



Inner Thames Estuary Feasibility Study

*Response to Airports Commission Call for Evidence*

**The Mayor of London's Submission:  
Supporting technical documents**

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Title: **Wildlife Hazards Good Practice (2013)**

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To provide case studies which identify best practice in relation to wildlife hazards, particularly bird strikes, in the UK and Internationally.

**Key messages:**

- Produced in 2013 to support the Mayor of London's submissions to the Airports Commission: Outline proposals for long term aviation capacity.
- To be read in conjunction with Atkins: Potential Bird Strike 2013.



# Hub for London

## Wildlife Hazards Good Practice - Technical Note

Transport for London

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# 1. Introduction

The Mayor of London Aviation Work Programme is currently investigating how to increase London's hub airport capacity. Transport for London (TfL) are co-ordinating this work stream which includes a review of a number of short listed options that meet the necessary requirements of a future hub airport. This Technical Notes provides case studies which identify best practice in relation to wildlife hazards, particularly bird strikes, in the UK and abroad. A separate Technical Note considers bird strike in relation to the three shortlisted options i.e. Inner Estuary, Stansted and Outer Estuary.

It is considered that in opening year the new hub airport will cater for 90 million passengers per annum (mppa) increasing to 180 mppa in 2050.

The Civil Aviation Authority (CAA) indicates over 2,200 aircraft bird strikes have been reported annually since 2010, with incidents peaking during summer (June-August) months. Since most bird strikes happen during takeoff and landing (or low altitude flight), airport operations at all airports should include mitigation measures for addressing potential avian hazards to aircraft.

The CAA requires all aerodrome (airport) license holders and operators to identify, manage, and mitigate wildlife hazards on and in the vicinity of airports to minimize the risk of aircraft and wildlife collisions. Considerations for airport siting, design, management systems, operations, and adjacent wildlife habitats are imperative to the mitigation of wildlife hazards for aircraft. Wildlife and habitat evaluations during the siting and design phases and hazard mitigation during the operational phase can greatly reduce the risk associated with avian species wildlife strikes.

Over the past two decades, advances in avian detection radar technology have made its use valuable in the design, construction, and operational phases of airport when combined with standard field biology assessments and comprehensive management plans. The US Air Force installed the first operational bird detection radar in 2003 at Dare County Bombing Range in North Carolina, USA. It has since added units to airfields with high bird strike risk potential and/or critical mission assets including Dover Air Force Base (AFB), Delaware, USA; Whiteman AFB, Missouri, USA; Offutt AFB, Nebraska, USA; Beale AFB, California, USA; and Bagram Air Base, Afghanistan. Bird detection radar was deployed in support of the National Aeronautics and Space Agency (NASA) space shuttle launch program during 2005 and deemed mission essential through 2011 for the final 26 space shuttle launch missions.

Bird detection radar systems are slowly gaining acceptance internationally at commercial airports, as they transition from strictly environmental monitoring systems into real-time advisory systems. Often this equipment comes as a result of a direct request from the airlines. Many new, low-cost air carriers are operating under very narrow operational margins which require maximum availability of all of their aircraft assets. An aircraft that is out of service for hours or days due to maintenance associated with a bird strike can make a huge difference in profitability for that air carrier service.

However, it should be noted wildlife hazards to aviation are not limited solely to avian species. For example, Luis Munoz Marin International Airport in San Juan, Puerto Rico has encountered aircraft strikes and operational delays related to the presence of green iguanas. Within the United Kingdom, aircraft wildlife strike incidents at London Stansted Airport have included not just avian species, but also rabbits. Small mammals including rabbits, rats, mice, and voles also serve as a food source for larger predatory avian species like hawks, eagles, and owls. For this reason, an ecosystem-level monitoring approach should include all potential wildlife species hazards and attractants on or near proposed airport operations areas.

The case studies below include pertinent examples of how wildlife hazard mitigation has influenced airports from the design and construction to operational phases. The incorporation of standard wildlife biology field monitoring methodologies and the most current technological advances have resulted in significant contributions to wildlife hazard avoidance and mitigation on these global projects.

## 2. UK Case Studies

### 2.1. The UK Approach to management of Bird Strike Hazard

The International Civil Aviation Authority (ICAO) (Annex 14) has identified standards and practices that airports should take to monitor and reduce the risk to aircraft from bird strike. These are brought into operation by the Air Navigation Order which provides for the licensing of aerodromes by the Civil Aviation Authority (CAA), when satisfied that a licensed aerodrome is safe for use by aircraft, having regard in particular to the physical characteristics of the aerodrome and its surroundings. As part of that process bird control management plans (BCMP) are required.

All major aerodromes are officially safeguarded under The Town and Country Planning (Safeguarded Aerodromes, Technical Sites and Military Explosives Storage Areas) Direction 2002.

The accompanying circular identifies:

*“The primary aim is to guard against new or increased hazards caused by development. The most important types of development in this respect are: facilities intended for the handling, compaction, treatment or disposal of household or commercial wastes, which attract a variety of species, including gulls, starlings, lapwings and corvids; the creation or modification of areas of water such as reservoirs, lakes, ponds, wetlands and marshes, which attract gulls and waterfowl; nature reserves and bird sanctuaries; and sewage disposal and treatment plant and outfalls, which can attract gulls and other species. Planting trees and bushes normally creates a bird hazard only when it takes place relatively near to an aerodrome, but a potential starling roost site further away from an aerodrome can create a hazard.”*

In order to protect aerodromes from potentially hazardous development, safeguarding maps have been produced with a 13 kilometre radius (civilian) and 8 mile radius (military) to indicate the area within which developments likely to attract birds require consultation. CAP 772 (currently being updated) provides advice to aerodrome operators regarding safeguarding and the production of BCMPs.

There are two fundamental aspects to managing bird strike risk, on and off aerodrome, and these are described within the BCMP. The BCMP will assess the bird strike risk and define and implement the appropriate bird control measures to reduce or mitigate the risk. These measures will relate to each identified risk and may include bird control techniques.

Risk identification is the basis of bird hazard management and the species involved may be identified by any of observation, bird strike or by survey to assess the bird populations in the vicinity including seasonal factors, flightlines and attractants. The assessment will identify the species and associated habitats and will lead to an assessment of the probability of bird strike.

On aerodrome, bird strike hazard is managed by making the site unattractive to birds and by the use of surveillance and dispersal strategies depending on the assessed aerodrome risk. Counts of birds will be undertaken by airport staff and mobile patrols. Particularly important is the removal of feeding and roosting places. This may be by their direct removal, for example fruit and berry bearing plants and trees or by limiting access for example, netting water bodies or preventing access onto rooftops. The ‘long grass policy’ whereby grass is maintained at 150- 200mm, has been shown to reduce bird numbers.

Bird dispersal on aerodromes may be undertaken following their discovery either by visual or radar detection. This may be via distress calls, pyrotechnic devices and manual and passive techniques, for example the presence of bird controllers, raptors, lasers and startling techniques. Care is taken to avoid habituation. Lethal control may be taken under a general or specific licence, particularly to reduce numbers and for deterrence.

Off aerodrome bird control is undertaken by consultation of new developments in the process known as safeguarding. Where the development is assessed as increasing the potential bird strike risk, for example habitat changes or increased movements of birds in the vicinity of the aerodrome, then an objection to that development may be sustained until either modification to the development or planning conditions, which may include a bird control management plan for that site, are in place. As part of the BCMP the aerodrome also needs to be aware of activities such as ploughing fields off site which may affect the potential for increased hazard. Regular dialogue will permit any actions required to be carried out.

There is mandatory reporting of birdstrikes, confirmed and unconfirmed, to the CAA together with significant events, on aerodrome, aerodrome vicinity and en-route.

A case study in relation to Lydd Airport is provided below:

## 2.2. Lydd Airport, Kent

Plans to develop Lydd Airport in Kent were approved by the Government on 10th April 2013 after ministers agreed with a Planning Inspector's recommendation to grant approval for the construction of a 294m runway extension plus a 150m starter extension, and a new terminal building capable of handling up to 500,000 passengers a year. The airport caters for a wide range of aircraft operations, from executive jets and helicopters to private light aircraft and cargo. This case study may not be the final decision on the site, because in May 2013 the RSPB and Lydd Airport Action Group launched separate objections against the decision.

Lydd airport is located approximately 2km to the east of Lydd in Kent. Dungeness Special Area of Conservation (SAC) lies to the east of the existing runway and the paved area of the proposed runway extension would include 0.23 ha, some 0.007% of the overall SAC. The Dungeness to Pett Level Special Protection Area (SPA) is located approximately 750m east and 500m south of the existing runway. An extension to the SPA is proposed which would result in the boundary of the SPA being closer to the Airport but the proposals would not use any land within the SPA or the pSPA. Natural England (NE) is consulting on a proposed Ramsar site but again the applications would not use any land within the pRamsar. The Dungeness Site of Special Scientific Interest (SSSI) lies to the east of the existing runway and the proposed runway extension would include 1.62 hectares, around 0.018%, of the whole SSSI. The Dungeness National Nature Reserve (NNR), including an RSPB Reserve that falls within the SPA, proposed SPA (in part), SAC, proposed Ramsar, SSSI and NNR, lies around 2m from the south-eastern boundary of the Airport. The RSPB Reserve is in the region of 320m from the existing runway at its nearest point.

Concerns were initially raised by Kent Wildlife Trust and Natural England about air quality in terms of nitrogen deposition affecting plants. Both organisations were satisfied that, with the mitigation measures proposed, nitrogen deposition would be within acceptable levels and would not affect the integrity of Dungeness SAC or substantially damage the interest features of the SSSI. It was also concluded that agreed mitigation measures mean that impacts on protected species including great crested newt, common lizard, grass snake, water vole, medicinal leech and other aquatic invertebrates, bats and moths and other invertebrates would be adequately addressed.

The most notable ecology impacts identified was in relation to birds in the context of the Habitats Regulations. Within the SPA and proposed SPA there is a range of habitats offering opportunities for feeding, roosting and breeding for different species. The area around the airport has internationally important populations of overwintering waterfowl, as well as an overall assemblage of species. Particular concern was raised in regard to sandwich and common terns which were considered sensitive and at risk from disturbance by aircraft. There have been periods of much greater aviation activity at Lydd Airport, peaking in 1979, and sensitive terns established a colony at Dungeness whilst there was a similar number of movements to that now proposed. The Secretaries of State concluded with regard to ornithology that:

*'there is little evidence that there would be any, never mind a significant, decline in size, distribution, structure or function of the population such as to require an appropriate assessment (AA). Overall, having regard to the requirements on them as the competent authority in respect of the Conservation (Natural Habitats) Regulations 2010, the Secretaries of State are satisfied that they can proceed to grant permission for the applications before them without first being required to carry out an AA.'*

## 3. International Case Studies

### 3.1. King Shaka International Airport (La Mercy, South Africa)

The construction of a new airport (approximately 60km north of the previous Durban International Airport) near the town of LaMercy, South Africa, was scheduled for completion by 2010 to support the expected increase in air travel associated with the 2010 World Cup. Concerns had been raised by various project



stakeholders as to potential impacts that could be associated with a large swallow (*Hirundo rustica*) roost located in a reed bed at the base of Mt. Moreland. The roost is located approximately 3 km from the end of the proposed runway and used by an estimated 2-5 million migratory swallows from Europe that winter there during the summer months (October through April).

The two primary concerns associated with this population were the potential risk to aircraft from bird-aircraft strikes and potential mortality impact to the swallow population (which accounts for an estimated 15 percent of the world population). Several prior studies were conducted with the aim of determining how many birds use the roost, how they distribute across the landscape as they move in and out of the roost, and most importantly, how high these birds fly when they swarm in relation to aircraft traffic patterns. However, these studies exclusively used traditional field biology visual methods for estimating bird numbers, patterns, and heights. As a result, insufficient data was available to reliably assess the potential flight safety and environmental risk presented by the proposed new airport.

The Airports Company of South Africa Limited (ASCA; majority owned by the South African Government through the Department of Transportation) commissioned a MERLIN Avian Radar Survey and bird-aircraft strike hazard risk (BASH) assessment conducted on the new proposed airport location. A three month (February -April 2007), 24 hour-a-day MERLIN avian radar survey was conducted during the peak population period for the swallows to collect real-time data on bird densities, movement patterns, altitudes, and densities. The study design and program was developed and conducted in consultation with the ACSA biological consultant, the Endangered Wildlife Trust. The project utilized an XS1030e MERLIN Avian Radar System for the survey and included a three person support team: a Senior BASH Specialist, Radar Ornithologist, and Field Biologist. The MERLIN system uses two separate radar sensors to scan horizontally and vertically concurrently and continuously on a 24-7 schedule, stopping only briefly for routine maintenance or relocation. With this survey schedule, the unit made approximately 35,560 daily "observations" of the atmosphere around the reed bed roost area and the proposed airport area. This included recording the position and 63 additional parameters for each target to the internal system databases.

Over the 3 month study, the MERLIN radar system collected over 3 million "observations". Large "swarms" of swallows were detected no more than 150 m above the reed bed and were tracked leaving the roost in several waves each morning. The dispersals began around sunrise and lasted for approximately 15 to 25 minutes. The evening arrival behaviours were more varied in time, duration, and distribution and high altitude "swarms" (between 100 and 150 m) were not observed on every day. Dispersals and arrivals were detected from all directions and varied daily depending on a range of factors that included wind speed, wind direction, ambient light, precipitation, and cloud cover. Additional observations were obtained from other survey sites located further from the roost where the birds had had time to "thin out" in the atmosphere. Ultimately, the data did not suggest that movement patterns of the swallows posed a significant strike risk to aircraft and the maximum altitudes were well below the projected flight corridors. A risk assessment determined risk was manageable at low to moderate levels. Additional risk mitigation was identified if radar technology were used at the new operating airport to monitor activity and provide risk advisories.

The data was then used to develop recommendations for mitigation and management and a draft BASH plan for the airport. The survey plan, observations, and technical methodologies used in the studies, results, and proposed mitigation measures were presented during public and private meetings to local stakeholders, including environmental groups (e.g. Bird Life South Africa, Royal Society for Protection of Birds) and concerned citizens. Following the full environmental assessment process, a record of decision was issued that required the deployment and operation of a bird detection radar system and to use that system as part of an integrated bird and wildlife management program.

In 2008, a MERLIN XS2530i Aircraft Bird Avoidance Radar system was installed at the proposed airport location. Since the initial survey only lasted three months, continued support of the system included the development of specific radar processing algorithms for determining bird strike risk associations with the unique swallow movements during the spring and summer months. Several workshops on the radar system were also conducted with the various staff and stakeholders involved in bird strike avoidance. Coordination with various stakeholders was also used to develop a concept-of-operations (CONOPS) that would integrate radar risk analysis into air traffic control procedures as well as provide wildlife control officers real-time displays of hazardous bird activity. Coordination included, but was not limited to, ACSA, the Air Transportation Navigation Service (ATNS), air carriers (South African Airlines, Mango, Kalula, One Time, etc), and the CAA. Additionally, coordination with ATNS was required to produce a safety case analysis for the use of bird detection radar systems for bird strike avoidance. During the summer 2009 through fall 2010

radar data was calibrated with video data and site specific risk algorithms were developed to provide real-time risk assessment to the tower and wildlife control officers.

Following significant discussion regarding the use of segmented bird activity hazard level notifications, the radar system was configured to provide ATNS staff in the control tower a simple “green light” / “red light” indicator on their existing integrated information display system (IIDS). The light would indicate “green” when hazardous bird activity conditions were minimal and “red” when hazardous bird activity conditions increased (indicating special operations were warranted). A “grey” light box indicated when the radar or network was down. The radar system did not replace all the existing visual methods of bird and wildlife activity reporting that the airport was using at the previous airport location, it did however refine and supplement those methods. When the radar system detects a hazardous level of activity, the light box turns red, and the following procedures in the CONOPS plan were agreed upon among the ATNS representatives, the CAA, ACSA, and the air carriers present at the safety meetings:

- Tower will contact the Wildlife Control Officer to verify/identify activity.
- During swallow season (September through April), aircraft departing towards the Mt. Moreland reedbed will be held until the red light has gone back to green.
- Aircraft approaching King Shaka International Airport will be provided an advisory indicating that radar has detected a severe level of bird activity on the approach (if the approach is over the reed bed)
- Approaches and departures will be directed toward headings that do not over fly the reedbed (if winds allow).
- If the red light box is illuminated during periods of time when the wildlife control team is not on the airport (sunset to sunrise), aircraft will be held for departure until the light returns to green and approaching aircraft given a general advisory.

The new King Shaka International Airport (DUR) was completed and opened for commercial traffic on May 1, 2010. As a result of this plan, process ATNS staff implemented the first real time, radar-based bird hazard advisory procedures in an international air traffic control facility. The MERLIN bird detection radar system had been collecting data at the site for a year, and was on-line with real time risk assessment products when the airport opened.

In late September 2010, swallows from Europe returned to the region and began to re-establish the roost near Mt. Moreland. The extremely dry winter months had left the reedbed in poor condition, especially on the Lake Victoria side where most of these birds had been roosting over the past few years. The roost split into several sites including one closer to the airport and one near the mouth of the Imdloti River. Biologists and radar technicians implemented new software parameters to customise the swallow detection algorithm to compensate for the split roost and subsequent changes in bird mass that would generate risk advisories.

Wildlife control staff and tower staff continue to work interactively with the radar output and with each other to further refine advisories, procedures, adaptive management techniques to ensure the best possible flight safety outcomes. For instance, the wildlife control staff have recently incorporated the use of trained border collies to assist in wildlife hazard abatement efforts.

The ACSA reported the 2010 DUR relocation increased consolidated (i.e., international, domestic, regional, and unscheduled) aircraft movements 3.6% from the previous year (to 54,000). During the 2011-2012 fiscal year, ACSA reported over 55,000 consolidated aircraft movements at DUR. Preliminary results for the 2012-2013 fiscal year indicate increases in international aircraft movements and decreases in domestic aircraft movements will result in a decrease in consolidated aircraft movements from 2011-2012.

### **3.2. Northwest Florida Beaches International Airport (Panama City Beach, Florida, United States of America)**

During 2006, the proposed relocation of the Panama City-Bay County International Airport required the development of a Wildlife Management Plan and establishment of a Wildlife Management Program at the new proposed airport location. The proposed relocation site contained approximately 2,000 wetland acres (810 ha) which were scheduled for impacts from the construction of airport infrastructure, safety areas, roads, stormwater management, industrial development, and other facilities necessary for the operation of the airport. Less than 5 miles from the estuarine habitats of West Bay, these impacted wetlands are also part of larger contiguous wetland ecosystem and immediately adjacent to the new airport's nearly 10,000 acre (4,050 ha) mitigation area.

The purpose of the preliminary wildlife management plan for the new airport was to provide guidance in the design, development, and operation of the new facility to minimize damaging bird and wildlife strikes to aircraft. The preliminary wildlife management plan also utilized innovative wetland monitoring and management techniques to minimize environmental impacts on the relocation site, while simultaneously ensuring aircraft and flight safety. Wildlife hazard management plans are typically developed from an ecological study at the airport following a significant bird or wildlife strike event. However, this plan was developed in advance of airport construction to ensure that design and operations include bird and wildlife hazard avoidance and mitigation practices before the habitat is altered.

The plan provided construction, stormwater, and landscaping design principles, habitat management practices, wildlife resistant fencing and gate standards, and off-airport considerations to reduce bird and other wildlife attraction and access to aircraft operations at the new airport location. The plan also included the implementation of a tactically designed abatement program coupled with detailed data collection and analysis for program review and improvements. Finally, the plan created a Wildlife Hazard Advisory Group (WHAG) with a wide range of expertise for program management of the wildlife hazard plan, including plan implementation, monitoring, reporting and review. Oversight of the plan was ultimately established as the responsibility of the Executive Director at the new airport, with support from the WHAG.

The completed wildlife management plan met all requirements specified under the provisions of 14 CFR Part 139.337, was approved by the Federal Aviation Administration (FAA), and was incorporated into the Airport Certification Manual.

The new Northwest Florida Beaches International Airport (ECP) was completed and opened for commercial traffic on May 23, 2010. At the opening, it was the first international airport designed and constructed in the United States (US) since the terrorist attacks of September 11, 2001. As required by FAA guidelines, a Wildlife Hazard Assessment (WHA) is currently being completed to analyze and evaluate wildlife populations, habitat conditions, and wildlife attractants at ECP and the surrounding area. This WHA includes spatial data and aerial photography desktop analysis, coordination and interviews with ECP staff and stakeholders, identification of wildlife attractants, and daily and seasonal wildlife population surveys and monitoring. The results of this 12-month WHA may indicate modifications and revisions to the Wildlife Hazard Mitigation Plan (WHMP) to further mitigate wildlife hazards related to air travel at ECP. Ongoing staff training, adaptive management techniques and coordination with nearby development and land use changes are integral in the long-term at ECP. The integration of real-time avian avoidance and detection radar is also being evaluated at ECP.

By the conclusion of 2011, ECP exceeded 56,000 airport total operations (i.e., commercial airlines, military and general aviation flights) annually. While 2012 operations remained generally unchanged, 2013 YTD (May) total operations have increased by nearly 2%.

### **3.3. Riga International Latvia Airport (Riga, Latvia)**

During late 2009, a bird detection radar system was requested to monitor existing conditions at the international airport in Riga, Latvia (RIX). Standard wildlife hazard field monitoring, management, and abatement procedures were already conducted at RIX, but a new low-cost air carrier (Wizzair) had agreed to service the airport only if bird avoidance and detection radar was available to minimize risk of bird strikes. The RIX approach path requires flights to pass over marine and estuary habitats with significant avian densities. Additionally, flight patterns often include crossing migration paths between lakes, bird sanctuaries, and the main city landfill. Given these risk factors, the incorporation of radar-based detection of avian

hazards with existing wildlife monitoring and abatement procedures met the acceptable risk profile Wizzair required.

Once operational in January 2010, this radar system provided information to assist the full time wildlife control team at RIX. During summer 2012, the radar was integrated into tower operations and procedures, similar to DUR. The current MERLIN ABAR system at RIX was upgraded during August 2012 to include Doppler processing and state of the art MERLIN Advisor software, which includes custom risk zones (as opposed to just the green and red threat levels at DUR) and weather detection capabilities. The MERLIN Advisor system also allows controllers to visually see the risk trends over the past 30 minutes or hour(s) and to compare bird risk activity with the same time frame during the previous periods. These capabilities and the site-specific CONOPS plan allow air traffic control tower operations to adjust approach and departure corridors and timeframes to maximize aircraft safety and environmental impacts. At the time of installation, the MERLIN radar system was the only one system serving civil aerodromes in Europe.

Total flights at RIX rose from 60,000 to nearly 73,000 between 2009 and 2011. Over 4.7 million passengers and approximately 69,000 flights were recorded at RIX during 2012. Over 26,000 flights and approximately 1.8 million passengers have been recorded at RIX during 2013.

### **3.4. Warsaw-Modlin Mazovia Airport (Warsaw, Poland)**

Similar to RIX, a MERLIN ABAR system was installed at the new Warsaw-Modlin Mazovia International Airport (WMI) near Warsaw, Poland during July 2012. Upon completion, WMI and RIX became the first two European airports to permanently install a real-time bird radar technology system to avoid and mitigate aircraft birdstrike incidents.

The new WMI airport was in planning for nearly a decade and encountered serious debate and concerns from a wide range of environmental and aviation safety groups regarding the risk of serious birdstrikes to aircraft and impacts on avian populations. The airport is located near the confluence of two major rivers, the Narew and the Vistula, and is also in close proximity to several NATURA 2000 sites which are stopover areas for migrating birds.

Again with the encouragement of a low cost air carrier, the aviation authority in Poland (Polish Aviation Office; PAO) determined that using radar-based detection and remote sensing equipment would provide the best risk assessment for aircraft operations. Additionally, the PAO determined that this radar system in conjunction with field observations, management, and monitoring provided the premier method for determining the potential and extent of environmental influences on local bird populations and movement patterns. To ensure safe aircraft operations and to monitor bird activity in the surrounding areas, the MERLIN system provides both real-time risk advisories to the WMI air traffic control tower and detailed data for analysis. Analogous with DUR and RIX, a site-specific CONOPS plan was developed to provide response protocol to changes in the avian risk advisories generated by the MERLIN radar system. The compiled radar data is continuously evaluated with ongoing field monitoring, abatement, and management results to develop long-term avian management strategies on and off the airport.

The runway at WMI was closed during late December 2012 for safety repairs and is expected to reopen in July 2013. However, WMI averaged 170,000 passengers per month while operational from July-November 2012.

### **3.5. Sacramento International Airport (Sacramento, California, United States of America)**

Between 2011 and 2012, avian radar studies were conducted at Sacramento International Airport (SMF) in California, US. SMF experiences more birdstrikes annually than any other western US airport due to the volume of aircraft traffic and a variety of environmental conditions. For example, the airport is uniquely located in a bend of the Sacramento River, along the Pacific Flyway (a major North American avian migration route), and within 5 miles (8 km) of the Fremont Weir State Wildlife Area and several community and regional parks. Runway approach and departure flight paths at SMF also routinely occur over adjacent agricultural fields and wetland habitats which support significant avian densities.

The purpose of the avian radar study at SMF was to assist the full time wildlife and bird control staff in developing control strategies (e.g. manpower placement and scheduling) and evaluate the dynamics of bird movements that occurred within and significantly outside the airport property. Real-time updates were recorded every 2.2 seconds to document both horizontal and vertical avian movements on and off the airport. These movement patterns showed distinct trends over the course of the winter months as the sunrise/sunset periods shifted, as well as the influence of various weather patterns. Data and results of these radar studies were presented to SMF at the conclusions of the study.

Management recommendations included the incorporation of observed trends into field observations and data collection from daily wildlife control operations and FAA-required WHAs conducted at SMF. These trends may also assist the wildlife control staff in abatement and staffing plans, wildlife population and habitat management, and monitoring impacts associated with land use changes. The radar could also be used to schedule (or reschedule) aircraft departure and arrival times with air carriers (to avoid critical 20-30 minute windows of activity), provide specific air traffic control tower advisories via the Automated Terminal Information System (ATIS), and if necessary, allow air traffic control to hold departing aircraft during peak movement periods.

Ultimately, these risk management options provided through radar-detection technology can be incorporated in revisions of the FAA-required WHMP at SMF. An inclusive and integrated approach involving wildlife control field operations and observations, avian radar risk analysis, air traffic control operations, and air carrier flight flexibility and risk profile, was recommended to evaluate, minimize and mitigate environmental impacts and wildlife-aircraft strike hazards.

Total aircraft operations at SMF increased from approximately 115,000 to 117,000 (1.8%) between 2011 and 2012. Over 80,000 of these flights annually are commercial air carrier traffic. Total annual passenger traffic remained constant at approximately 9 million total passengers over this period. Total YTD (May) passengers and flights have increased 2.3% and 7.8% respectively during 2013 at SMF.

## 4. Conclusions

Wildlife hazard management (particularly bird strike risk) is a concern internationally for airport planners and operators. These case studies illustrate the need and benefit of technologically advanced monitoring, assessment, and planning during airport design and construction. There are international case studies where recent technological advances have allowed robust management of risks for airports, the largest of which had over 80,000 commercial flights annually with over 115,000 total flights. It is necessary to collect onsite and offsite habitat data, wildlife density and movement data, and evaluate the daily, seasonal, and annual fluctuations to these environmental components. Evaluations of these components are also required for any assessment of proposed airport impacts to existing ecosystems. Data from bird detection radar reliably assists in the establishment of baseline information regarding avian abundance and movement patterns. It can also assist in the determination of future impacts from land use changes, development, and operations on and off airports. These evaluations and assessments would be incorporated into wildlife hazard mitigation and management plans that provide guidance throughout the multidiscipline planning and design stages.

A programmatic and strategic approach to new airport design and construction, that includes wildlife hazard considerations, will ultimately lead to more streamlined operations for avoidance and mitigation of wildlife and aircraft incidents and increase airspace utilization. These proactive efforts increase awareness, indicate transparency, and demonstrate to local residents, environmental groups, air carriers, and other stakeholders that airport environmental planners appropriately and thoughtfully addressed flight safety issues and environmental concerns. Once established, wildlife hazard monitoring and management plans should be continuously evaluated, refined, and revised in conjunctions with airport operations using the most recent and pertinent data available.

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