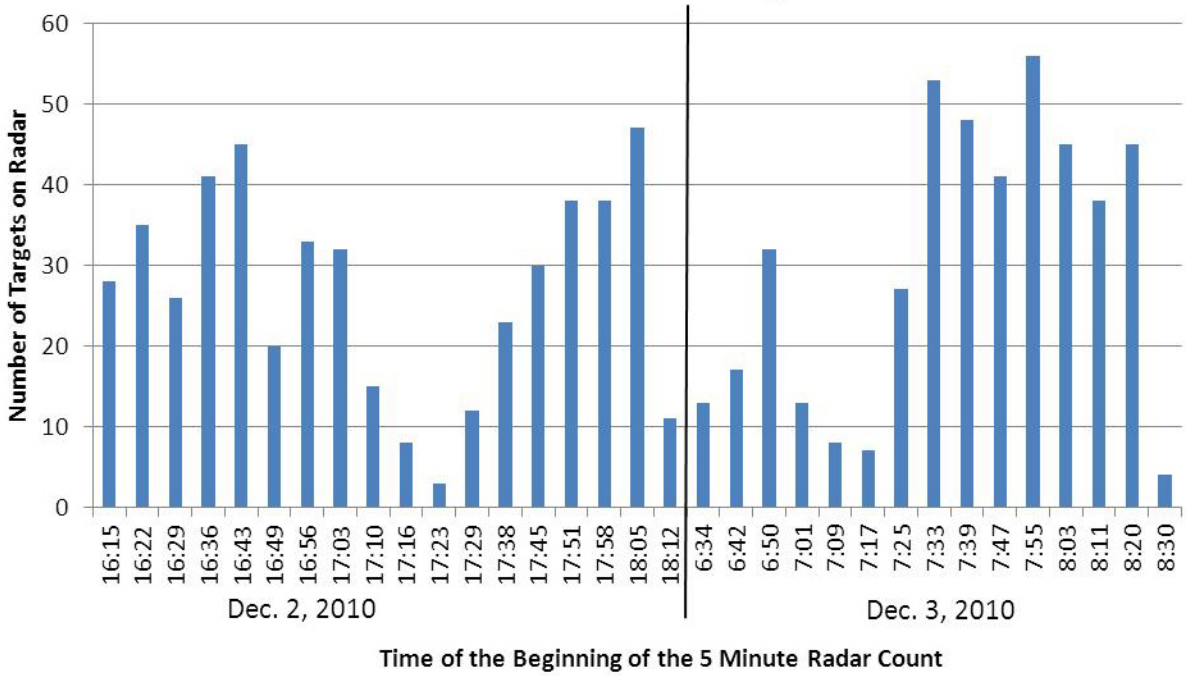


Figure 6. Number of Targets Observed During Dusk and Dawn, December 2-3, 2010

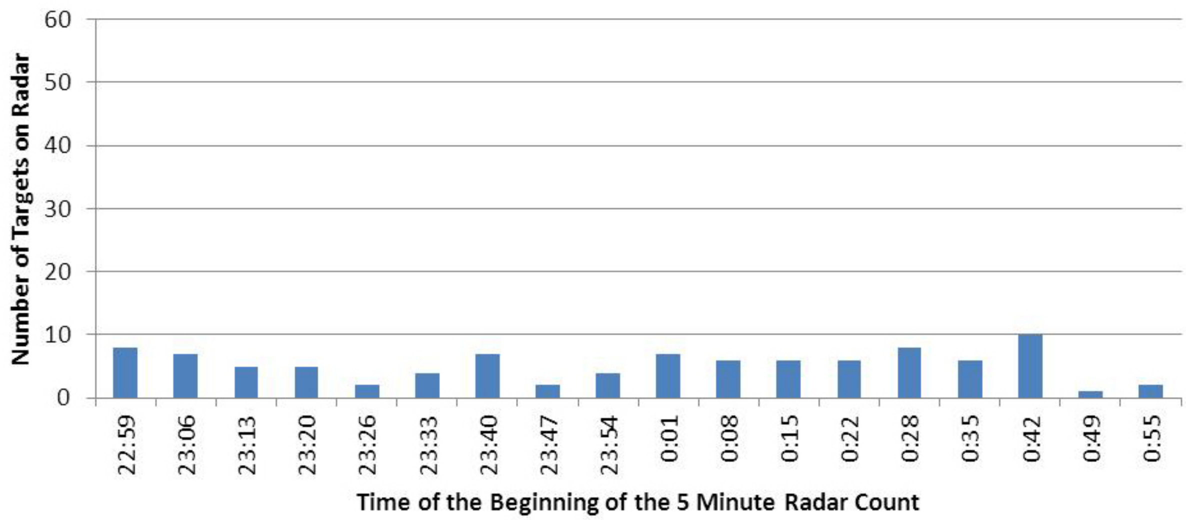


Figure 7. Number of Targets Observed Around Midnight, Between December 2-3, 2010

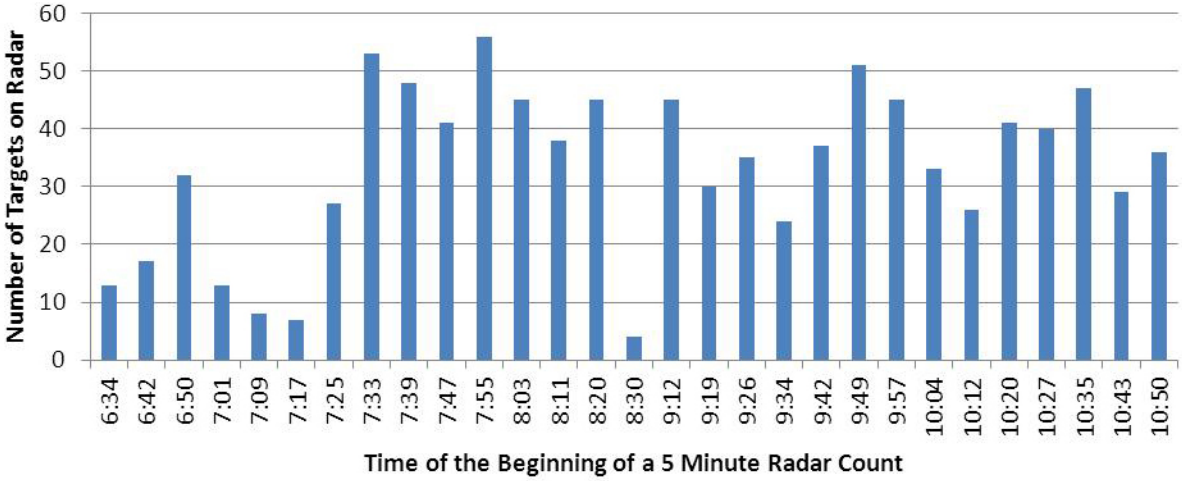


Figure 8. Number of Targets Observed During Daytime, December 3, 2010

RADAR VALIDATION STUDY. A validation study was conducted on December 3, 2010, using standard validation procedures (table 7). During approximately 2 hours of observation, 19 sightings of birds or groups of birds were noted by the visual observer. Twelve targets coinciding with visually observed birds were confirmed on the radar in postprocessing.

Table 7. Validation Observation Results for the CDC Radar Study

Date	Local Time	Time GMT	Species	Number of Birds Observed	Bearing in Degrees	Heading	Behavior /Notes	Detected on Radar
12/3/10	9:56:29	17:56:29	CORA	1	33.1	NE	FLE	Yes
12/3/10	9:57:43	17:57:43	PASS	10	33.1	N	FLE/ May be too close	Yes
12/3/10	9:58:11	17:58:11	CORA	2	33.1	S	FLE/ May be too close	Yes
12/3/10	9:59:24	17:59:24	PASS	9	33.1	SW	FLE	Yes
12/3/10	10:11:11	18:11:11	PASS	1	298	S	FLE	No
12/3/10	10:12:25	18:12:25	CORA	1	298	NE	FLE	Yes
12/3/10	10:13:40	18:13:40	CORA	2	298	NW	Distant	Yes
12/3/10	10:19:05	18:19:05	CORA	1	347	NE	FLE	No
12/3/10	10:19:28	18:19:28	CORA	1	347	SW	More than 6 Passerines	No
12/3/10	10:20:52	18:20:52	CORA	1	347	SW	FLE	Yes
12/3/10	10:20:56	18:10:56	CORA	1	347	NE	FLE	No
12/3/10	10:34:34	18:34:34	CORA	1	24	W	FLS	No
12/3/10	10:34:38	18:34:38	CORA	1	24	NE	FLS	No
12/3/10	10:37:31	18:37:31	CORA	1	24	W	FLE	Yes

Table 7. Validation Observation Results for the CDC Radar Study (Continued)

Date	Local Time	Time GMT	Species	Number of Birds Observed	Bearing in Degrees	Heading	Behavior /Notes	Detected on Radar
12/3/10	11:56:24	19:56:24	CORA	1	336	SW	FLE	Yes
12/3/10	11:56:48	19:56:48	PASS	20	336	Null Zone	RA/ May be too close	No
12/3/10	11:57:51	19:57:51	CORA	1	336	S	FLS	Yes
12/3/10	11:58:34	19:58:34	CORA	1	336	N TO E	FLE	Yes
12/3/10	12:04:43	20:04:43	CORA	1	242	N	FLE	Yes

Species Codes:
CORA—Common Raven
PASS—Passerine

Behavior Codes:
FLS—Flying steady course close to surface <20 ft or <5 ft
FLE—Flying steady course elevation >20 ft
RA—Random flying movements
SO—Soaring

IDENTIFICATION OF RAVEN ROOSTS.

During the WHA, a large number of Common Ravens were visually observed by location (table 1) and by number (table 2). Because of their size and numbers, Common Ravens are a species known to be hazardous to airport operations, as described in table 1 of FAA AC 150/5200-33B [1]. Thus, CDC personnel expressed a strong interest in identifying roost locations. To aid them in this effort, CEAT and SER/AS observers viewed the avian radar during operations at dusk when Common Ravens usually aggregate in roosts; radar video records were also reviewed to determine if movement patterns were typical of roost assembly or dispersion. The avian radar identified a potential roost and suggested other locations of possible roosts. A temporary roost was identified near the airport by SER/AS observers, and on further investigation, a separate, major roost was identified beyond expected radar coverage.

DISCUSSION

Avian radar has been the focus of evaluations and performance assessments conducted by the CEAT since 1999, as part of research sponsored by the FAA William Hughes Technical Center. This research supported the development of an FAA Advisory Circular on Avian Radar (AC 150/5220-25) [6], which describes avian radar and provides standards and requirements for avian radar systems. The avian radar research program includes assessment of the sensors used for tracking bird targets. It also considers simple sensor configurations as well as complex avian radar systems that incorporate digital processing, advanced visualization, and comprehensive data management. Because the WHA is the starting point for a wildlife hazard management plan, (WHMP) it is important that the assessment provide sufficient information on bird movement and dynamics to support management activities that address avian hazards and known bird attractants. However, current WHAs are based primarily on visual observations, which are recognized to have specific limitations. From experience gained in avian radar performance assessments, CEAT recognized the potential for avian radars to supplement a WHA.

The primary difficulty associated with using radar as a supplement to a WHA is the relatively high cost of avian radar systems and the technical sophistication needed for radar deployment and operation. CEAT considered this issue and identified a radar sensor that could be obtained at a relatively low cost and operated with minimal technical sophistication. CEAT selected a JRC X-band marine radar system and developed a simple deployment system that provided portability, ease of set up, and recording of radar detection results. The radar system consisted of a scanner unit and a console with associated digital recording capability. For CDC testing, the radar console and associated equipment were mounted in a utility trailer. However, designs have also been developed for a modular unit that would fit in a sport utility vehicle. The scanner was mounted on a base with wheels for portability when deployed on the ground. The radar was powered by a 1000-watt generator that supported portability and extended operation time. A critical feature of the portable CEAT radar was its digital recording capability. The JRC radar provided a raster-based image typical of a plan position indicator, which was displayed on a standard LCD computer screen. The video signal was split, enabling a screen display and a digital recording of the radar images. The portable radar was set up and operational in less than 30 minutes. This provided a powerful, radar-based capability that could be easily transported to WHA field campaigns, which typically lasted only a few days a month.

To evaluate the portable avian radar in an ongoing WHA, CEAT arranged for a portable avian radar sensor to be sent to CDC. SER/AS initiated a WHA at CDC in June 2010 and was conducting monthly field observation campaigns from July 2010. CEAT deployed the portable avian radar at CDC to support the December 2010 field campaign. CEAT arrived in Cedar City on December 1, 2010, and initiated a reconnaissance to determine the best location for the radar. This reconnaissance included operation of the radar at several locations to assess clutter interference to identify a location where clutter was minimal in the desired observation areas. A site on the airport helipad was selected for radar deployment, and operation of the avian radar began on the morning of December 2, 2010. The radar was calibrated and tuned to the site, and the recording systems were tested. Full operation began in the late morning of December 2, 2010. The operational schedule was intended to assess bird movement in areas where point-counts were underway. The schedule was also intended to supplement visual observations with data from dawn/dusk time periods when bird observations are difficult and at night when visual observations are not possible. The radar data consisted of digital records with time stamps synchronized to field observations. The digital records were postprocessed with an emphasis on correlative observations with WHA point-counts and a general analysis of bird movement and dynamics throughout the day and night. The primary focus was on target movement within 1 nmi of the radar, although observations of movement at a greater distance were made.

In addition to WHA observation correlation and general bird movement analysis, CEAT conducted a validation exercise in which observations with a spotting scope followed previously developed validation procedures to correlate identified birds with observed radar targets. The validation study confirmed 12 of 19 targets, which is an expected confirmation rate considering operator and technological limitations. The validation studies confirmed the capability of the avian radar to detect and track the Common Raven and flocks of passerines, probably Finches. The validation exercise, along with opportunistic observations and ground-truth activities, supported correlation of birds with radar detections and provided the foundation to interpret the digital recordings in postprocessing.

The point-count method used by SER/AS in the WHA identified 11 bird species, with the Common Raven being the most common and most widely distributed species. SER/AS visually observed 871 birds in 19 species during the December 2010 field campaign. Avian radar provided good target detection for only 6 of the 13 point-count locations, but these locations were along the runway in areas where bird hazard potential was the greatest. SER/AS visually observed 206 birds at locations 1-6. Assuming four 30-minute-long observation periods during the morning and afternoon and 5 minutes of observation per each of the six locations, the average number of birds visually observed per observation period was 51.2. As shown in table 2, the number of birds visually observed varied among the six observation locations with a low of 6 at locations 1 and 4 and a high of 103 at location 6, where the high numbers were associated with a Starling flock. The average for the four 5-minute periods varied from a low of 1.5 to a high of 24.75 birds per 5-minute visual observation. Bird targets in the same location were counted at approximately the same time using the avian radar. The radar counts ranged from a low of 5.3 to a high of 39 in a 5-minute period. This increase clearly illustrates how avian radar can supplement point-count WHA observation techniques. The radar detects all targets in an area, not just targets along a single bearing. Thus, targets behind an observer and targets that would otherwise not be observed are counted by the radar. Tables 1 and 2 also provide other statistics from the SER/AS field campaign. The number of visual observations of birds varied, reflecting the variability in the presence of birds by location and related to the timing of observations.

Avian radar also provides a means to assess general activity patterns by counting the number of targets per unit time. In the CDC radar operations, the expected variability in bird numbers was noted. The average number of targets per 5-minute period was in the low 30s (31.95) during the daytime and the low teens (12.07) during the nighttime. The dawn/dusk average was near 30 (28.24). Standard deviations for all periods were high, indicating the high inherent variability in bird movement patterns (figures 6 through 9).

Avian radar provided a valuable supplement to observations made as part of a standard airport WHA. WHAs are designed to identify hazardous species and assess the threat posed by bird movement on and around the airport. Standard point-count and other visual observation techniques provide species identification and a quantitative data set to support a WHA. In the CDC assessment, observations in December 2010 were supplemented by avian radar. At the altitude of CDC and considering seasonal timing, the number of different bird species was low, but hazardous birds, particularly the Common Raven, were present in high numbers.

The visual observations used in WHAs have known limitations, but the point-count method is a standard procedure used in ornithological studies that provides accurate information and a species per area/effort metric [7]. To overcome the disadvantages of point-count methods, other observation methods are also used, such as flyway/runway surveys and opportunistic observations. The end result of combined observation methods is the identification of hazardous bird species, assessment of species numbers, and location information that supports the development of WHMPs. When avian radar is added to the tool set of a WHA, additional and very important insights into bird movement dynamics are available for analysis in the assessment and corresponding recommendations in a WHMP. Avian radar is capable of detecting targets at longer ranges and tracking those targets to reveal valuable information such as source areas/bird roosts, movement patterns and periods, and most importantly, movement during low light and nighttime periods when visual observations are compromised. However, avian radar is also limited. Targets are not definitively identified on the radar screen and clutter, as well as basic physics, limit radar coverage and target detection. The sophistication of the radar system is another important consideration. Higher-quality data will be available from more sophisticated systems, but cost and complexity must be considered. The operation of a relatively simple radar system, tuned to avian targets, provided a useful supplement to a WHA at CDC. The radar tended to detect more birds per each 5-minute period than the point-count method. This was expected because the area of coverage comparison between radar and point-count location is different, and point-count observers have a limited-sight view, which potentially allows birds to move outside their field of view. The avian radar supplemented point-count methods at CDC, providing a means to evaluate point-count success in relation to a more comprehensive measurement of bird activity.

One of the most valuable supplements provided by avian radar is a better characterization of movement patterns over both short- and longer-time periods. It is possible to conduct a number of postprocessing analyses that evaluate different averaging periods and different time periods in the radar record. In the CDC analysis, averaging periods were selected to coincide with typical point-count time periods, and it was possible to assess daytime, dawn/dusk, and nighttime differences in bird activity. Most importantly, avian radar supplemented visual observations during periods of low visibility and darkness. This was particularly important for dawn/dusk periods, when bird activity at CDC was shown to be at the same level as daytime observations.

Avian radar is also a valuable tool when analyzing origin of movements and the concentration of birds in roosts. In the CDC WHA, a large number of Common Ravens was noted, and there was a strong interest in identifying their roost locations. At critical movement times (dawn/dusk), the avian radar was helpful in identifying the potential origin of bird movements and enabled WHA observers to focus their attention on areas where roosts were eventually identified.

Avian radar can also extend the range of observations, supporting a comprehensive airport analysis from a single data set. At CDC, avian radar provided excellent coverage for critical areas of the airport as well as comprehensive coverage around the airport. At CDC, a range of 1 nmi was selected, which captured the WHA point-count locations nearest the airport. The radar also detected targets beyond the 1-nmi range.

The avian radar data allowed consolidation of information on bird movement and movement dynamics in different ways than those possible from point-count or other WHA observation methods. Avian radar provided a continuous record that allowed interpretation of sequence and timing. This enabled analysis of possible cause-and-effect and supported integration between radar observations and other data sources to better support management planning. For example, the land cover analysis for CDC provided a base map for overlays of radar data that identified hot spots in the landscape that are attractive to birds. From this information, airport personnel can manage those locations to make them less attractive to birds. It also provided a detailed analysis of hazard where common movement patterns intersected with expected aircraft flight paths.

CONCLUSIONS

Testing avian radar as a supplement to a wildlife hazard assessment (WHA) at Cedar City Regional Airport (CDC) provided evidence that a low-cost avian radar system can be useful to an ongoing WHA. Avian radar improved the assessment of the total number of birds and consistently observed more bird targets than could be identified by visual observation. Avian radar improved situational awareness by presenting, on a single screen, a summary of activity surrounding the radar location to ranges that were beyond the capability of visual observation. In addition, avian radar supplemented visual observations by providing information on bird presence and movement during periods of lighting change and at night, times when visual observation is ineffective. CDC personnel were supported in their development of a wildlife hazard management plan with postprocessing information and a data set based on radar observations. These offered a more comprehensive picture of bird movements on and around the airport and provided opportunities to relate the location of avian activities to landscape characteristics that are subject to management. Avian radar also provided a time-sequenced record of bird movement and radar data that can be used to identify a short-lived event. When CDC visual observations revealed the presence of a large number of Common Ravens, a known hazard to aircraft, the radar was used as an effective aid in the identification of a possible roosting location.

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APPENDIX A—SUMMARY OF WILDLIFE HAZARD ASSESSMENT VISUAL OBSERVATIONS

Summary of WHA Visual Observation of Birds by Location on December 1-3, 2010, When Avian Radar Was Also Operated

Location Number	Date	Species	Population	Observed Direction	Observed Distance (yards)
1	12/01/10	C. Raven	1	E	440
	12/01/10	C. Raven	1	NW	440
	12/01/10	C. Raven	2	NW	880
	12/02/10	C. Raven	2	N	880
	12/02/10	C. Raven	1	W	880
	12/02/10	C. Raven	1	W	100
	12/03/10	C. Raven	1	N	100
	12/03/10	C. Raven	1	W	880
	12/03/10	None	n/a	n/a	n/a
	Population total for location 1		10		
2	12/01/10	C. Raven	2	NW	440
	12/02/10	Am. Goldfinch	5	Overhead	33
	12/02/10	C. Raven	1	E	33
	12/02/10	C. Raven	2	?	880
	12/02/10	C. Raven	3	W	880
	12/02/10	C. Raven	1	SE	440
	12/02/10	C. Raven	2	?	100
	12/03/10	C. Raven	4	E	150
	12/03/10	C. Raven	7	N	880
	12/03/10	C. Raven	10	N	880
	12/03/10	C. Raven	1	E	17
	12/03/10	C. Raven	1	E	100
	12/03/10	C. Raven	3	E	100
	12/03/10	Starling	10	Overhead	33
	12/03/10	C. Raven	1	W	67
	12/03/10	C. Raven	3	NE	200
	12/03/10	C. Raven	5	NE	100
	12/03/10	C. Raven	2	W	440
	12/03/10	C. Raven	2	NE	440
	Population total for location 2		65		

Summary of WHA Visual Observation of Birds by Location on December 1-3, 2010, When Avian Radar Was Also Operated (Continued)

Location Number	Date	Species	Population	Observed Direction	Observed Distance (yards)
3	12/01/10	C. Raven	1	NE	440
	12/01/10	C. Raven	1	NW	200
	12/01/10	C. Raven	1	E	50
	12/01/10	C. Raven	1	NW	17
	12/01/10	C. Raven	1	S	1760
	12/01/10	C. Raven	2	W	880
	12/01/10	C. Raven	1	W	440
	12/01/10	Starling	6	W	100
	12/01/10	Harrier	1	N	100
	12/01/10	C. Raven	1	NW	200
	12/01/10	C. Raven	1	W	200
	12/02/10	C. Raven	2	WNW	100
	12/02/10	Starling	1	WNW	100
	12/02/10	Golden Eagle	1	NE	440
	12/02/10	C. Raven	2	NE	440
	12/02/10	C. Raven	4	NE	1760
	12/02/10	C. Raven	1	NE	440
	12/02/10	C. Raven	1	E	880
	12/02/10	C. Raven	2	NE	1760
	12/02/10	C. Raven	1	W	33
	12/02/10	RW Blackbird	2	E	135
	12/02/10	C. Raven	1	E	33
	12/02/10	Golden Eagle	1	NE	440
	12/02/10	C. Raven	1	E	67
	12/03/10	C. Raven	1	W	100
	12/03/10	Golden Eagle	1	NE	300
	12/03/10	C. Raven	1	NE	200
	12/03/10	Harrier	1	SE	200
	12/03/10	C. Raven	3	NE	300
	12/03/10	C. Raven	3	W	200

Summary of WHA Visual Observation of Birds by Location on December 1-3, 2010, When Avian Radar Was Also Operated (Continued)

Location Number	Date	Species	Population	Observed Direction	Observed Distance (yards)
3 (cont'd.)	12/03/10	C. Raven	1	NW	440
	12/03/10	Golden Eagle	1	NE	200
	12/03/10	C. Raven	8	N	880
	12/03/10	C. Raven	11	SE	440
	12/03/10	C. Raven	1	S	67
	Population total for location 3		69		
4	12/01/10	C. Raven	1	E	200
	12/01/10	C. Raven	1	W	100
	12/01/10	Am. Goldfinch	2	N	40
	12/01/10	Song Sparrow	1	NE	20
	12/01/10	Magpie	1	W	100
	12/01/10	W. Crn. Sparrow	10	W	30
	12/01/10	Harrier	1	E	15
	12/02/10	C. Raven	1	W	880
	12/02/10	No. Flicker	1	W	100
	12/02/10	C. Raven	?	N	880
	12/03/10	Bald Eagle	1	WSW	300
	12/03/10	C. Raven	1	N	67
	12/03/10	C. Raven	2	WSW	200
	Population total for location 4		23		
5	12/01/10	C. Raven	4	N	880
	12/01/10	Starling	30	N	880
	12/01/10	C. Raven	1	NW	100
	12/02/10	House Finch	2	SE	20
	12/02/10	C. Raven	5	NW	880
	12/02/10	Am. Goldfinch	15	SE	20
	12/02/10	C. Raven	1	SW	25
	12/02/10	C. Raven	1	SW	25
	12/02/10	C. Raven	1	?	880

Summary of WHA Visual Observation of Birds by Location on December 1-3, 2010, When Avian Radar Was Also Operated (Continued)

Location Number	Date	Species	Population	Observed Direction	Observed Distance in Yards
5 (cont''d.)	12/03/10	C. Raven	2	NW	880
	12/03/10	C. Raven	2	NE	67
	12/03/10	C. Raven	1	N	100
	12/03/10	W Crn Sparrow	1	N	17
	12/03/10	C. Raven	1	NW	100
	12/03/10	C. Raven	2	N	880
	12/03/10	C. Raven	1	NW	880
	Population total for location 5		70		
6	12/01/10	C. Raven	1	W	1760
	12/01/10	C. Raven	3	NW	1760
	12/01/10	C. Raven	1	NE	880
	12/02/10	C. Raven	2	N	33
	12/03/10	Ferruginous Hawk	1	NW	440
	12/03/10	Starling	100	NW	1760
	Population total for location 6		108		

APPENDIX B—SURVEY PERIOD WITH RADAR OPERATIONAL TIMES

Table B-1. All Wildlife Hazard Assessment Visual Survey Periods From December 1-3, 2010

Date	Location	Time Observation Period Began (GMT)	Time Observation Period Ended (GMT)	Time at Location (minutes)
12/1/2010 Nighttime	1	16:32:00	16:37:00	5
	2	16:51:00	17:11:00	20
	3	14:44:00	15:04:00	20
	4	15:33:00	15:38:00	5
	5	15:49:00	16:09:00	20
	6	16:22:00	16:27:00	5
12/2/2010 Daytime	1	10:06:00	10:11:00	5
	2	10:15:00	10:35:00	20
	3	08:02	08:22	20
	4	07:48	07:55	7
	5	09:33	09:53	20
	6	09:57	10:02	5
12/2/2010 Nighttime	1	16:36:00	16:41:00	5
	2	16:44:00	17:04:00	20
	3	15:17	15:37	20
	4	15:43	15:49	6
	5	17:20	17:40	20
	6	17:10	17:15	5
12/3/2010 Daytime	1	07:48	07:53	5
	2	07:24	07:44	20
	3	08:54	09:14	20
	4	08:42	08:47	5
	5	08:15	08:35	20
	6	08:05	08:10	5
12/3/2010 Nighttime	1	17:22	17:27	5
	2	17:00	17:20	20
	3	16:27	16:47	20
	4	18:06	18:13	7
	5	17:38	17:58	20
	6	17:30	17:35	5

(Shaded areas show time periods when avian radar was also operating.)