WPI

Bird Strike Prevention Part 2

An Investigation of Bird Strike Prevention Methods in Israel and a Comparison to Panama City's Tocumen International Airport

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An Investigation of Bird Strike Prevention Methods in Israel and a Comparison to Panama City's Tocumen International Airport

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Disclaimer

Appendix E is a supplementary material to the TBR-AAT3 submission. The TBR-AAT3 report along with the supplementary material will be submitted as AS5-OKRA.

ABSTRACT

This project addressed the problem of bird strikes at Panama's Tocumen International Airport. Globally and in Panama, bird strikes threaten passenger safety, damage aircraft, and harm wildlife. Through data analysis, interviews, observations, benchmarking, and case study research, we found that black vultures are the biggest bird strike risk in Panama. In addition, bird strike risk increases during raptor migratory seasons. We also determined Tocumen Airport has many factors that attract birds to the property. Some of these factors are man-made, including trash in surrounding communities and new construction, while others are environmental causes, such as mangroves and tall grass. No single method can remove all the contributing factors, so the airport should consider using multiple bird strike prevention methods, such as landscape management and avian radar, as well as work together with the surrounding communities to reduce trash near the airport property.

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ACRONYMS AND KEY TERMS

Acronyms

AAC- Autoridad Aeronautica Civil, the Panamanian national civil aviation regulatory body

AHAS- US National Avian Hazard Advisory System

ATC- air traffic control, often refers specifically to the control tower at an airport

FAA- Federal Aviation Administration, the U.S. national civil aviation regulatory body

FDA- U.S. Food and Drug Administration

JFK- John F. Kennedy International Airport, Queens, New York, United States

MA- Methyl Anthranilate, a non-toxic chemical that irritates the eyes and nasal passages of birds

USAF- United States Air Force

Terms

Bird strike- a collision between an aircraft and a bird

Mangrove- a type of tree that is able to grow in salt water, often found in tidal flats and estuaries where salt water meets fresh water. They have one of the most diverse ecosystems in the world.

Phases of flight (in order)

Taxi-out- the period between when the plane pushes away from the gate and travels to the runway

Takeoff- the period when the plane starts accelerating down the runway until the landing gear is raised by the pilot

Climb- the period between when the pilot raises the landing gear until the plane levels out at its cruising altitude

Descent- the time between when the plane starts coming down from its cruising altitude until it enters the landing pattern around the airport

Approach- the landing pattern around the airport.

Landing- the period between when the pilot lowers the landing gear until the plane comes to a stop on the runway, usually a straight line into the runway.

Raptor- A large bird of prey. This includes hawks, eagles, falcons, and vultures.

Roost- when birds settle to rest or sleep at night

Thermal- a localized rising column of warm air. Birds use these to climb to higher altitudes with little effort. When raptors migrate they glide from thermal to thermal, expending as little energy as possible

EXECUTIVE SUMMARY

Bird strikes, or bird-aircraft collisions, are a major wildlife hazard to the aviation industry. As air traffic increases worldwide, strike numbers are increasing as well.[1] Bird strikes put passenger safety at risk: strikes are capable of causing emergency landings and even tragic plane crashes. Bird strike damage is also expensive, costing the global airline industry over $1.2 billion dollars annually.[2]

Bird strikes are almost routine at Panama's Tocumen International Airport. Copa Airlines, the national airline of Panama, records an average of ten bird strikes a month, with 1 in 5 of them causing damage. The airport has several internal and external factors that attract birds including wetlands, tall grass, mangroves, and trash heaps. In addition, raptors fly over the airport during their migratory seasons in the spring and fall. "The airport," said one airport inspector, "is a five star hotel for birds." Panama's Tocumen International Airport has experimented with firecrackers and noise guns as bird deterrents, but birds have acclimated to them and no longer respond to the deterrents.

Project Goal, Research Questions, and Methodology

The goal of our project was to develop an effective and feasible bird strike mitigation plan for Panama's Tocumen International Airport. To accomplish our goal, we developed the following four research objectives:

1. Identify bird strike causes at Tocumen International Airport by analyzing patterns of reported bird strikes.
2. Assess the environmental factors and man-made factors contributing to bird strikes inside and adjacent to Tocumen International Airport
3. Examine the interests of the administrative stakeholders – Tocumen S.A., Copa Airlines, and the Autoridad Aeronautica Civil, regarding bird strikes.
4. Analyze the effectiveness, cost, and environmental sustainability of five options for bird strike reduction at Tocumen Airport: bird deterrents, minimizing trash in adjacent areas, landscape management, avian radar, and early warning systems.

[1] Allan, John R. (2000). The Costs of Bird Strikes And Bird Strike Prevention. Human Conflicts with Wildlife: Economic Considerations. Paper 18.

[2] Uhlfelder, E. (2013, November 8). "Bloody Skies: The Fight to Reduce Deadly Bird-Plane Collisions." *National Geographic*.

Our team accomplished these objectives by analyzing bird strike report data from our sponsor, Copa Airlines. We also conducted interviews with Copa Airlines' employees, the Tocumen Airport wildlife management team, and members of Panama's Autoridad Aeronautica Civil. In addition, our team made observations of contributing factors to bird strikes while visiting Tocumen airport and its surrounding areas. We also made a benchmark visit to the José Joaquín de Olmedo International Airport in Guayaquil, Ecuador. This airport has similar contributing factors to Tocumen Airport and has successfully reduced bird strike numbers.

Findings

The following findings highlight an important concept: no single bird strike prevention method will completely eliminate bird strikes. It is important to choose different methods that complement each other because different methods would target different contributing factors of bird strikes. Both bird attractants on and off airport property, as well as migratory birds, should be considered when choosing methods of prevention.

Bird strike risk factors fall under two categories: man-made and environmental. Man-made factors include new construction, fencing, and poor drainage, which are all directly on airport property. The trash in surrounding communities is a man-made attractant outside of the airport property. Environmental factors on airport property include wetlands, tall grass, and trees while factors off airport property include mangroves.

Objective 1: Bird Strike Causes

1. Because most birds fly below 3,500 feet and aircraft have less leeway to maneuver below that altitude, the majority of bird strikes occur during approach and landing, with about 1 bird strike in every 1000 landings.

Because pilots have to land correctly on the runway, any maneuvering around birds is prohibited. During takeoffs, pilots have more airspace to maneuver and have options to increase the rate of climb and velocity of the plane. Once they reach 3,500 feet, bird strike risk is significantly lowered because birds do not fly above that altitude.

2. Of the many resident bird species at the airport, black vultures pose the biggest risk to aircraft and passenger safety because of their large numbers, large size, and tendency to circle in groups on thermal columns above the airport.

Black vultures, which typically weigh between 1.6 and 2.8 kg (3.5-6.1 lb.), challenge impact standards for aircraft engines, which are designed to best withstand ingestions from up to a 1.81 kg (4 lb.) bird. At the airport, we observed vultures perching on fences and trees, as well as using thermal columns to gain altitude. Our interviewees also expressed that black vultures are the most prevalent birds around the airport.

3. Migratory raptors- mostly Swainson's hawks and turkey vultures- appear to cause about 50% more bird strikes during the peak migratory months of October and April.

During peak months of migration in Panama, April and October, the average number of bird strikes were 12.3 and 25.5 from 2013 to 2015. However, the average number of bird strikes during the other months were 8 strikes per month.

Objective 2: Internal and External Factors of Bird Strikes

4. Compared to external factors, the airport can more easily control environmental factors on their property that attract birds, such as wetlands, tall grass, and trees, as well as man-made factors such as fencing, new construction, and poor drainage.

Wetlands and tall grass provide birds with food and nesting while trees and fencing provide roosting and perching locations for the birds. The new construction creates thermals that raptors use to fly. Poor drainage creates standing water that also attracts birds. The airport has the ability to make airport land less desirable by mitigating contributing factors of bird strikes, causing birds to move to other locations.

5. Bird attractions outside of Tocumen International Airport that are harder to manage include mangroves, an environmental factor, and trash, a man-made factor.

Many resident bird species nest, roost, and feed within the trees of the mangrove forests. Black vultures fly across airways when scavenging for food within the trash heaps in the neighborhoods surrounding the airport.

Objective 3: Stakeholder Relationships

6. Copa Airlines and the AAC have communicated their need for an effective bird strike mitigation strategy to Tocumen S.A., but Tocumen does not fully understand this need.

Members of the Panama Audubon Society, DeTect, and the U.S. Federal Aviation Administration (FAA) have made several presentations and suggestions for Tocumen S.A. regarding bird strike prevention, but none have been implemented. Copa Airlines wants Tocumen Airport to implement an effective bird strike mitigation method because they are concerned about passenger safety and damage to aircraft. Tocumen S.A. desires concrete evidence of a proven bird strike mitigation solution before they are willing to invest. The AAC is only a regulatory agency, so they cannot make or enforce laws.

Objective 4: Bird Strike Solutions

7. Bird deterrents are only a temporary bird strike prevention method because birds become acclimated to them. Tocumen Airport uses two methods of bird deterrents - firecrackers and noise guns - which have had minimal effect.

Bird deterrents are not very effective, low cost, and have minimal effect on the environment. The cheapest way to move birds is to scare them using methods such as lasers, and noise deterrents, but they will only move for a short time. Birds may eventually acclimate to these methods.

8. Trash cleanup in the surrounding neighborhoods may be an effective and low cost solution to bird strikes because it will reduce the presence of vultures on and near the airport property.

Trash cleanup may be moderately effective, is low cost, and beneficial to the environment. The neighborhoods near the airport have exposed heaps of trash because of unreliable garbage pickup. Community members leave trash in piles on the side of major roads and bus stops. Pilots and the wildlife control team at Tocumen believe that trash attracts black vultures to areas near flight paths, but very little data supports this.

9. Landscape Management, such as nets/grid lines or non-toxic irritant, is an effective option for Tocumen Airport because of its potential to reduce the number of birds on the property.

Landscape management is very effective, has a moderate cost, and has a moderate negative effect on the environment. Several options exist for making wetlands inhospitable to birds, but many of these would disturb the environment. Both the grid line system and Methyl Anthranilate (MA) are designed to deter birds and have minimal effect on the surrounding environment. Overhead grid line systems are made of a fine wire stretched across attractants such as grassy areas or standing water. MA is a non-toxic, U.S. Food and Drug Administration approved bird irritant that would deter birds from landing in targeted grass or water areas to feed. Non-toxic irritant is a good option because birds do not become used to it.

10. Avian radar and early warning systems are high cost but effective at warning airports about periods of high bird strike risk, such as migration, and allow the study of bird behavior patterns, making it an effective option for Tocumen.

Avian radar and early warning systems are very effective, high cost, and have no effect on the environment. Avian radar provides real-time information on where birds are around the airport property. It is also effective in establishing bird behavior patterns. Early warning systems will monitor a specific space in the sky to measure how many birds fly through it and which direction they are flying.

Recommendations

For Tocumen Airport:

1. Keep a logbook of the airport conditions each day such as grass height, weather conditions, temperature, and number of birds present to help identify bird strike causes.

In Copa Airlines' reported bird strike data, as well as the data provided by the airport, information on what may have caused the bird strikes is missing. A logbook of possible bird attractants may provide insights to bird strike occurrences with previously unknown reasons.

2. Implement multiple bird strike prevention methods to best mitigate the risk of bird strikes at the airport because no single method will completely prevent the risk of bird strikes.

The airport must realize that one bird strike prevention method will not completely solve the problem. Many unique factors attract birds to the airport, which all need to be addressed to mitigate the bird strike risk. Options that complement each other would need to take into account both internal and external bird attractants, as well as migratory birds.

3. Test different low cost, but effective options of landscape management: overhead nets/grid lines, Methyl Anthranilate, and drainage canal repairs.

Landscape management is a viable option for Tocumen Airport because it would reduce the number of birds present on the property. Overhead Grid lines and the irritant Methyl Anthranilate (MA) would deter birds from standing water in the airport without harming any land. Since the drainage canal is not actually draining anymore, repairing it would remove standing water where food is available for birds.

4. Implement avian radar to provide data for tracking and managing bird threats up to a 10 km radius around the airport. Radar can monitor birds 24 hours a day to provide data on bird patterns and behaviors. This allows it to assess bird strike threats from both resident and migratory birds.

Radar is capable of tracking all of the present bird hazards. The radar can store data on bird movements that can later be analyzed by bird experts to better understand the migrations in Panama, which will provide long term benefits for the airport. This is the only prevention method that can be used to mitigate the threat from both resident and migratory birds.

5. Study the trash problem in the communities surrounding the airport to find a solution that benefits the community, airport, and government.

All the residents of the communities surrounding the airport that we spoke with had a problem with the excess trash, telling us that it is a cultural issue that will not be simple to solve. Even though finding a solution to this problem would be beneficial to both, the airport and the community have not reached out to each other on this matter. Since this problem is a wide reaching cultural issue, we suggest that a team research and analyze possible solutions to find the best one.

For Copa Airlines:

6. Improve Copa Airlines' bird strike reporting system: create a uniform database to efficiently store bird strike report data including costs, damages from the bird strikes, and species of birds.

While analyzing Copa's bird strike reports, we realized the data lacked information. Items were often left out of reports, and we had to search through other databases to find the damages and costs associated with bird strikes. Species of birds struck are also not recorded anywhere. This results in a lack of evidence for what birds cause the most strikes at Tocumen.

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TABLE OF CONTENTS

ABSTRACT i
ACKNOWLEDGEMENTS ii
ACRONYMS AND KEY TERMS iii
EXECUTIVE SUMMARY iv
AUTHORSHIP xi
TABLE OF CONTENTS xii
TABLE OF FIGURES xiii
1. INTRODUCTION 1
2. BACKGROUND 4
2.1 The Relationship Between Airports and Their Environments 4
2.2 Bird Strikes on Aircraft Around the World 5
2.3 Soaring Bird Strike Risk at Panama City's Tocumen International Airport 7
2.4 Bird Strike Prevention Methods 12
3. RESEARCH QUESTIONS & METHODOLOGY 17
OBJECTIVE 1: Identify bird strike causes 17
OBJECTIVE 2: Assess the environmental factors and man-made factors 18
OBJECTIVE 3: Examine the interests of the administrative stakeholders 19
OBJECTIVE 4: Analyze five options for bird strike reduction 20
4. FINDINGS & ANALYSIS 23
5. CONCLUSIONS AND RECOMMENDATIONS 37
RECOMMENDATIONS 40
PROJECT DESIGN PRINCIPLES 44
BIBLIOGRAPHY 46
APPENDIX A 50
APPENDIX B 53
APPENDIX C 54
APPENDIX D 55

TABLE OF FIGURES

Figure 1: The Layout of Tocumen Airport. 9
Figure 2: Red Mangroves in the approach corridor of the airport. 10
Figure 3: Trash in neighborhoods surrounding Tocumen. Resident dumping trash (top left). Broken, overflowing dumpster (top right). Trash heap along airport property (lower left). Littered bus stop by the airport (lower right)..... 11
Figure 4a: Migratory Routes through North and South America (left) National Audubon Society 2015.. 12
Figure 4b: Estimated fall migratory routes of raptors through Panama City (right) Panama Audubon Society. 12
Figure 6: Flight phases when bird strikes occurred from January 2013 and August 2015. Purple shows phases of departure, blue shows phases of arrival. 24
Figure 7: Black vulture perched on a roof (left). Black vultures flying in a thermal above the runway at Tocumen Airport (right). 25
Figure 8: Number of bird strikes on Copa Aircraft from 2013-2015..... 26
Figure 9: The Assessment for Methods of Bird Strike Prevention 31
Figure 10: Net system at Guayaquil Airport..... 34

1. INTRODUCTION

Captain Jose Rodriguez of Copa Airlines will not soon forget the explosion caused by two birds ingested by the engine of his Boeing 737 on a return flight to Panama in 2005. The cabin filled with smoke and the smell of fuel and burnt feathers. Observers reported that flames trailed past the tail of the plane. Jose was able to coax the airplane back to the airport without any casualties, but this incident could have easily ended in tragedy.

Bird strikes threaten the aviation industry worldwide. "Almost everywhere," Eric Uhlfelder wrote in *National Geographic*, "wildlife and airports exist in close proximity to each other."[3] As air traffic increases worldwide, strike numbers are going up.[4] Bird strikes put passenger safety at risk, causing at least one premature landing per day.[5] The impact of a 3 kg (6.6 lb.) bird with an aircraft is equivalent to a force of 40 tons, comparable to the weight of an adult sperm whale.[6] Bird strike damage is also expensive, costing the worldwide airline industry over $1.2 billion dollars annually.[7] In addition to bird strikes, the expanding aviation industry will continue to create large impacts on the environment such as land alteration, water and land pollution, and wildlife hazards.[8]

Few places are more familiar with bird strikes than Panama's Tocumen International Airport. "The airport," said one airport inspector, "is a five star hotel for birds." The property contains wetlands and tall grasses that attract herons, plovers, pipers, and kingfishers. The airport sits adjacent to a broad swath of protected mangroves on the Pacific coast. Large numbers of birds, including thrushes, hawks, swallows, and caracaras, often make their way from the mangroves onto airport property to feed, posing a threat to moving aircraft. On the opposite side of the airport, trash heaps in low income communities attract black vultures. In addition, massive clouds of raptors, such as turkey vultures and Swainson's hawks, fly through the airport during

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[3] Uhlfelder, E. (2013, November 8). "Bloody Skies: The Fight to Reduce Deadly Bird-Plane Collisions*." National Geographic*.

[4] Allan, John R. (2000). "The Costs of Bird Strikes And Bird Strike Prevention. Human Conflicts with Wildlife: Economic Considerations." Paper 18.

[5] Uhlfelder. (2013, November 8). "Bloody Skies: The Fight."

[6] Rosenthal, D. (1998). "When Birds Become Missiles." *International Wildlife* Nov. 1998: NA. *General OneFile*. Web. 29 Sept. 2015.

[7] Uhlfelder. (2013, November 8). "Bloody Skies: The Fight."

[8] Ashford, N. Mumayiz, S. A., Wright, P. H., Culberson, S., (2011). *Environmental Impacts of Airports. In Airport engineering: Planning, design, and development of 21st century airports(4th ed.)*. Hoboken, N.J.: Wiley; Blackwell, B. F., DeVault, T. L., Fernández-Juricic, E., & Dolbeer, R. A. (2009). Wildlife collisions with aircraft: A missing component of land-use planning for airports. *Landscape and Urban Planning, 93*(1), 1-9. doi:10.1016/j.landurbplan.2009.07.005.

their migratory seasons and often roost on airport trees or fences. Copa Airlines, the national airline of Panama, records an average of ten bird strikes a month at Tocumen Airport, with 1 in 5 causing damage.[9] Because not all strikes are reported, the number of bird strikes is probably over twice their reported number.[10]

Airports around the world have attempted to decrease bird strikes. John F. Kennedy (JFK) International Airport in New York has experimented with shooting birds and oiling eggs to decrease bird population.[11] Homestead Air Reserve Station in Florida tested the use of Methyl Anthranilate aerosol, a substance that is an irritant to birds.[12] Other airports have used avian radar. Radar does not prevent birds from coming onto airport property but instead monitors their movement, enabling the airport to make decisions about delaying or changing the path of flights to avoid birds. Panama's Tocumen International Airport has experimented with firecrackers and noise guns as bird deterrents, but birds have acclimated to them and no longer respond to the noise.

Our team worked with Copa Airlines to develop an effective and feasible bird strike mitigation plan for Panama's Tocumen International Airport. To achieve this goal, we pursued four objectives:

1. Identify bird strike causes at Tocumen International Airport by analyzing patterns of reported bird strikes.
2. Assess the environmental factors and man-made factors contributing to bird strikes inside and adjacent to Tocumen International Airport
3. Examine the interests of the administrative stakeholders – Tocumen S.A., Copa Airlines, and the Autoridad Aeronautica Civil, regarding bird strikes.
4. Analyze the effectiveness, cost, and environmental sustainability of five options for bird strike reduction at Tocumen Airport: bird deterrents, minimizing trash in adjacent areas, landscape management, avian radar, and early warning systems.

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[9] Copa Airlines. (2015). *Bird Strike Data*. Retrieved from Copa Airlines bird strike reporting database.

[10] Uhlfelder. (2013, November 8). "Bloody Skies: The Fight."

[11] Belant, J. L., Dolbeer, R. A., Sillings, J. L. (1993). "Shooting Gulls Reduces Strikes With Aircraft at John F. Kennedy International Airport." *Wildlife Society Bulliten. Vol. 21* (No. 4). pp 442-450.

[12] Constantin, B., Engeman, R. M., Peterla, J. (2002). "Methyl Anthranilate Aerosol for Dispersing Birds from the Flight Lines at Homestead Air Reserve Station." *International Biodeterioration and Biodegradation. Vol 49* pp175-178.

We hope our suggestions meet the interests of Copa Airlines, the Autoridad Aeronautica Civil of Panama, and the board at Tocumen International Airport, and that they will come together to find a solution that benefits themselves, passengers, and the environment.

2. BACKGROUND

Airports have many detrimental effects on the environment, one of which is bird strikes. At Panama's Tocumen International Airport, bird strikes are a large problem. This chapter examines the following topics:

1. The Relationship Between Airports and Their Environments
2. Bird Strikes on Aircraft Around the World
3. Soaring Bird Strike Risk at Panama City's Tocumen International Airport
4. Bird Strike Prevention Methods

2.1 The Relationship Between Airports and Their Environments

The U.S. government's Federal Aviation Administration (FAA) suggests eighteen environmental impact categories to consider when constructing and operating an airport.[13] This section briefly addresses three of the categories: land use, pollution, and wildlife.

Land Use of Airports. The effects that airports have on land have changed throughout the past century. In the early 1900s, airports were large areas of level terrain, with naturally draining soil and tough all-year grass. After World War II, these natural airports were outdated compared to the fast growing technology of airplanes. Therefore, land had to be altered and destroyed to accommodate these new airplanes. For example, land was dredged to create artificial lakes for drainage at Chicago's O'Hare Airport. O'Hare Airport's land was originally a thriving wetland ecosystem; it was destroyed during construction of the airport.[14] Denver International Airport was constructed on 53 square miles of land that was altered to host several mineral extraction sites and oil wells for extra profit.[15] Airport construction has also flattened mountains in West Virginia and Missouri and filled bodies of water in Japan and Washington, D.C.[16]

Pollution Caused by Aviation. Land pollution includes litter, illegal dumping, and hazardous material spills. Airport construction, operation, and maintenance creates solid waste on the

[13] Ibid.
[14] Waldheim, Charles. "Airport Landscape." *Log* 8 (2006): 120-30.
[15] Ibid.
[16] Dümpelmann. *Flights of imagination: Aviation*, 352.

property. Hazardous waste may also be created by daily airport activities such as aircraft fueling and maintenance, and emergency generators.[17]

Airport construction and operation also contaminates water resources. Impacts to the quality of surface water (rivers, lakes, streams) and groundwater, and increased storm water quantities are a concern.[18] A major problem in airport management is when snow and ice removal chemicals, fuel and oil spills, or fire retardant chemicals contaminate storm runoff water.[19]

Aviation and Wildlife. Airport construction and landscaping often leads to animal habitat loss. This is because many airports provide grassy, spacious areas ideal for animals to live and feed on. Different methods are used to deal with wildlife on airports, such as removing attractions, trapping, or killing, which can pose a threat to animal populations. Because of protected species, development in sensitive areas may be legally restricted.[20]

2.2 Bird Strikes on Aircraft Around the World

The following section explains the impacts of bird strikes around the word, a brief history of bird strikes, and the causes of bird strikes.

Global Impacts of Bird Strikes. Animals are often considered a nuisance to airports because they increase the risk of wildlife strikes. Wildlife strikes involve a collision of an aircraft with an animal. Of all wildlife strikes, about 98% involve birds.[21] Because bird strikes are a large problem for airports around the world, they must be mitigated to improve passenger safety, prevent damage to aircraft, and protect wildlife. Globally, bird strikes will cause a plane to land prematurely at least once a day.[22] It is also estimated that bird strikes cost airlines $1.2 billion a year, worldwide.[23] In the United States alone, annual aircraft downtime from bird strikes can range from 94,000 hours to over 400,000 hours, costing over $50 million.[24]

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17 Ashford, Mumayiz, Wright, Culberson. (2011). *Environmental Impacts of Airports*

18 Ibid.

19 Sulej, A., Polkowska, Ż, & Namieśnik, J. (2011). "Analysis of Airport Runoff Waters." *Critical Reviews in Analytical Chemistry,* 190-213.

20 Ashford, Mumayiz, Wright, Culberson. (2011). *Environmental Impacts of Airports.*

21 Blackwell, B. F., DeVault, T. L., Fernández-Juricic, E., & Dolbeer, R. A. (2009). "Wildlife collisions with aircraft: A missing component of land-use planning for airports." *Landscape and Urban Planning, 93*(1), 1-9. doi:10.1016/j.landurbplan.2009.07.005.

22 Uhlfelder. (2013, November 8). "Bloody Skies: The Fight."

23 Uhlfelder. (2013, November 8). "Bloody Skies: The Fight."

24 Allan. (2000). "The Costs of Bird."

Brief History of Bird Strikes. Bird strikes have been a problem since aviation first came to be. The first known bird strike occurred in 1908 in Dayton Ohio, when Orville Wright killed a bird in a flock he was following.[25] The most fatal bird strike recorded was on October 4, 1960 when Eastern Air Lines Flight 375 from Boston flew through a flock of starlings during takeoff. Ingested birds damaged all four engines, causing the plane to crash into the Boston Harbor, killing 62 people.[26] More recently, in 2008, a cargo plane taking off in Belgium actually broke in half after striking a flock of birds because it could not stop in time. Luckily, the plane was full of cargo, not passengers.[27] In 2009, bird strikes gained a lot of publicity following Captain Chelsey "Sully" Sullenberger's heroic landing on the Hudson River in New York after flying through a flock of geese. The plane suffered a loss in the thrust of both engines, but, fortunately, the plane landed safely.[28] "What happened to [me]," stresses Captain Sullenberger "could happen again tomorrow."[29] The Hudson landing sparked several initiatives to reduce bird strikes, including goose culling efforts from the mayor of New York City at the time, Michael Bloomberg.[30]

Causes of Bird Strikes. Bird strikes are becoming more frequent as air traffic increases and plane manufacturers develop quieter turbine engines. Manufacturers are making aircraft smaller and more aerodynamic to reduce drag and increase lift.[31] Many aircraft engines have decreased from four to two turbine engines, reducing aircraft noise levels and the distances birds can hear planes approaching. Turbine engines are also more likely to ingest birds than piston engines, commonly used on older planes.[32] These airplane modifications increase bird strikes because birds mainly rely on sight and hearing to avoid colliding with airplanes.[33]

Bird strikes rates are going up because of increasing bird populations. Environmental regulations created in the 1970s and 1980s have allowed some species of large birds to repopulate. For example, the Canada goose population in the United States has increased from 1 million to

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25 Thorpe, J. (2003, May). "Fatalities and destroyed civil aircraft due to bird strikes." 1912-2002. In *International Bird Strike Committee, 26th Meeting. Warsaw, Poland*.

26 Ibid.

27 Borrell, B. (2009, January 15). "What is a bird strike? How can we keep planes safe from them in the future?" *Scientific American.*

28 Hersman, D. A., Hart, C. A., & Sumwalt, R. L. (2010). "Loss of Thrust in Both Engines After Encountering a Flock of Birds and Subsequent Ditching on the Hudson River." *Accident Report NTSB/AAR-10/03*, National Transportation Safety Board, Washington DC.

29 Uhlfelder. (2013, November 8). "Bloody Skies: The Fight."

30 Ibid.

31 Allan, (2000). "The Costs of Bird."

32 Blackwell, DeVault, Fernandez-Juricic, Dolbeer. (2009) "Wildlife collisions with aircraft."

33 Nicholson Ph.D, R. & Reed, W. S. (2011). "Strategies for Prevention of Bird-Strike Events." *Aero Quarterly*, QTR_03,11ich

nearly 4 million in 18 years.[34] Geese are also better adapting to urban environments.[35] In addition, numbers of migrating birds are increasing in some areas of the world.

2.3 Soaring Bird Strike Risk at Panama City's Tocumen International Airport

This section discusses four major contributing factors that make Tocumen International Airport at high risk for a bird strike:

1. Construction of the airport
2. Attractants inside the airport
3. Land surrounding the airport
4. Bird migration over the airport

Construction of the airport. Tocumen International Airport, 23km (15 mi.) from downtown Panama City, is the hub of Panama's national airline, Copa Airlines. Construction of the airport began on June 1, 1947; the airport was built on wetlands that were home to many species of animals. In 1971, the airport expanded to support Panama's growing transit operations. This new expansion resulted in alterations of the surrounding land and diversion of the Tocumen River.[36]

Since 2003, Tocumen Airport has been owned by Tocumen S.A., a corporation that abides by civil law, whose shares are completely owned by the Panamanian Government.[37] Autoridad Aeronautica Civil (AAC), the civil aviation authority of Panama, supervises and sets regulations for Tocumen S.A. Tocumen continues to renovate and expand the airport, eventually hoping to establish an "aerotropolis" using 300 acres of land near the site.[38] Some current renovations have included expanding the main passenger terminal and cargo terminal, updating and adding new boarding gates, upgrading terminal facilities, and beginning construction for a new terminal.[39]

The new construction contributes to increasing bird strike risk because of the alterations being made to the environment. The new parking lots and buildings associated with the terminal generate more thermals. The construction has already diverted the river twice, leaving some

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[34] Dolbeer, R. (2011). "Increasing Trend of Damaging Bird Strikes with Aircraft Outside the Airport Boundary: Implications for Mitigation Measures." *Human–Wildlife Interactions* 5(2), 235–248.
[35] Ibid.
[36] History of the Airport. (2011). Retrieved September 14, 2015, from http://www.tocumenpanama.aero/index.php?cccpage=historia.
[37] Kasarda, J. D. (2011). "Big plans for Panama." *Airport World*, *16*(03), 01-07.
[38] Ibid.
[39] Ibid.

areas with improper drainage, causing larger amounts of standing water. Its construction led to the displacement of many animals, which the birds like to feed on, onto the airport property.

Bird strikes are an increasing problem at Tocumen International Airport in Panama City, largely because of increasing numbers of flights in and out of the airport. Along with an increasing number of Copa Airlines' flights since 2011, there have been increases in the number of bird strikes reported.[40] Bird strikes are a large concern to Copa Airlines because they pose a threat to passenger safety and can cause damage to aircraft.

Attractants Inside the Airport. Tocumen International Airport's landscape contributes to bird strikes by providing an ideal habitat for birds. Several species of birds live on the airport property year round, including swallows, herons, and owls. Wetlands, trees, and other shrubbery draw these birds to the airport.[41] Birds eat fish, insects, and rodents living in the grass and wetlands on the airport premises. Trees and shrubs provide excellent homes for birds to nest or roost for the night. **Figure 1** below shows the layout of Tocumen Airport and its surrounding areas.

[40] Copa Airlines. (2015). *Bird Strike Data*.

[41] International Civil Aviation Organization (ICAO). (2014) *Nineteenth Meeting of the Regional Aviation Safety Group* (RASG-PA ESC/19-WP/09) Lima, Peru.

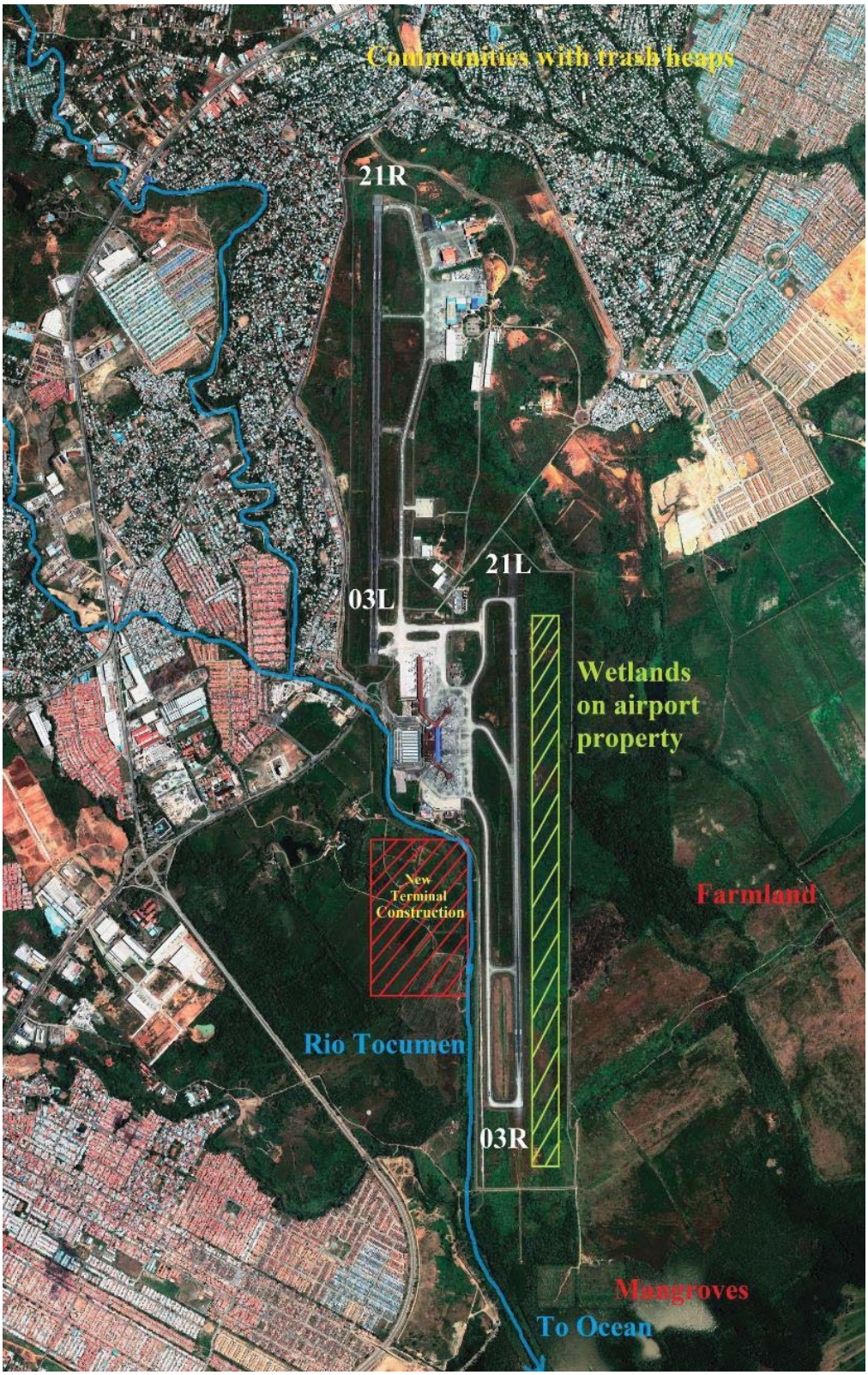

Figure 1: The Layout of Tocumen Airport.

Land Surrounding the Airport. Tocumen International Airport is adjacent to the shoreline of the Panama Bay. Protected wetlands and mangroves run between the Pacific coast and airport property. Mangroves are species of trees and shrubs that grow near the equator in swampy, coastal wetlands. They provide a rich habitat for several different types of wildlife like fish, shrimp, crabs, monkeys, and birds.[42] Mangroves are threatened worldwide due to destruction from housing developments, farms, roads, and pollution.[43]

Figure 2: Red Mangroves in the approach corridor of the airport.

Trash and other debris litter many streets in the communities near the airport.[44] These are lower income communities, with a poor sanitation infrastructure. Cattle farms and slaughterhouses next to these communities leave scraps and other garbage outside, contributing to the bird strike problem. These communities are densely packed, with narrow streets that don't allow for trash pickup at individual houses. Residents must bring their garbage to dumpsters on the main street; often, these dumpsters are not where they are supposed to be, or overflowing with previous weeks' trash. Because the city waste collection system is unreliable, it will often miss assigned weekly pickups. In response, residents dump their garbage on streets away from their homes.

42 Warne, K. (2007, February). "Mangroves: Forests of the Tide." *National Geographic.*

43 Ibid.

44 Domínguez, C. (2015). Landscape around Tocumen International Airport [Personal interview].

Figure 3: Trash in neighborhoods surrounding Tocumen. Resident dumping trash (top left). Broken, overflowing dumpster (top right). Trash heap along airport property (lower left). Littered bus stop by the airport (lower right)

Bird Migration Over the Airport. Many species of birds migrate through Panama on their way from North America to South America, and back again. These migrations contribute to increasing bird strike numbers. Each year, over 5 million raptors, or birds of prey, migrate into Central and South America. Along with raptors, 1 to 2 million shorebirds migrate in and out of the Panama Bay wetlands, near the airport, every year.[45] In 2014, Panama saw record numbers of raptors passing over Panama City. Over 2 million passed over the city in one day, which was more than double the record for migrating birds in a single day. [46] Panama contains a major migratory route, the Trans-American flyway. **Figure 4a** illustrates the multiple migratory routes that different species take, several of which go directly through Panama.[47] **Figure 4b** on the right illustrates the approximate path that raptors take when flying through Panama City. The Panama

[45] Suman, D. (2014, September 11-13). "Panama Bay Wetlands: Case Study of a Threatened Ecosystem." *Water Resources and Wetlands.* pp 366-371.

[46] "Panama Shatter Raptor Migration Record." (2014, November 11). Smithsonian Tropical Research Institute News. retrieved October 4, 2015 from http://www.stri.si.edu/english/about_stri/headline_news/news/article.php?id=1879

[47] Goodrich, Laurie J. (2008). "Raptor Migration in North America". In *State of North America's Birds of Prey*, 37-150. Vol. 3. Cambridge, MA: Nuttall Ornithological Club and American Ornithologists., 2008.

Audubon Society monitors raptor migrations from Cerro Ancon, a high point in the city. The figure shows that some birds migrate along the shore, while some go over the area where Tocumen Airport is located.

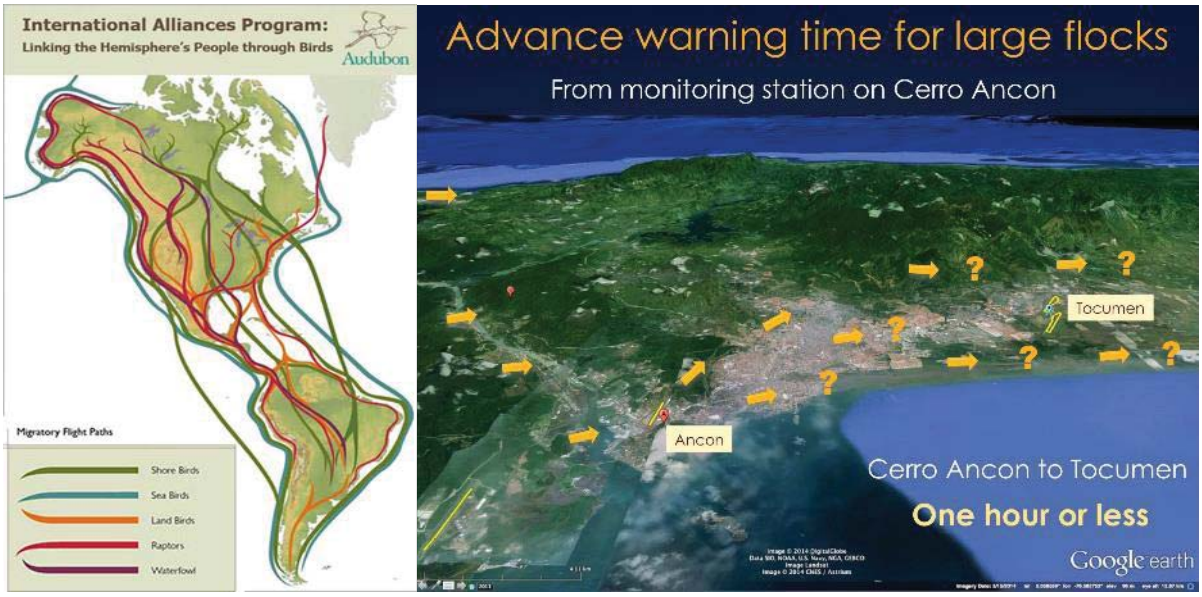

Figure 4a: Migratory Routes through North and South America (left) National Audubon Society 2015.
Figure 4b: Estimated fall migratory routes of raptors through Panama City (right) Panama Audubon Society.

2.4 Bird Strike Prevention Methods

Airports around the world are using many different bird strike prevention methods. Prevention methods vary widely because no two airports are the same. When airports choose a prevention method, they must not only consider their own property, but also the environment surrounding their property. Prevention methods should target bird attractants rather than bird population at airports especially where birds are a protected species. The following methods rely on different techniques to reduce bird strikes including reducing bird population, making land less desirable to birds, scaring birds away, and predicting bird movement.

1. **Shooting Birds:** Shooting not only directly reduces the number of birds on airport properties by killing them, but also scares other birds away with noise and the sight of dying birds. In 1991 and 1992, in an attempt to reduce bird strikes involving laughing gulls, biologists started shooting them at John F. Kennedy (JFK) International Airport in New York. In the first year, the study showed a two thirds reduction in laughing gull strikes compared to the previous three years, 1988-1990. In the second year, the study

saw a nearly 90% reduction in laughing gull strikes.[48] This program worked so well that by 2006 there were almost no bird strikes involving laughing gulls. However, other more dangerous birds, such as geese, flourished without natural competition from the gulls.[49]

Even though shooting birds can be effective, it is also highly controversial, as it often involves killing protected species. Between 2009 and 2013, wildlife contractors at JFK shot 1,628 birds from 18 different protected species.[50] The killing of these species is forbidden under the Migratory Bird Treaty Act. Others debate exactly how effective the killing of birds is, because it doesn't address the underlying problems, such as what attracts birds to airports.[51] Some airports have avoided killing birds by using guns and small cannons loaded with blanks, which make all the noise of a gunshot without firing a bullet, to scare birds. Noisemakers soon lose their effectiveness when birds become acclimated to them.[52]

2. **Egg Oiling:** Because Canadian Geese pose such a threat to airplanes, JFK also oiled geese eggs with vegetable oil to prevent hatching. Along with egg oiling, JFK culled (killed with carbon dioxide) the adult geese by the thousands to keep populations down.[53] A United Kingdom airport used the egg oiling method as well, but with paraffin wax instead.[54] These methods are not generally recommended because nesting birds will still remain at the airport, incubating non-viable eggs.[55] Egg oiling is also often seen as inhumane by bird enthusiasts and wildlife lovers.[56] There is a need for a more effective and environmentally conscious method of reducing the risk of bird strikes with airplanes, especially in locations where the number of protected bird species is high.

3. **Overhead Netting and Grid Line:** A promising technology for airports near wetlands is the use of overhead grid line systems. These grids of wires, suspended at least 1.5 meters

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48 Belant., Dolbeer., Sillings. (1993). "Shooting Gulls Reduces Strikes."

49 Uhlfelder. (2013, November 8). 'Bloody Skies: The Fight."

50 "Wildlife control contractors have shot almost 26,000 birds at New York JFK airport." *Airguide Online* 2 May 2014. *Business Insights: Essentials*. Web. 2 Sept. 2015.

51 Uhlfelder. (2013, November 8). "Bloody Skies: The Fight."

52 Constantin, Engeman, Peterla. (2002). "Methyl Anthranilate Aerosol for."

53 Uhlfelder. (2013, November 8). "Bloody Skies: The Fight."

54 Baxter, A., & Robinson, A. (2007). "Monitoring and influencing feral Canada goose (Branta canadensis) Behaviour to Reduce Birdstrike Risks to Aircraft."*International Journal of Pest Management, 53*(4), 341-346. doi:10.1080/09670870701245231.

55 DeFusco, Russell P., and Edward T. Unangst. *Airport Wildlife Population Management*. Vol. 39. Transportation Research Board, 2013.

56 Walsh, B. (2009). "Man vs Goose." *Time, 173*(26), 52-53.

(5 feet) above the ground, can cover lengths up to 675 meters (2214.5 feet).[57] The wires deter waterfowl from landing and feeding in wetland areas near airports, without seriously damaging the surrounding environment. At the José Joaquín de Olmedo International Airport in Guayaquil, Ecuador, they have implemented netting to deter birds from the standing water with great success. They have seen a significant decrease in the amount of birds present around the airport's standing water.

4. **Methyl Anthranilate (MA):** Another promising method is the use of Methyl Anthranilate (MA) aerosol, a minor irritant for birds.[58] MA is the primary component of synthetic grape flavoring. When it is spread through use of an airborne fogging device over an area that birds congregate and feed in, such as an airport, it acts as an irritant to their eyes and nasal passages.[59] Not only does this irritant deter birds that are present at the time of fogging, it also deters birds from landing on that area in the future to feed on the grass. In 2000, at Homestead Air Reserve Station in Florida, after 45 minutes of the irritant being applied, flight restrictions from bird hazards were lifted.[60] In addition, birds are less likely to get used to the effects of MA than they are to get acclimated to other forms of hazing such as pyrotechnics, sirens, and even shooting.[61]

5. **Predators:** In the past, airports have tried introducing natural predators to scare off flocks of smaller birds. Falconry, the hunting of wild quarry by a trained bird of prey, is one such way airports introduce predators to their property. Trained raptors, such as gyrfalcons, eagles, and peregrine falcons are released by falconers to scare away resident birds. At JFK, falconers work for up to 17 hours a day.[62] Though falconry can be effective, it can be limited during high winds, extreme temperatures, rain, and fog. Falconry is also often overlooked due to its high cost.[63]

6. **Drones:** Some airports have experimented with remote controlled planes or drones. Sometimes these drones replicate the facade of raptors or other predatory birds to scare

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[57] Duffiney, T. (2006). "Overhead Grid Line Systems to Exclude Waterfowl from Large Bodies of Water." *2006 Bird Strike Committee USA/Canada, 8th Annual Meeting, St. Louis, MO.* Paper 20

[58] Constantin, Engeman, Peterla. "Methyl Anthranilate Aerosol for." pp175-179.

[59] Ibid.

[60] Ibid.

[61] Ibid.

[62] Walker, Cameron. "Falconry Used to Secure North American Airports." *National Geographic News, March* 25 (2003).

[63] Battistoni, Valter, Alessandro Montemaggiori, and Paolo Iori. "Beyond falconry between tradition and modernity: a new device for bird strike hazard prevention at airports." In *Proceedings of International Bird Strike Committee, IBSC Meeting and Seminario Internacional Perigo Aviario e Fauna. Brasilia*, pp. 1-13. 2008.

birds away. Others incorporate the use of pyrotechnics or noise making devices to scare birds away. The only drone shown to work was in the "Falco Robot GBRS" tests at Italy in 2008. A goshawk model with many colors and larger than its normal size garnered positive results. In 17 drone raids, the drones were able to clear out birds from an area in about 8 seconds. The area stayed clear of birds for 1 hour and 30 minutes. A limitation of these drones is their effectiveness depends on the operator's skill. The drones' interference with the ATC is another limitation.[64]

7. **Avian Radar:** One method gaining popularity among airports is the use of avian radar. Avian radar specifically tracks the movements of birds. Before the introduction of avian radar in the mid 80's, all monitoring and surveillance of birds had to be done by human observation. The data that was collected then had to be manually analyzed to obtain useful knowledge. However, avian radar now provides the ability to automatically observe and track bird movement. This information can be analyzed to find specific trends in the movements of both resident and migratory birds.

   An avian radar system consists of a scanning and radar unit, a signal processor, and the visual display. The system works by emitting an energy wave from the scanning unit or antenna which reflects from surrounding objects and returns an analog response signal. The response signal is then converted to a digital signal and refined to remove excess noise and interference (known as clutter). Finally, the signal is identified and plotted to the visual display. From this visual display, aviation officials can track birds in the proximity of an airport.[65] Once the aviation officials are aware of where the birds are, they can make informed decisions about the safety of the airport and aircraft. Some detractors of avian radar claim that current systems are not good enough at filtering out clutter, which means the systems cannot identify bird species.[66] Yoshi Leshem, an Israeli researcher, says identifying species by radar is not important for immediate threat assessment.[67] He says that quickly identifying dangerous flocks of birds before they become a problem is more important than identifying species for academic purposes.

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64 Ibid.

65 Federal Aviation Administration. (2010). "Advisory Circular 150/5220-25." *Airport Avian Radar Systems*. Retrieved from http://www.faa.gov/documentLibrary/media/Advisory_Circular/150_5220_25.pdf

66 Uhlfelder. (2013, November 8). "Bloody Skies: The Fight."

67 Ibid.

8. **Landscape Management:** Landscape management is an option that would be implemented over a long period of time. Managing the landscape surrounding the airport limits or removes the attractiveness of the airport to birds, thereby reducing the hazard of bird strikes.[68] For example, the FAA suggests keeping landfills at least 5 miles (8 km) away from airports to keep mammals and birds away.[69] These measures will reduce the attractions present in the airport, discouraging birds from going to that area.[70]

   One of the first steps of landscape management is a wildlife risk assessment. A risk assessment determines the current risk of strike which can be used as a starting point for wildlife control. Next, an analysis determines what features the birds find attractive.[71] Careful planning is necessary to minimize harm to wildlife residing in areas surrounding the airport.

   Landscape management is a viable option, but this method also has challenges. Because it is difficult to manage wildlife in the wetland areas, landscape management is something that may never be completely accomplished. In addition, it is difficult to manage the land that is not owned by the airport.[72] Because private owners may not be compliant with landscape management on their property, they may even try to stall the process.

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68 Stevens, M.R., Schafer, L. M., Washburn, B.E. (2005). "Trash and Water: Managing On-Airport Wildlife Attractants at Paine Field, Washington." *Bird Strike Committee Proceedings from 2005 Bird Strike Committee-USA/Canada 7th Annual Meeting, Vancouver, British Columbia.*

69 Ashford, Mumayiz, Wright, Culberson. (2011). *Environmental Impacts of Airports.*

70 "Landscape Management on Airports for Reduction of Bird Populations." (1984). Retrieved March 29, 2015, from http://www.dtic.mil/docs/citations/ADP004194.

71 Stevens, Schafer,Washburn. (2005, Vancouver). "Trash and Water: Managing."

72 Ibid.

3. RESEARCH QUESTIONS & METHODOLOGY

The goal of our project was to develop an effective and feasible bird strike mitigation plan for Panama's Tocumen International Airport.

To achieve our goal, we pursued four objectives:

1. Identify bird strike causes at Tocumen International Airport by analyzing patterns of reported bird strikes.
2. Assess the environmental factors and man-made factors contributing to bird strikes inside and adjacent to Tocumen International Airport
3. Examine the interests, regarding bird strikes, of the administrative stakeholders – Tocumen S.A., Copa Airlines, and the Autoridad Aeronautica Civil.
4. Analyze the effectiveness, cost, and environmental sustainability of five options for bird strike reduction at Tocumen Airport: bird deterrents, minimizing trash in adjacent areas, landscape management, avian radar, and early warning systems.

OBJECTIVE 1: Identify bird strike causes on Copa Airlines' aircraft at Tocumen International Airport by analyzing patterns of reported bird strikes.

Desired Knowledge: Patterns in bird strike occurrence rates, locations, and times along with the most common species involved in bird strikes.

Methods:

1. **Analysis of data provided by Copa Airlines:** Copa Airlines provided bird strike records on type of plane, phase of flight, time of day, time of year, and runway used. They also provided maintenance records, which included reports on repairs to suspected bird strikes.

2. **Interviews with the following:**

   Copa Airlines' Safety Department: Carol Dominguez, ground safety manager, and Michael New, vice president of corporate safety and quality assurance.

Five Copa Airlines Pilots: Jose Rodriguez, Rolando Rios, Alvaro Pereira, Luis Moreno, Carlos Morales.

Method Justification: Analyzing the data allowed us to identify different aspects of the bird strike problem, such as locating high risk times and phases of flight. The data also helped provide a basis for interview questions with Copa employees and pilots. Copa Airlines employees provided useful information based on their years of experience. They gave us advice on the best ways to analyze the bird strike data they provided.

Limitations of Data. Many reported bird strikes lacked important information, such as unknown phase of flight or location. Copa does not have a standard method for matching repair costs to reported bird strikes, so it was very hard to analyze the specific costs of bird strikes.

OBJECTIVE 2: Assess the environmental factors and man-made factors contributing to bird strikes inside and adjacent to Tocumen International Airport

Desired Knowledge: Features of the airport and its surroundings that attract birds and what species of birds frequent each attraction. The daily operations of the airport and the process of addressing bird strikes.

Methods:

1. **Visits to Tocumen International Airport**: Members of the wildlife management team at the airport provided tours of the airport and surrounding areas. We noted the conditions on and around the airport that seemed to attract birds, such as wetlands, grass conditions, and trash present. During the visits we observed birds while they were hunting, perching and migrating.

2. **Interviews**:

   Wildlife Management at Tocumen Airport: Melissa Hines, head of wildlife control, and Yenny Gomez, a field biologist.

Autoridad Aeronautica Civil (AAC): Everardo Berrio, airport inspector from the Aeronautical Management Office.

Bird Experts: Karl Kaufmann, data manager, and Rosabel Mira, executive director, from the Panama Audubon Society.

Method Justification: Since all airports are unique, they provide different attractions to birds. Visiting the airport allowed us to see firsthand what bird attractants were present. Being at the airport in person gives us a better grasp on the scope of the problems. Interviews with the wildlife control team and AAC members that work with the bird strike problem everyday gives us a perspective that less experienced people would not have. Interviews with local bird experts gives us their personal understanding of local bird species and patterns.

Analysis Method: While at the airport, we observed where birds were flying and landing, as well as the landscape on and around the airport. We took pictures of birds and features that they were attracted to, as well as marked locations of attractants on a map.

Limitations of Data: Because airport visits were only completed during midday hours, we were only able to assess the bird species and attractants that were present during the day. We had to rely on secondhand sources to identify species that may be present during the night.

OBJECTIVE 3: Examine the interests of the administrative stakeholders- Tocumen S.A., Copa Airlines, and the Autoridad Aeronautica Civil, regarding bird strikes.

Desired Knowledge: Priorities of the three entities and how they interact with each other in regards to bird strike management. How the three have worked together in the past. Methods the airport used to prevent bird strikes and best ways to present our suggestions to the airport.

Methods:

1. **Historical Research**: We researched the history of the Tocumen International Airport, Copa Airlines, and Panamanian Government.

2. **Interviews:**

   Copa Airlines Employees: Carol Dominguez, Mike New, and Xochy Cerrud, lead investigator of aviation safety.

   Tocumen S.A. Employees: Melissa Hines and Yenny Gomez.

   AAC Employees: Everardo Berrio and Fernando Bunting, manager of air traffic control.

Method Justification: Interviews were used to learn what employees had to say about their organization and its priorities. The Copa employees could provide insight into what Copa's interests are and how they interact with the AAC and the airport. Members from the AAC informed us what role the AAC and other government agencies have in the safety decisions at the airport. The Tocumen S.A. employees were able to explain their roles and what they knew the airport had done in regards to bird strike prevention.

Limitations of Data: A limitation of this objective was the reliability of our internal sources. During the interview process, interviewees could have biased or inaccurate answers. In addition, the interview sample size was limited based on our project timeline, the language barrier, and available personnel. To minimize this limitation we tried to interview as many personnel as possible.

OBJECTIVE 4: Analyze the effectiveness, cost, and environmental sustainability of five options for bird strike reduction at Tocumen Airport: bird deterrents, minimizing trash in adjacent areas, landscape management, avian radar, and early warning systems.

Desired Knowledge: Advantages and disadvantages of each of the five methods, as applied to Tocumen Airport. Will a combination of methods would work best for mitigating bird strikes? We are including the first, bird deterrents, because that includes the current measures Tocumen is taking to prevent bird strikes. We chose the other four methods because they seemed the most promising based on our background research.

Methods:

1. **Case Study Research**: We conducted research on case studies for effective methods to solve the problems mentioned in each option. This helped us determine what methods were effective and how the methods can be applied to the situation at Tocumen International Airport using information and suggestions gained from our research.

2. **Benchmark Airport Visit:** We visited the José Joaquín de Olmedo International Airport in Guayaquil, Ecuador to see successful bird strike prevention methods the airport has implemented.

3. **Interviews:**

   DeTect MERLIN Avian Radar - An avian radar company based out of Panama City, Florida.

   Community Members - Members of the community surrounding the airport.

   Wildlife Management Experts - Yenny Gomez and Melissa Hines.

   Panama Audubon Society - Karl Kaufmann and Rosabel Miro.

Method Justification: The case studies we researched illustrated the effectiveness of a certain method. Visiting the airport in Guayaquil allowed us to see successful bird strike prevention methods at an airport with conditions similar to Tocumen airport. Interviews with DeTect gave us the personal perspective from a company that manufactures avian radar. The community member interviews were the only way to learn about their first-hand experience with the trash problem.

Analysis Method: By combining the information we researched, the methods used in Guayaquil, and the suggestions from expert interviews, we were able to give strong suggestions on which methods would fit best at Tocumen International Airport. We created a table of advantages and disadvantages to provide a more objective analysis of each option. In these tables, we analyzed the effectiveness, cost, and environmental sustainability of the five methods mentioned (bird deterrents, trash removal, landscape management, radar, and early warning). We chose these three criteria because the airport is interested in finding the most effective form of bird strike

mitigation at the lowest cost to them. Based on past methods they have used, such as cutting down trees, it seems they may not be thinking about environmental sustainability, despite the fact that they are surrounded by protected lands.

Limitations of Data: Because every airport is different, methods for preventing bird strikes at other airports may not work at Tocumen. To address this limitation, we attempted to use as much information as possible from experts familiar with Tocumen Airport and the environment of Panama.

4. FINDINGS & ANALYSIS

Through our research, we identified bird strike patterns at Tocumen International Airport and options to reduce the risk of bird strikes. Internal and external airport attractants, as well as bird patterns, must be addressed to reduce the risk of bird strikes. In addition, attractants can be categorized into either environmental factors or man-made factors.

It is important to use multiple prevention methods to solve the bird strike problem because of the multiple contributing factors. The following findings emphasize the contributing factors to bird strikes and ways to mitigate these factors.

Objective 1: Identify bird strike causes at Tocumen International Airport by analyzing patterns of reported bird strikes.

Finding #1: Because most birds fly below 3,500 feet and aircraft have less leeway to maneuver below that altitude, the majority of bird strikes occur during approach and landing, with about 1 bird strike in every 1000 landings.

Summary of Evidence: According to the data that Copa provided, summarized below in **Figure 6**, 52% of bird strikes occurred during the approach and landing stages at Tocumen Airport, with another quarter of bird strikes occurring during takeoff. All of the pilots we interviewed said they felt most vulnerable to bird strikes during takeoff and landing phases of flight. Because of limited maneuverability and the altitudes that birds fly at, the majority of bird strikes occur under 3500 feet, making takeoff and landing phases the highest risk for a bird strike. On both the 03L and 03R runways at Tocumen Airport, 0.11% of aircraft, or about 1 in 1000, were involved in a bird strike while landing. When aircraft land on either of these runways, they fly over the mangroves, where many birds hunt and roost. In comparison only .037% of aircraft were involved in a bird strike on takeoff from the 03R runway, and .06% of aircraft were involved in a bird strike on takeoff from 03L. The difference in bird strike rates after takeoff on the two runways could most likely be attributed to the trash in the neighborhoods to the north of the airport. Aircraft taking off from the 03L runway, with the higher bird strike rates, cannot avoid flying over the communities with trash, no matter which way they turn after takeoff. However, planes taking off from the 03R runway can start turning away from the communities soon after takeoff, avoiding the communities.

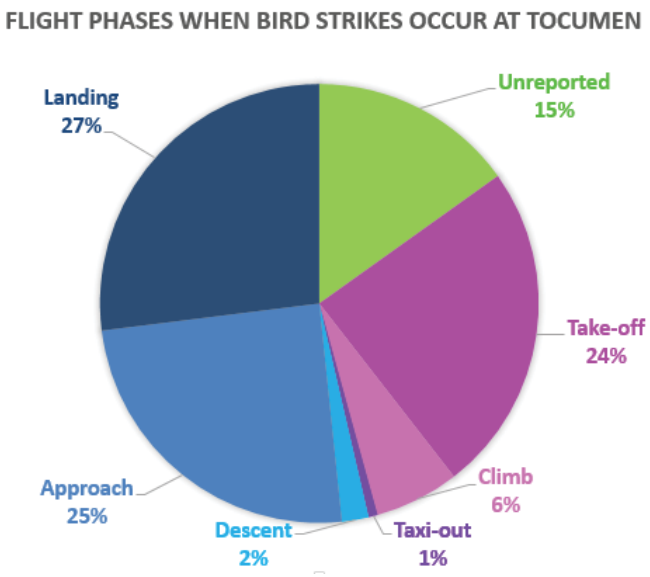

Figure 6: Flight phases when bird strikes occurred from January 2013 and August 2015. Purple shows phases of departure, blue shows phases of arrival.

Explanation: More strikes happen during the approach and landing phases of flight because the flight path is limited due to other planes waiting to land and take off as well. Pilots also have to land correctly on the runway which prohibits any maneuvering around birds. Takeoff offers slightly more flexibility in flight path than landing, but still has limited maneuverability. Pilots taking off from 03R can limit the risk of a bird strike by turning away from the communities with trash as soon as possible.

Finding #2: Of the many resident bird species at the airport, black vultures pose the biggest risk to aircraft and passenger safety because of their large numbers, large size, and tendency to circle in groups on thermal columns above the airport.

Summary of Evidence: All of our interviewees (Tocumen wildlife team, Panama Audubon Society members, Copa employees, and pilots) expressed concerns that black vultures are the greatest risk for damaging aircraft, due to their size and large population at the airport. During our daytime visit to the airport, we saw a large number of vultures on the property. Vultures perched on fences, perched in trees, and flew in circles above the airport. Black vultures, which typically weigh between 1.6 and 2.8 kg (3.5-6.1 lb.), challenge impact standards for aircraft engines, which are designed to best withstand impacts and ingestions from up to a 1.81 kg (4 lb.) bird. 1 in 5 reported bird strikes caused damage to Copa Aircraft in the past two years. This damage is most likely caused by birds like vultures, with relatively large weights and sizes. This

suggests that methods specifically targeting the presence of vultures could help reduce bird strikes at Tocumen.

Figure 7: Black vulture perched on a roof (left). Black vultures flying in a thermal above the runway at Tocumen Airport (right).

Explanation: Vultures fly over the areas on the north side of the airport that contain excess trash and also circle in great numbers at the south end of the runway, near the mangroves, which provides animal carcasses. Vultures use thermals, or updrafts of warm air, that are present in the airport to circle and gain altitude. No one is entirely sure how thermals form, but one theory is that black tarmac runways absorb a lot of heat, which creates thermals because of the contrast with the surrounding landscape. Vultures have keen vision, but cannot move their eye muscles. When their eyes are locked on a food source below, they would have to move their entire head to see a plane coming, making it difficult for vultures to see oncoming planes.[73]

Limitation: No hard evidence of what species results in the most bird strikes exists because species are not recorded for bird strike reports. Bird strike occurrence rates are similar during the day and at night, but it is not entirely known which species causes the most problems at night because our team only visited the airport during the day. Furthermore, Tocumen's wildlife team has difficulties monitoring the airport property in the dark. The team does have suspicions of bird

[73] Birkhead, T. (2013). "What Makes Bird Vision So Cool." *Audubon.*

species struck at night based on what birds are active at nighttime. Some nocturnal birds at the airport include owls, nighthawks, and oilbirds.

Finding #3: Migratory raptors- mostly Swainson's hawks and turkey vultures- appear to cause about 50% more bird strikes during the peak migratory months of October and April.

Summary of Evidence: The average number of bird strikes from 2013 to 2015 were 8 strikes per month. However, during the months of April and October, the average number of bird strikes were 12.3 and 25.5 respectively.

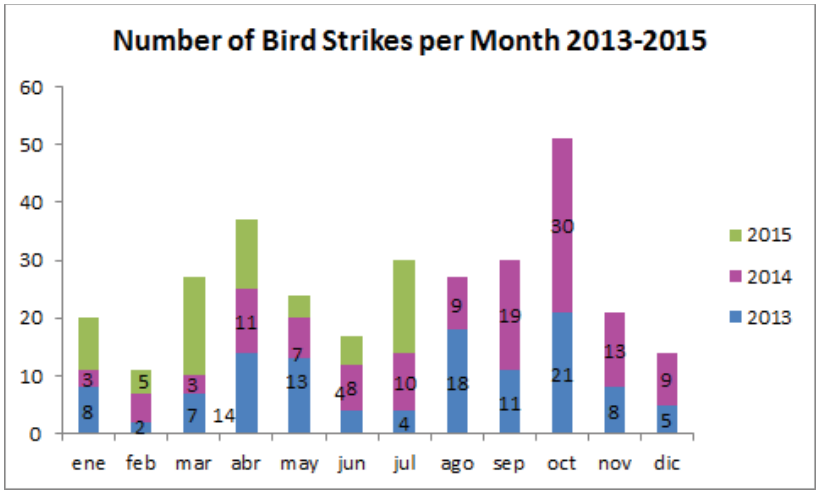

Figure 8: Number of bird strikes on Copa Aircraft from 2013-2015

Explanation: Since Panama is located on the isthmus between North and South America, most birds migrating between these two continents pass over the country. These migrations occur in the spring and fall, with the peak months of migration being October and April. "The risk migratory birds pose to flight is impossible to control," says Eric Uhlfelder.[74] Small peaks and fluctuations occur during other months as well, which could be attributed to weather conditions, thermals, or changes to the airport property. Changes include grass cutting, wetland flooding, and new construction.

[74] Uhlfelder. (2013, November 8). Bloody Skies: The Fight

Limitations: Some months had disproportionate rises in bird strikes compared to others. Because the airport staff did not keep track of all the possible contributing factors to bird strikes during this time period, the exact causes of some of these peaks are unknown.

Objective 2: Assess the environmental factors and man-made factors contributing to bird strikes inside and adjacent to Tocumen International Airport

Finding #4: Compared to external factors, the airport can more easily control environmental factors on their property that attract birds, such as wetlands, tall grass, and trees, as well as man-made factors such as fencing, new construction, and poor drainage.

Summary of Evidence: After visiting the airport, interviewing two of their wildlife team employees, five pilots, and meeting with Panama Audubon employees, we found that six factors attract various birds to the airport property,

Environmental Factors:

1. **Wetlands:** Waterfowl, such as herons, sandpipers, and plovers, are attracted to the fish, insects, and frogs in the wetlands on the airport property.
2. **Tall Grass:** The airport has a lot of tall, marsh grass which can be difficult to keep cut short because of the large amounts and the water underneath. The grass is home to rodents and insects that attract several birds to the area for food like swallows, owls, and nighthawks. It also provides a nesting area for some species such as plovers. Grass also contains seeds that birds feed on that wind can blow onto runways.
3. **Trees:** Black vultures and migrating birds, such as turkey vultures and Swainson's hawks, will roost at night in trees on airport property.

Man-Made Factors:

4. **Fencing:** The fence surrounding the airport does not prevent birds from perching. Birds like owls, vultures, and potoo will perch on the fence to roost or look out for food.
5. **New Construction:** Thermals are created by the heat from new construction. Raptors and vultures ride these thermals to conserve energy when flying. New construction has also

led to river blockage which attracts more waterfowl to the area, especially pipers and plovers.

6. **Poor drainage:** The water drainage system implemented does not drain downhill so water is permanently in the concrete canal. This results in more insects and fish for birds to eat, especially when the tide comes in and raises the water levels.

Analysis: Any bird on the airport property is considered a hazard. Focusing on the inside of the airport is essential to reducing bird strike risk because reducing the contributing internal factors will lower the count of birds. The land will seem less desirable to birds which means they will move to other locations. The airport can make changes to the land that it owns more easily than it can change the land outside of the airport.

Finding #5: Bird attractions outside of Tocumen International Airport that are harder to manage include mangroves, an environmental factor, and trash, a man-made factor.

Summary of Evidence: After observing the areas surrounding the airport, we determined the following to be bird attractants outside of the airport property.

Environmental Factors:

1. **Mangroves:** Many bird species nest, roost, and feed within the trees of the mangrove forests. These include nighthawks, kingfishers, caracaras, black hawks, and swallows. Vultures will also feed on dead animals within the mangroves. Not only do the mangroves attract birds to the general area of the airport, aircraft also fly over the mangroves during the approach and landing phases for both runways. This could increase the risk of bird strikes because of the large numbers of birds within the mangroves and aircrafts' decreasing altitudes.

Man-Made Factors:

2. **Trash:** Black vultures are attracted to the trash piles in the neighborhoods surrounding the airport. The vultures fly across airways when scavenging for food within the trash heaps. Aircraft also takeoff from both runways over these communities. This is dangerous because the vultures are present on airport property and in the communities.

Analysis: Because the trash and mangroves are outside of the airport property, it will be harder for the airport to make changes to them. They would have to work with local landowners and community members, as well as the national government to make any effective changes. Some of these groups may not be willing to cooperate because they may not see the potential benefit to themselves. It may be more effective for the airport to change what it can on its own property before focusing on changing the surrounding area.

Objective 3: Examine the interests of the administrative stakeholders- Tocumen S.A., Copa Airlines, and the Autoridad Aeronautica Civil, regarding bird strikes.

Finding #6: Copa Airlines and the AAC have communicated their need for an effective bird strike mitigation strategy to Tocumen S.A., but Tocumen does not fully understand this need.

Summary of Evidence: There have been several presentations and suggestions made to Tocumen S.A. regarding bird strike prevention, but none have been implemented. DeTect gave a presentation to Tocumen S.A. about their MERLIN Aircraft Birdstrike Avoidance Radar system. In November 2014, Members of the Panama Audubon Society made presentations to Tocumen about addressing the bird strike problem. The FAA also made a presentation with suggestions on bird strike prevention.

Copa Airlines wants Tocumen Airport to implement an effective bird strike mitigation method because it's concerned about passenger safety and damage to aircraft. Copa is familiar with the landscape of the airport and receives pilot opinions about the problem, but is not familiar with all the bird species present and the actions Tocumen has taken to reduce bird strikes. Copa has made requests to the airport to implement an effective prevention method, but is not familiar with any new actions taken.

Tocumen S.A. runs all operations of the airport, excluding the ATC. Currently, the majority of Tocumen's expenses are going into renovations and airport expansions. They desire concrete evidence of a proven bird strike mitigation solution before they are willing to invest.

The AAC realizes the risk of bird strikes and knows what attracts the birds. In addition to knowing the risk at Tocumen, they know the risk throughout the rest of Panama as well.

However, because they are only a regulatory agency, the AAC cannot make or enforce laws. They could conceivably make a regulation about bird strike mitigation, but it is not guaranteed that the airport would follow this regulation if it is not convenient for them. Because the AAC runs the control tower at the airport, they can observe bird behaviors from there and decide to delay flights if there is a large enough flock of birds.

Analysis: We lack information about how the three stakeholders interact. This information will allow us to determine why nothing has been done, and how we can push them towards taking action.

Objective 4: Analyze the effectiveness, cost, and environmental sustainability of five options for bird strike reduction at Tocumen Airport: bird deterrents, minimizing trash in adjacent areas, landscape management, avian radar, and early warning systems.

Below is a table that briefly assesses the strengths and challenges of each bird strike prevention method we analyzed.

Figure 9: The Assessment for Methods of Bird Strike Prevention

Methods	Advantages	Disadvantages
Bird Deterrents	• Scares or deters birds from airport property • Low cost	• Temporary (birds adapt) • Can be dangerous (fireworks, noise guns) • Disrupts wildlife
Minimizing Trash	• Reduces bird presence by removing food source • Cleans environment • Improves community relations • Low cost	• Work with government • Purchase new dumpsters • Establish trust with community members
Landscape Management	• Reduces birds presence by removing attractions • Prevents nesting and roosting • Moderate cost	• Consider the environmental impacts • Protected lands and species
Avian Radar	• Tracks bird movement for patterns and predictions • No effect to environment • Assesses risk of resident and migratory birds	• High cost
Early Warning	• Estimates bird movements • No effect to environment	• Only effective for migrating birds • Varying costs

Finding #7: Bird deterrents are only a temporary bird strike prevention method because birds become acclimated to them. Tocumen Airport uses two methods of bird deterrents - firecrackers and noise guns - which have had minimal effect.

Summary of Evidence: Currently, Tocumen's wildlife control team uses firecrackers and noise guns that do not yield consistent results. These are also dangerous, since the team has to light the firecrackers by hand and fire the noise guns very close to the birds. The wildlife control team say that the birds will scatter for about 15 minutes and then go right back to what they were doing, whether it was flying or eating. When the fireworks are fired at flocks of migrating birds, biologist Yenny Gomez said the birds briefly create a gap around the noise, then fill the gap back in once they realize there's no real threat.

Several studies have been conducted on whether additional lights on aircraft would make them more visible to birds. In one study conducted between 2000 and 2002, a team tested the reactions of five bird species to lights of different powers and flashing at different frequencies, only one of which reacted to any of the lights.[75] In another study, Swiss ornithologists tried to determine whether radar tracking caused migratory birds to alter their behavior at night by tracking them visually with a spotlight as well as with radar.[76] They found that the radar had no effect on the birds, but that the spotlight caused the birds to change course about 8-15 degrees, slow down between 15-30% average airspeed and increase rate of climb.[77] Another possible solution is the use of a robot controlled green laser that scares birds by flashing in their eyes, but there are safety concerns.[78]

The airport at Guayaquil has experimented with the use of Scarecrow's Patrol Two, which is a bio-acoustic bird dispersal system shaped as a megaphone. The Patrol Two is used to imitate sounds that will distress targeted birds and cause them to leave the area. Because the sounds usually imitate predator birds, this can be effective for smaller birds but may not be as effective on birds of prey such as raptors and vultures.

Explanation: "Panamanian birds are very smart," says Carol Dominguez. Birds will acclimate to methods such as lasers and noise deterrents. Bird strikes are a complex problem that many different groups are working to solve. The cheapest way to move birds is to scare them, but they will only move for a short time, and they eventually get used to this harassment.

Finding #8: Trash cleanup in the surrounding neighborhoods may be an effective and low cost solution to bird strikes because it will reduce the presence of vultures on and near the airport property.

Summary of Evidence: After interviewing five pilots, the wildlife management team, and bird experts, they all believed the amount of trash near the airport was attracting black vultures to some extent. The bird strike rate on the 03L runway, which is closest to the communities, is about two times higher than the rate on the 03R runway. On our visits to the airport and its surrounding areas, we saw vultures flying above areas with trash, but did not see many birds

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75 Blackwell, B.F. Bernhardt, G.E. (2004) "Lasers as Nonlethal Avian Repellents." *Journal of Wildlife Management*. 68(3):725-732.

76 Bruderer, B., Peter, D., Steuri, T. (1999) "Behaviour of Migratory Birds Exposed to X-band Radar and a Bright Light Beam." *The Journal of Experimental Biology* 202, 1015-1022.

77 Ibid.

78 "Lasers being deployed in campaign against bird strikes." *Air Safety Week Vol 18 issue 17* 4/26/2004.

actually eating the trash, even after fresh garbage had been dumped. We were informed by Carol Dominguez that vultures generally land to feed in the mornings and afternoons. People in the community told us that the trash is not picked up often enough, or at convenient locations.

The garbage in the communities around the airport is supposed to be picked up three times a week by a private company contracted by the national government. Residents we spoke to said trash pickup three days a week worked 10 to 15 years ago when it was first introduced, but since then the population, as well as the amount of trash, has inflated. We observed large trash heaps by bus stops, restaurants, and parking lots along the main roads in the communities. A woman working for the trash company said she collects litter once a week in the communities, but many community members said that they don't see the trash collectors that often. The roads of these communities are very narrow, so garbage trucks cannot pick up trash in front of every house. There are dumpsters on the main roads where the garbage trucks can get to, but community members tell us that the dumpsters are often too full, broken or just not there. Many people take their garbage with them to the bus stop and leave it by the side of the road when they leave for work in the morning. The bus stops have become home to large piles of garbage; even if the trash is picked up one day, it reappears the next.

The residents told us they were already paying too much money for a service that is not getting done, so they did not like the idea of paying more for better garbage service. Many residents realized that it is a cultural issue because many Panamanians don't want to leave trash near their houses nor touch a dumpster lid to put trash inside. The local representative said that they invested in two garbage trucks to supplement the trash pickups by the government contractor, but she says even that is not enough to make a difference.

The airport in Guayaquil used to see vultures regularly on the airport property, but no longer see many vultures present. The staff at the airport in Guayaquil believe this is because excess trash in surrounding neighborhoods was effectively cleaned. In 2011, Ecuador's government required environmental licenses for all companies which resulted in improved trash pickup throughout the country.

Explanation: "The most effective thing to prevent these collisions," says Captain Chesley Sullenberger of the Hudson River landing, "is not to allow anything anywhere near an airport that's likely to be a bird attractant."[79] This is good advice from somebody who knows the dangers

[79] Uhlfelder. (2013, November 8). "Bloody Skies: The Fight."

of bird strikes firsthand. If possible, it could be beneficial to limit bird attractions outside of the airport. The trash in the communities around the airport attracts vultures to the area. They perch on and near the airport property and circle overhead in thermals over the runways while looking for trash and dead animals to eat.

Finding #9: Landscape Management, such as nets/grid lines or non-toxic irritant, is an effective option for Tocumen Airport because of its potential to reduce the number of birds on the property.

Summary of Evidence: The Tocumen airport wildlife control team has expressed interest in making the wetlands near the airport less hospitable to birds to deter them from flying near the landing aircraft. The wildlife team at Tocumen airport was very interested in the irritant methyl anthranilate (MA) and our contacts at Copa were excited by the idea of a successful net/grid line system at the airport in Guayaquil, Ecuador. The land management team at Guayaquil placed a thin plastic netting over all of the standing water on the airport property as well as places birds would roost (light towers and trees near the airport buildings). This included the covering of an effective drainage system. Guayaquil's drainage system was implemented to drain excess water from wetlands on the property along with excess water from Ecuador's rainy season. A list of bird strike prevention methods used in Guayaquil can be found in **Appendix A**. Panama has several protected bird species, so methods that do not directly harm the land or birds, like the MA, nets and grid lines, and improved drainage, would be more suitable than completely destroying wetlands or trees.

Figure 10: Net system at Guayaquil Airport

Explanation: There are several options for making wetlands inhospitable to birds, but many of these would disturb the environment. Both the net/grid line system and MA are methods that will deter birds, and have minimal effect on the surrounding environment. Overhead grid line systems are made of a fine wire stretched across areas of attraction such as tall grassy areas or bodies of water. Nets are very similar, but use sheets of netting instead of wires. MA is a non-toxic, FDA approved bird irritant that would deter birds from landing in targeted grass or water areas to feed. Non-toxic irritant is a good option because birds will not become acclimated to it. The irritant also will not significantly harm the environment when applied.

Finding #10: Avian radar and early warning systems are high cost but effective at warning airports about periods of high bird strike risk, such as migration, and allow the study of bird behavior patterns, making it an effective option for Tocumen.

Summary of Evidence: Not many civilian airports throughout the world have integrated radar into their bird strike avoidance plans, so almost all data comes from tests with military aircraft. In a study ending in 1985, Yossi Leshem of Tel Aviv University's zoology department tracked birds using radar, gliders, drones and infrared tracking devices.[80] Using this data, as well as weather data from the same period, he was able to create an effective algorithm that can predict the paths of birds when combined with active radar tracking.[81] Since adopting his system in 1985, the Israeli military has seen a 76% drop in bird strike incidents.[82] Likewise, according to DeTect Inc., "Since implementing [their] US National Avian Hazard Advisory System (AHAS) in 2003, the US Air Force (USAF) has reduced bird strikes and damage costs [...] by more than 50%."[83] Radars will cost between $450,000 and $2.5 million, depending on the coverage needed.[84] Certain radars claim to have the ability to identify specific species, but it is debatable how useful this is outside of academic interest.[85]

Camera based early warning systems, such as the thermal early warning system in place at the Frankfurt Airport will monitor a specific space in the sky to measure how many birds fly through it and which direction they are flying.[86] Another option for implementing an early warning

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80 Uhlfelder. (2013, November 8). "Bloody Skies: The Fight."

81 Ibid.

82 Uhlfelder. (2013) "Those Hazardous Flying Birds" *The New York Times* October 17, 2013

83 DeTect Inc. (2014) "Briefing - MERLIN ABAR Commercial Airport."

84 Uhlfelder. (2013) "Those Hazardous Flying Birds"; Uhlfelder, (2013, November 8). "Bloody Skies: The Fight."

85 Uhlfelder. (2013, November 8). "Bloody Skies: The Fight."

86 Münzberg, M., Schilling, A., Schlemmer, H. Vogel, H., Cramer, H., Schlosshauer, J. (2011) "The infrared-based early warning system for bird strike prevention at Frankfurt airport." Proc. SPIE 8012, *Infrared Technology and Applications* XXXVII, (May 20, 2011).

system would be to have a network of bird experts and airport officials who observed migrations as they passed through their countries and cities, then warned the next airport along their path.

Explanation: Because an avian radar system can be implemented in a very short amount of time, it can start tracking birds immediately. The radar can collect data that can later be used to determine the behaviors of birds and build prediction algorithms like the one Yossi Leshem made in Israel. Long term forecasts of bird activity can lead to a better understanding of bird behavior.

Limitations: Because the exact path of migratory birds is not known, it would be very hard for Panama to implement a camera based warning system. However, it may be possible to set up a network of observers through a partnership with the Audubon society.

5. CONCLUSIONS AND RECOMMENDATIONS

Through the use of interviews, on-site visits, data analysis, and case study research, we developed ten key findings that provide information on bird strike patterns at Tocumen International Airport and options to reduce the risk of bird strikes. These findings point out the man-made and environmental attractants to birds on and around the airport, as well as emphasizing the need for multiple bird strike prevention methods to counter the attractants at the airport.

Objective 1: Bird Strike Causes

1. Because most birds fly below 3,500 feet and aircraft have less leeway to maneuver below that altitude, the majority of bird strikes occur during approach and landing, with about 1 bird strike in every 1000 landings.

Because pilots have to land correctly on the runway, any maneuvering around birds is prohibited. During takeoffs, pilots have more airspace to maneuver and have options to increase the rate of climb and velocity of the plane. Once they reach 3,500 feet, bird strike risk is significantly lowered because birds do not fly above that altitude.

2. Of the many resident bird species at the airport, black vultures pose the biggest risk to aircraft and passenger safety because of their large numbers, large size, and tendency to circle in groups on thermal columns above the airport.

Black vultures, which typically weigh between 1.6 and 2.8 kg (3.5-6.1 lb.), challenge impact standards for aircraft engines, which are designed to best withstand ingestions from up to a 1.81 kg (4 lb.) bird. At the airport, we observed vultures perching on fences and trees, as well as using thermal columns to gain altitude. Our interviewees also expressed that black vultures are the most prevalent birds around the airport.

3. Migratory raptors- mostly Swainson's hawks and turkey vultures- appear to cause about 50% more bird strikes during the peak migratory months of October and April.

During peak months of migration in Panama, April and October, the average number of bird strikes were 12.3 and 25.5 from 2013 to 2015. However, the average number of bird strikes during the other months were 8 strikes per month.

Objective 2: Internal and External Factors of Bird Strikes

4. Compared to external factors, the airport can more easily control environmental factors on their property that attract birds, such as wetlands, tall grass, and trees, as well as man-made factors such as fencing, new construction, and poor drainage.

Wetlands and tall grass provide birds with food and nesting while trees and fencing provide roosting and perching locations for the birds. The new construction creates thermals that raptors use to fly. Poor drainage creates standing water that also attracts birds. The airport has the ability to make airport land less desirable by mitigating contributing factors of bird strikes, causing birds to move to other locations.

5. Bird attractions outside of Tocumen International Airport that are harder to manage, include mangroves an environmental factor, and trash, a man-made factor.

Many resident bird species nest, roost, and feed within the trees of the mangrove forests. Black vultures fly across airways when scavenging for food within the trash heaps in the neighborhoods surrounding the airport.

Objective 3: Stakeholders' Relationships

6. Copa Airlines and the AAC have communicated their need for an effective bird strike mitigation strategy to Tocumen S.A., but Tocumen does not fully understand this need.

Members of the Panama Audubon Society, DeTect, and the U.S. Federal Aviation Administration (FAA) have made several presentations and suggestions for Tocumen S.A. regarding bird strike prevention, but none have been implemented. Copa Airlines wants Tocumen Airport to implement an effective bird strike mitigation method because they are concerned about passenger safety and damage to aircraft. Tocumen S.A. desires concrete evidence of a proven bird strike mitigation solution before they are willing to invest. The AAC is only a regulatory agency, so they cannot make or enforce laws.

Objective 4: Bird Strike Solutions

7. Bird deterrents are only a temporary bird strike prevention method because birds become acclimated to them. Tocumen Airport uses two methods of bird deterrents - firecrackers and noise guns - which have had minimal effect.

Bird deterrents are not very effective, low cost, and have minimal effect on the environment. The cheapest way to move birds is to scare them using methods such as lasers, and noise deterrents, but they will only move for a short time. Birds may eventually acclimate to these methods.

8. Trash cleanup in the surrounding neighborhoods may be an effective and low cost solution to bird strikes because it will reduce the presence of vultures on and near the airport property.

Trash cleanup may be moderately effective, is low cost, and beneficial to the environment. The neighborhoods near the airport have exposed heaps of trash because of unreliable garbage pickup. Community members leave trash in piles on the side of major roads and bus stops. Pilots and the wildlife control team at Tocumen believe that trash attracts black vultures to areas near flight paths, but very little data supports this.

9. Landscape Management, such as nets/grid lines or non-toxic irritant, is an effective option for Tocumen Airport because of its potential to reduce the number of birds on the property.

Landscape management is very effective, has a moderate cost, and has a moderate negative effect on the environment. Several options exist for making wetlands inhospitable to birds, but many of these would disturb the environment. Both the grid line system and Methyl Anthranilate (MA) are designed to deter birds and have minimal effect on the surrounding environment. Overhead grid line systems are made of a fine wire stretched across attractants such as grassy areas or standing water. MA is a non-toxic, U.S. Food and Drug Administration approved bird irritant that would deter birds from landing in targeted grass or water areas to feed. Non-toxic irritant is a good option because birds do not become used to it.

10. Avian radar and early warning systems are high cost but effective at warning airports about periods of high bird strike risk, such as migration, and allow the study of bird behavior patterns, making it an effective option for Tocumen.

Avian radar and early warning systems are very effective, high cost, and have no effect on the environment. Avian radar provides real-time information on where birds are around the airport property. It is also effective in establishing bird behavior patterns. Early warning systems will monitor a specific space in the sky to measure how many birds fly through it and which direction they are flying.

RECOMMENDATIONS

From the information provided by our findings, we made six recommendations that fall under two categories:

1. Recommendations for the airport
2. Recommendations for Copa Airlines

For Tocumen Airport

1. Keep a logbook of the airport conditions each day such as grass height, weather conditions, temperature, and number of birds present to help identify bird strike causes.

Explanation: In the reported bird strike data, specific information on the bird strike is included, but information on what may have caused the bird strike is missing. There are peaks in bird strike occurrences for certain months in some years with no reasonable explanation for why they happened. The wildlife management team has inclinations that increased bird movement through the airport could be due to varying weather conditions or temperatures. It would be useful to create a logbook of all conditions that contribute to an increased bird strike risk. The logbook may provide insights to bird strike occurrences with previously unknown reasons.

Limitations: It is not always entirely clear what will attract birds, so this logbook would have to include large amounts of data for each day. Many different factors must be taken into account before any conclusions can be drawn. It may take a long time before a pattern emerges in the data.

2. Implement multiple bird strike prevention methods to best mitigate the risk of bird strikes at the airport because no single method will completely prevent the risk of bird strikes.

Explanation: According to Air Safety Week, "In military terms, bird control is like a combined arms operation, involving the integration of numerous complementary measures."[87] It is important for Tocumen to understand that there is no single method that will solve the bird strike problem. Many unique factors attract birds to the airport, all of which need to be addressed to mitigate the bird strike risk. Factors that complement each other would need to take into account both internal and external bird attractants, as well as migratory birds. For example, pursuing landscape management could reduce the resident bird population around the airport, while radar could help track and avoid threats from migrating birds.

3. Test different low cost, but effective options of landscape management: overhead nets/grid lines, Methyl Anthranilate, and drainage canal repairs.

Explanation: Landscape management is a viable option for Tocumen Airport because it would reduce the number of birds present on the property. The overhead nets/grid lines would not harm any land. The function of the nets/grid lines would be to deter birds away from standing water in the airport. The irritant Methyl Anthranilate (MA) could be a suitable option because it would deter the birds from wherever the chemical is dispersed. MA is considered non-toxic by the United States Food and Drug Administration; MA would not alter or destroy any lands on or near the airport property. Both options mentioned would allow the airport to choose what areas to target and could be expanded over time. Repairing the drainage canal would remove some sites of water where food is available for birds. The canal is not serving its original purpose, instead making other problems worse.

Limitations: It is unknown how much land Tocumen would need to cover with the MA and grid lines to see the most effective results. This makes it difficult to assess the exact monetary costs of implementing these methods. The situation is similar for the canal because we were unable to assess the exact repairs that would need to be made to fix the drainage canal.

[87] Lasers being deployed in campaign against bird strikes. *Air Safety Week Vol 18 issue 17* 4/26/2004

4. Implement avian radar to provide data for tracking and managing bird threats up to a 10 km radius around the airport. Radar can monitor birds 24 hours a day to provide data on bird patterns and behaviors. This allows it to assess bird strike threats from both resident and migratory birds.

Explanation: Rosabel Miro and Karl Kaufmann of the Panama Audubon Society say the airport must "think big" and invest in radar. It's the only way to track all of the numerous bird hazards present. Radar would track bird threats and be much more reliable than any human. Rosabel of the Audubon Society pointed out that first, humans must look up to see oncoming birds, then they must take the time to call and warn the airport. She admits that this is not always easy or convenient and would like to see the airport take this into their own hands, since they are a big company that hopes to keep expanding. Rosabel also notes that Tocumen Airport has been lucky no serious accidents have occurred from bird strikes, but they should not keep relying on luck. One serious accident could tarnish the airport's reputation and poorly affect Panama's tourism industry. Tocumen most likely has a budget for Tourism Marketing; radar could be added to this budget. Another available option would be to rent an avian radar unit for a few years. If the radar proves effective, the airport could purchase one when they have more room in their budget. The radar can store data on bird movements that can later be analyzed by bird experts to better understand the migrations in Panama, which will provide long term benefits for the airport.

Along with radar, setting up a volunteer network to report on bird movements could be useful. This has been done successfully in Israel. Israel, like Panama, sits on a major bird migratory route, with up to 500 million birds passing overhead twice a year.[88] Over the past 30 years, the Israeli military has made a comprehensive analysis of weather and migration patterns, combined with the use of avian radar to reduce the number of bird strikes by 76%.[89] This study was conducted by Yossi Leshem of Tel Aviv University. In addition to studying past migrations, Leshem has a network of 150 volunteers throughout Israel who report on present migrations to supplement the radar findings.[90] One way to find volunteers to report bird movements could be by partnering with the Audubon Society of Panama.

Limitations: Implementing avian radar would require some training of employees. Radar would also need to be included in their daily flight operations. The airport would need to be willing to purchase the radar, as well as consider these procedures.

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88 Uhlfelder. (2013) "Those Hazardous Flying Birds"

89 Ibid.

90 Rosenthal. (1998) "When Birds Become Missiles."

5. Study the trash problem in the communities surrounding the airport to find a solution that benefits the community, airport, and government.

Explanation: All the residents of communities surrounding the airport that we interviewed had a problem with the excess trash, expressing that it is a cultural issue with no simple solution. The residents worry that the problem is increasing as the population in the area goes up. Finding a solution to this problem will greatly benefit the growing community and the airport. Despite being mutually beneficial, the airport and the community have not reached out to each other on this matter. Perhaps they do not realize this is a problem that negatively affects both of them. The community representative claimed that the residents plan to build gardens along the airport property to beautify the area and discourage waste disposal near the airport. We suggest that the airport reach out to the community on this matter to help them design these gardens to be less attractive to birds. The airport could post informative flyers or posters about the negative effects of littering at the bus stops. Many residents leave their garbage at bus stops while they are waiting for their ride making bus stops an ideal place for community dumpsters. In addition, the airport could organize a volunteer clean-up day for employees of the airport and local residents to work together to better the community and remove the trash. Since this problem is a wide reaching cultural issue, we suggest that a team study it further and analyze possible solutions to find the best one.

Limitations: Solving the trash problem relies on government as well as community cooperation. Plans for reform must be considerate to the community members by not disrupting their cultural norms.

For Copa Airlines

6. Improve Copa Airlines' bird strike reporting system: create a uniform database to efficiently store bird strike report data including costs, damages from the bird strikes, and species of birds.

Explanation: While analyzing Copa's bird strike reports, we realized the data lacked information. Items were often left out of reports, such as the time or location of the strike. We also had to search through a different maintenance database to find the damages and costs associated to each bird strike. Only a few damage reports were actually labeled as a bird strike. There was no way to filter the bird strike reports from the other damage reports, and the number

of bird strikes reported did not match the number of bird strikes on the maintenance records. Species of birds struck are also not recorded anywhere. This results in a lack of evidence for what birds cause the most strikes at Tocumen.

Limitations: Knowing what bird species was struck may require a DNA or feather analyses, though remains may not always be found from the strike. An analyses this complex is not practical for every bird strike incident. Also, not all sources of damages are known; some damages are discovered much later than when they occurred.

PROJECT DESIGN PRINCIPLES

The following are lessons we learned about the relationship between technology, project design, and society while working abroad in Panama City:

Principle #1: It is important to understand the differences and disagreements among the stakeholders involved. Solutions that seem effective and feasible for one stakeholder may not be effective and feasible for another.

Explanation: Different organizations have varying intentions and values. This presents a challenge to outsiders trying to make recommendations. This situation arose when we were working on our project; Copa Airlines, Tocumen S.A., and The AAC all have different interests. The best way to meet all of the stakeholders needs is to find needs that overlap to build on. It is also important to remember that the sponsor is not the only stakeholder. Oftentimes, it is tempting to look at problems solely from the sponsor's point of view, but this excludes the needs of the other stakeholders. It is important to approach the problem with an unbiased point of view. If the work is presented only from the sponsor's viewpoint and doesn't make an attempt to understand other views, other stakeholders may just dismiss it.

Principle #2: There are many social and technical challenges that arise upon arrival in the host country so it is crucial to be open-minded and flexible.

Explanation: Often times, plans change. The key to success abroad is being flexible and approaching any problems with an open mind. Upon arrival in Panama, our project was not clearly defined, but we quickly learned what our sponsor and school wanted. From there, we could define our project further by intertwining the two needs. We stayed flexible throughout the entirety of the project, always open to new ideas and opinions.

Principle #3: A reputable and experienced liaison helps with gathering reliable information.

Explanation: Our liaison was the Ground Safety Manager at Copa Airlines. She had worked at Copa for nine years, meaning she had many connections within Copa and other organizations. She provided several contacts for us to interview. She also helped translate interviews with Spanish speaking community members and airport employees. Without having a reliable liaison to answer questions and connect us with others, we would have had several more limitations and gaps in our research.

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APPENDIX A

Methods of Bird Strike Prevention at José Joaquín de Olmedo International Airport in Guayaquil, Ecuador:

1. Nets over water and on roosting sites

2. Insect Fumigation

3. Effective Drainage System

4. Animal Proof Fences

5. Propane cannons and Scarecrow Patrol Two Noisemaker

It should also be noted that the wildlife team reports directly to the airport general manager. This allows the airport to find solutions quickly to mitigate the problem because the problem does not have to go through other levels of management. The wildlife team also receives suggestions from other departments of airport operations. This interdisciplinary partnership generates unique solution ideas from different perspectives.

The airport in Guayaquil also has a better understanding of what bird species are most frequently struck. The wildlife staff make an effort to collect bird remains from strikes. The staff also created identification books of birds commonly struck in Ecuador. These books are given to pilots to help identify birds after a strike if no remains are found.

APPENDIX B

Pilot Interview Questions

Name: **Position/Rank:**

1. How long have you been flying? How many years have you been at Copa/elsewhere?
2. Have you been involved in a bird strike incident? If so, please describe it (type of bird, type of aircraft, phase of flight, amount of damage, action taken etc.)
3. When do you see the most birds/feel the most vulnerable to a bird strike? (phase of flight, time of year, geographical location, etc.)
4. What airports have you flown to that seem to have good bird control? What measures have they taken?
5. Has Tocumen Airport taken any bird mitigation measures lately? Have they worked?
6. When you spot a bird, are you able to identify the species, or are you only able to tell the basics like size?
7. What is more concerning: a flock of smaller birds or a single larger bird?
8. Do you think changing the landscape around the airport (cutting grass, draining wetlands etc.) will help reduce the amount of birds?
9. What do you think the best way to integrate avian radar is? (i.e. before pushing away from the gate, right before takeoff, in the landing pattern, before the pattern)
10. Through our research, we found that last fall (2014) was the largest bird migration on record. How did that affect flight operations at Tocumen Airport?
11. The E-190 has higher numbers of bird strikes according to Copa's data. Is it louder/quieter than the Boeing, is it better lit? What other factors play into that?

APPENDIX C

Panama Audubon Society Interview Questions

1. Are there any laws that protect any species of birds in Panama, migrating or native?
2. What species of birds are largely present in the area around Tocumen Airport?
3. What do you think are the largest attractions to birds on and around the airport?
4. When do most birds migrate over Panama and what routes do they take?
5. Do you think migrating birds pose a threat to airport operations?
6. Would you be interested in partnering with Copa Airlines to help with the bird strike problem?
7. How effective do you think avian radar would be at Tocumen Airport?
8. What are some of your suggestions for reducing bird strikes at Tocumen Airport?

APPENDIX D

Tocumen Community Member Interview Questions

1. How long have you been living in the community?
2. Are you unhappy with the amount of trash on the streets?
3. How long has there been a trash problem in this community?
4. What is your process for taking out trash? How often? How much?
5. What is the biggest inconvenience for you, regarding trash disposal (dumpsters, pickup times)?
6. Do you have any ideas to improve the problem?
7. Would you support a program for better trash management?
8. Would you be willing to spend money for a better program?

APPENDIX E

Overview of Israel

Israel is a Middle-Eastern country located in Southwest Asia on the Mediterranean Sea and northern shore of the Gulf of Aqaba on the Red Sea. It is bordered by Lebanon to the north, Syria to the northeast, Jordan to the east, and Egypt to the southwest. Israel is approximately 470 km (290 miles) in length and 135 km (85 miles) across as the widest point, and is about the size of the state of New Jersey.[1]

Temperatures vary widely in Israel, especially in the winter and there are many climate zones throughout the country. Coastal areas have a more Mediterranean climate, while other parts have semi-arid and desert climates.[2] Israel can be divided into four geographical regions, including three parallel strips that run north to south, and a large, arid zone in the southern half. The coastal plain is composed of a sandy shoreline and runs parallel to the Mediterranean Sea with fertile farmland borders inland.[3]

Israel is rich in diversity of plants and animals, like birds, due to its proximity to Europe, Asia, and Africa. Israel is a very attractive area for birds due to the variety of habitats and climates. There are agricultural, coastal, and forested areas that all offer something to different species of birds.[4] There are species of birds that are native to and nest in Israel, some that stay for winter, and some that only migrate through. Different species will go to areas of Israel for these purposes. Some species of migratory birds prefer the route that is more level along the Mediterranean shore in order to feed on fish and other food sources in the sea. Other species utilize the air streams created inland for gliding in order to achieve longer distances with less effort. The air streams are intensified by the topography, which varies greatly (Figure 4).[5]

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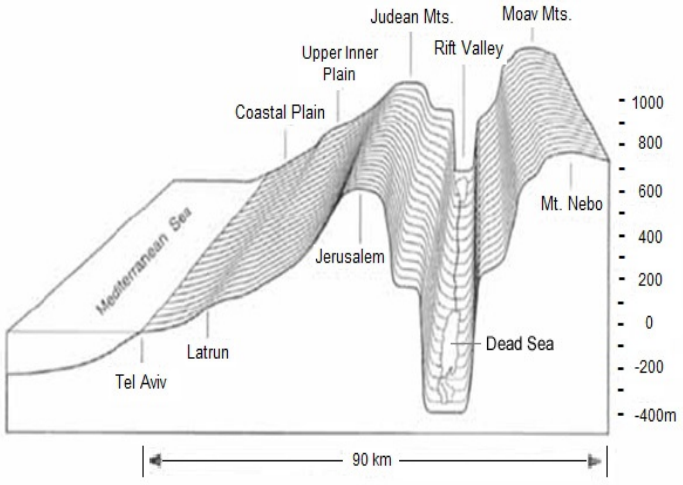
[1] Land: Geography and Climate. (n.d.). Retrieved November 25, 2015, from http://www.israelemb.org/washington/AboutIsrael/Land/Pages/LAND-Geography-Climate.aspx

[2] Ibid.

[3] The Land: Geography and Climate. (2013). Retrieved November 25, 2015, from http://www.mfa.gov.il/mfa/aboutisrael/land/pages/the land- geography and climate.aspx

[4] Kislev, L. (n.d.). Birds of Israel. Retrieved November 26, 2015, from http://www.tatzpit.com/site/en/pages/inPage.asp?catID=9

[5] Birds Without Boundaries. (2006). Retrieved November 25, 2015, from http://www.wysinfo.com/Migratory_Birds/Migratory_Birds_Without_Boundaries.htm



Figures 1 and 2: Map of Israel (Left) and A cross section from the Mediterranean Sea on the west to the mountains bordering the Rift Valley on the east (Right)

Map of Israel. (2012). Retrieved November 25, 2015, from https://lax2tlvbus404.wordpress.com/2012/11/30/ready/map-of-israel/ and Birds Without Boundaries. (n.d.). Retrieved December 7, 2015, from http://www.wysinfo.com/Migratory_Birds/Migratory_Birds_Without_Boundaries.htm

Bird Migration in Israel

Being at the crossroads of three continents, Israel boasts one of the largest bird migrations in the world.[6] Migratory birds fly over nine global migration routes. Israel experiences bird migration through the Black Sea/Mediterranean Flyway (Figure 2). Israel is at a bottleneck where the migratory paths converge and about 540 species come together.[7] The Hula Valley in Galilee, (Figure 1) is a resting place for birds migrating from Europe and Asia to Africa and back, a multi-thousand kilometer journey. Another hotspot for the bird migration in Israel is the city of Eilat. Located on the southernmost tip of Israel on the Red Sea, it is estimated that anywhere between one half- and one billion birds migrate through the Arava region in central Israel to Eilat each year during the fall and spring migrations.[8] Leshem has explained that per square mile, Israel has one of the highest concentrations of birds in the world. "In one morning" he states, "we can see maybe 10,000 eagles".[9] Birds arrive in Eilat in four structured and independent waves during the spring migration.[10]

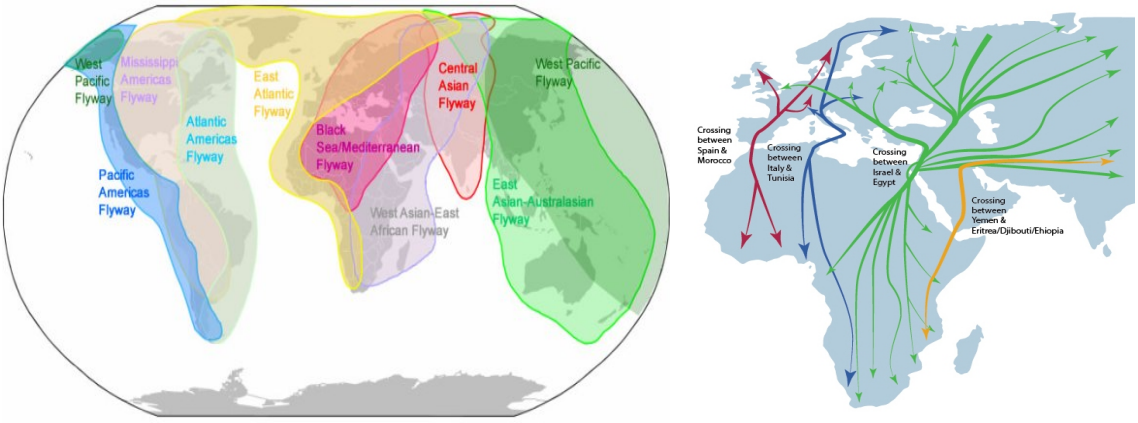
[6] Chandler, A. (2013). Israel's Bird Migration Would Make Alfred Hitchcock Blush. Retrieved November 27, 2015, from http://www.tabletmag.com/scroll/122759/500-million-migrating-birds-cant-be-wrong

[7] Israel's hotspot for migrating birds, a modern day wonder - CNN.com. (2014). Retrieved November 12, 2015, from http://www.cnn.com/2014/04/09/travel/israel-bird-migrations-sea-galilee/

[8] Birding in Eilat. (2010). Retrieved November 11, 2015, from http://www.redseaeilat.com/eilat-birding/

[9] Chandler, A. (2013). Israel's Bird Migration Would.

[10] Yosef, R (2009). Spring Bird Migration Phenology in Eilat, Israel. ZooKeys 31: 193-210.



Figures 2 and 3: Global Flyways of Migratory Birds (Left)
and Migratory Bird Crossings of Europe and Asia (Right)

Main Flyways of Migratory Birds - based on commons.wikimedia.org main international flyways of bird migration, Wikigraphists of the Graphic Lab

Bird Strikes in Israel

The bird strike issue is especially important in military aviation. Achieving high speeds and high maneuverability within specific height ranges makes making it difficult to protect their planes from bird strikes.[11] In Israel, during the intensive seasonal bird migration, the number of birds can reach over 500 individuals per cubic kilometer of air. In addition, Israel has a special situation in the region that requires an extremely high concentration of military aircraft in the air, increasing the likeliness of a collision.[12] [13] Israel lies squarely beneath the fall and spring migration paths of approximately 500 million birds. In the past 25 years, ten Air Force planes have crashed in collisions with birds, with each collision costing about one million dollars.[14]

There have been three fatalities reported in Israel due to bird strikes. Most of the recorded aircraft losses have been due to engine ingestion or windshield penetration, when the bird cracks the windshield of the aircraft. Gulls, hawks, pigeons, and ducks were most commonly identified as the responsibility in these collisions.[15]

[11] Dinevich, L., & Leshem, Y. (2010). Radar monitoring of seasonal bird migration over central Israel. *Ring*.
[12] Ibid.
[13] Uhlfelder, E. (2013). Bloody Skies: The Fight to Reduce Deadly Bird-Plane Collisions. National Geographic.
[14] Israeli Bird Radar Technology Promises Clear Skies for Pilots. (2012, January 16). Retrieved December 8, 2015, from http://www.wallstreetdaily.com/2012/01/16/israeli-bird-radar-technology/
[15] Richardson, W. (1996).Serious Birdstrike-Related Accidents to Military Aircraft of Europe and Israel: List and Analysis of Circumstances. Retrieved November 27, 2015, from http://worldbirdstrike.com/IBSC/London/IBSC23 WP2.pdf

Professor Yossi Leshem is a Senior Researcher in the Department of Zoology in the Faculty of Life Sciences of Tel Aviv University in Israel. Leshem is the founder and Director of the International Center of the Study of Bird Migration at Latrun, Israel. Involved in many aspects of nature conservation, Leshem focused on bird research for 38 years. His research for his doctorate was conducted with cooperation of the Israeli Air Force and Ministry of Science, and the implementation of his research in the form of bird radar has resulted in a 76% decrease in bird strikes.[16] Leshem used radar, drones and gliders to collect data to identify and understand the behaviors and movements of bird flocks. In order to do so, species, time, altitude and habitual routes were studied. Leshem believes that understanding the migratory movement would help reduce the number of bird strikes.[17] For reference, Figure 5 shows a bird radar system display from a fishing boat in Cape Cod, Massachusetts.

Prevention Methods in Israel

In "Nocturnal Bird Migration in the Negev (Israel)" it was determined that autumn migrations in Israel host larger numbers of birds and that the spring migration is only 65% of the autumn migration. In this study there were two radar tracking sites in the Negev Highlands and the Arava Valley. The elevation in the Negev Highlands is 450 m (1475 ft) above sea level and in the Arava Valley is 150 m (490 ft) below sea level. When the highest densities were tracked,

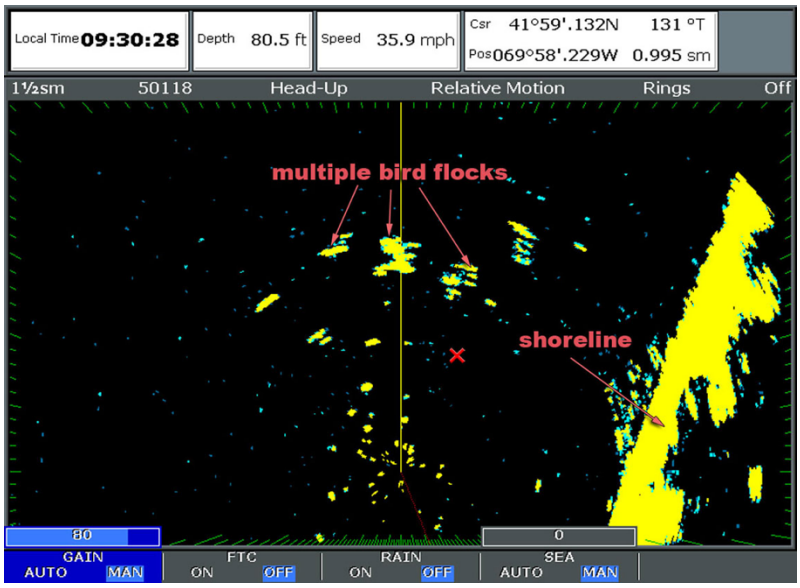


Figure 5: An Example of a Boating Bird Radar Display in Cape Cod, MA

Nugent, T. (2013). Using Radar to Locate Birds. Retrieved December 5, 2015, from http://newenglandboating.com/fishing/using-radar-to-locate-birds.html

[16] Prof. Yossi Leshem. (n.d.). Retrieved November 14, 2015, from https://en-lifesci.tau.ac.il/profile/yleshem
[17] Uhlfelder, E. (2013). Bloody Skies: The Fight

there was an indication that the flightlevels of the flocks were adjusted based on atmospheric conditions. Wind speed was a decisive factor in the altitude choice for migration.[18]

To conceptually understand the coexistence of aircraft and birds within their common air space, a detailed picture that shows how the birds use the air space needs to be developed. Data on multiple characteristics need to be collected, such as bird concentrations, day and night-time activity, and dominant directions, speeds and heights of bird flocks engaged in intercontinental migration. This can be successfully completed with the help of radars, which can report the bird presence in the air and measure the above characteristics of birds within the radar's radius of coverage.[19]

An ornithological radar station has been created in Israel based on the meteorological radar MRL-5 and a specifically designed algorithm (Figure 6). This radar system creates charts of data within the 60 km (37 mi) radius and passes the charts online to air traffic controllers. The data obtained in this study aided the collection of certain characteristics of seasonal bird migration over Central Israel. The results of the study and the radar system have become an important part of ensuring air safety for the Israeli military aircraft. The radar system has made it possible to perform regular observations of bird activity and establish the characteristics of seasonal bird migration across Israel from Europe to Africa and back as displayed in the case study "Recommendations of the Use of Information Obtained by the Radar Ornithological System in Israel".[20]

Figure 6: Bird Migration Tracking Station in Latrun, Israel

Migratory Birds - International Cooperation. (2006). Retrieved December 7, 2015, from http://www.wysinfo.com/Migratory_Birds/Migratory_Birds_International_Cooperation.htm

[18] Bruderer, B. (2010). Nocturnal Bird Migration In The Negev (Israel)—A Tracking Radar Study. *Ostrich,* 204-212.

[19] Dinevich, L., & Leshem, Y. (2010). Radar monitoring of seasonal bird migration over central Israel. *Ring*.

[20] Dinevich, L., & Leshem, Y. (2012). Recommendations of the Use of Information Obtained by the Radar Ornithological System in Israel. Journal "Scientific Israel- Technological Advantages"

The ornithological radar system sends information to flight executive officers or ornithological personnel every 15-20 minutes. The information is in the form three charts; information from the MRL-5 station in Central Israel and from the North and South at other radar stations. There is also an additional feature of real-time analysis of bird echo. In the spring-autumn migrations, it is recommended that the neighboring airports have a system for information exchange in order to stay updated on the migrations. Information should include the exact time of when a mass was detected, the approximate number of birds or echoes on radar screen, the species and size of birds, and flight height and direction.[21] Leshem says that when this information is combined with weather radar and infrared or ultraviolet-based tracking systems, that it is possible to predict where the birds are going.[22]

In cases of high intensity of flights during a bird migration, all of the nearby airports should be kept updated, as the ornithological radar information is updated every 10-15 minutes. Control towers operators are advised to take all necessary precautions, such as closing their terminals for departures and/or arrivals and redirecting airborne aircraft to land at other airfields in the meantime during any situation in the air at the time. For example, Leshem believes that the bird strike incident at LaGuardia airport that caused Flight 1549 to land in the Hudson River could have been prevented if a radar of this type had been in operation.[23]

Overview of Bird Strikes and Panama

Panama suffers from a severe bird strike problem due to the large numbers of birds that inhabit the country and that pass through during the migration seasons. Similarly to Israel, Panama acts as a bottleneck for the birds migrating from North America to South America. Both countries have very attractive areas that bring in different species of birds, but Panama also has a serious pollution/trash problem. The trash attracts black vultures who scavenge for food and scraps. Even though Panama has strong natural attractants for birds, there are also man-made attractants, like trash and debris, that are not caused by the land.[24]

Panama has seen increasing numbers of birds during the bird migration, especially in the autumn. The largest migration occurs in September-October and last year they saw record-breaking numbers.[25] Tocumen International Airport has limited contact with the airport in Mexico City, Mexico, which sees the bird migration approximately one to two days before the birds arrive in Panama. If contact is made between them, the Mexican airport will alert Tocumen of the flocks flying over so they can prepare.[26] Another resource officials at Tocumen use is the researchers at Audubon Bird Society who go birding at Ancon Hill, one of the best places to see birds. There are counters at Ancon who record the number of birds during the migrations. It has

[21] Ibid.
[22] Uhlfelder, E. (2013). Bloody Skies: The Fight
[23] Ibid.
[24] Gomez, Y. (2015). Bird Migration at Tocumen International Airport. [personal interview].
[25] Ibid.
[26] Dominguez, C. (2015). Bird Migration at Tocumen International Airport. [personal interview]

been determined that it may be helpful to have contact with the airport at Bocas del Toro, because they experience the bird migration shortly before Panama City.

Tocumen has closed terminals before due to bird migration. There was an incident just last year where the migration was at a record high and they had to shut down operation of one of their two terminals for an hour or two. At Tocumen, flights are at the highest concentration in the morning, and on this particular morning there were birds leaving nearby trees after nesting for the night by the thousand.[27]

Tocumen International Airport in Panama City, Panama

Tocumen International Airport has tried to implement bird deterrents such as firecrackers and noise guns into their daily operations. Though these deterrents were once successful in diverting birds from the airport property, birds quickly adapt to the light and sound and no longer respond to these measures. Tocumen officials expressed how they believe an ornithological radar system would be extremely helpful in Panama due to the intense bird migration they experience.[28] Panama City's Tocumen could benefit extensively if they decided to implement a bird radar system similar to those used in Israel based on its success.

Conclusion

Israel has seen very much success from the implementation of the ornithological radar systems. The bird migration conditions in Panama and Israel are very similar and Tocumen International Airport could expect to see the same results if they were to implement a comparable system as well. A radar system is a prevention method that has been previously discussed at Tocumen, but if actually implemented, could significantly help to decrease the number of bird strikes that occur, especially during the migration seasons.

[27] Berrio, E. (2015). Tocumen Intl. Airport. [personal interview].
[28] Ibid.

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