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Oliver Tambo International Airport, South Africa: Land-Use Conflicts Between Airports and Wildlife Habitats

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Airports stimulate tourism and trade and are a vital link in any country's tourism infrastructure and economy. Large airports such as South Africa's busiest airport, the OR Tambo International Airport, in Ekurhuleni, Gauteng, are usually located on the periphery of cities, usually on land that forms part of the peri-urban economy, reserved perhaps for farming or left undeveloped. As a result, such land often becomes a wildlife haven within the more "urbanized" or developed areas. Unfortunately, this places wildlife, especially birds on a collision course with aircraft. So much so that bird and other animal strikes cost the aviation industry millions of US dollars annually. Therefore, it is essential to reduce the number of wildlife strikes, not only lower the risk of damage to aircraft, increase passenger safety and reduce operational delays, but also prevent a decline in local wildlife populations. Thus, this paper argues that South Africa must improve its management of land-use close to airports to minimize the potential for wildlife strikes. In that regard, this study catalogs the different habitats and land-use types surrounding OR Tambo International Airport, identifying potential bird hazard zones using kernel density analysis. This identifies which areas pose the highest risk of bird strikes. Although land-use and land zoning by the International Civil Aviation Organization (ICAO) recommends a 13 km buffer zone around airports, this study shows that land-use in the buffer zone must also take potential bird strikes into account. Thus, airport operators need to work with land-use planning authorities and neighboring stakeholders to do so.

Keywords: airports, bird strikes, aviation safety, OR Tambo International Airport, land use conflict

INTRODUCTION

Airports play a critical economic role, serving as hubs for commerce, trade and tourism (Luke and Walters, 2010). Airports are crucial for both job and enterprise creation (Mokhele, 2017). In this regard, the Air Transport Action Group [ATAG], 2020 reported that the global economic impact of air transportation through direct, indirect, or induced means accounts for around 4.1% of the world's Gross Domestic Product. Within a globalized economy the rise of "airport cities" or "aerotropolises," where the urban economy takes shape around aviation-related businesses and associated developments has been noted (Kasarda, 2006). One such aerotropolis is Ekurhuleni, Gauteng, South Africa, population 4 million. Ekurhuleni is a sprawling administrative metropolitan area consisting of nine small towns or cities (Alberton, Benoni, Boksburg, Brakpan, Edenvale, Germiston, Kempton Park, Nigel, and Springs) (Mthombeni, 2017). All were once gold mining towns, with some evolving into industrial towns (especially Germiston and Boksburg), but most now dormitory towns, with residents traveling to Johannesburg or Tshwane for work (Bonner and Nieftagodien, 2012). Since the decline of gold mining and deindustrialization, the region has suffered from serious economic decline reporting unemployment rates in the region of 60% (McKay et al., 2017). Within this context, the OR Tambo International Airport (formerly Jan Smuts Airport), is a crucial economic resource, even in the time of COVID-19 and the associated decline in travel and tourism (Rogerson and Rogerson, 2021). It has reported substantial growth since 1994, becoming South Africa's principal airport as well as the biggest and busiest airport in Africa. In 2011 the City of Ekurhuleni elected to capitalize on this with the objective of being Africa's first aerotropolis written into its Metropolitan Spatial Development Framework (Hancock, 2011). The aim is to leverage the airport to develop an aviation, manufacturing, industrial, logistics and tourism hub to stimulate economic growth and development in the region (Rogerson, 2018). While international and domestic aerial traffic is at the core of the development and planning of the Ekurhuleni Aerotropolis, a key element of aviation is safety. In that regard, it is posited here that the OR Tambo is uniquely at risk of bird strike hazards, due to the initial site not taking bird hazards into account. In particular, the airport was built to United States of America guidelines and the site was selected based on soil type, accessibility, population density, ground water availability and land not deemed to be suitable for gold mining (Greathead and Hawkins, 1948). Furthermore, South African legislation does not comply with international guidelines with respect to buffer zones. Lastly, South Africa was a pariah state until 1994, with low levels of air traffic and limited international engagement politically, diplomatically or in terms of aviation, thus, there is a mismatch between how the airport operated in the past compared to what is required to operate optimally with regard to mitigating risks from wildlife now.

Collisions between aircraft and birds, pose a threat to both passenger and crew safety (Hasilci and Bogoclu, 2021). Bird strikes are well documented with the first one recorded in 1905 when Orville Wright, one of the aviation pioneers, struck a bird in flight. The first recorded human fatality was in 1912 when pilot, Calbraith Rogers, the first person to fly across the United States of America (USA), drowned after a gull caused his aircraft to crash into the sea (Mackinnon et al., 2001). Since 1912, over 200 people have lost their lives as a result of bird strikes. Since 1988 over 200 aircraft have been wrecked (Dolbeer and Wright, 2008). Marra et al. (2009) reported over 7,400 bird-aircraft collisions in the United States in 2007 alone. This is likely a low figure as the Federal Aviation Administration (FAA) estimates that 80 percent of bird strikes go unreported. Various studies have revealed that most bird strikes occur on, or near an airport when the aircraft is at low altitude during take-off or landing (Dolbeer, 2006, 2011; Transport Canada, 2007; Blackwell et al., 2009). A well-publicized incident was that of US Airways Flight 1549 that crash-landed into the Hudson River, New York, on 15 January 2009. The plane collided with migratory Canadian Geese (*Branta canadensis*) just 884 m above ground and 8 km from the airport, causing both engines to fail. This event was made into a Hollywood movie in 2016, "*Sulley, miracle on the Hudson*™" (Marra et al., 2009). Migratory birds are a known hazard, as this flight indicates. Bird strikes cost the aviation industry millions of dollars annually due to aircraft downtime, lost revenue, the cost of putting passengers in hotels, re-scheduling of flights, and flight cancelations. The World Birdstrike Association (formerly known as the *International Bird Strike* Committee) estimates annual financial losses of US$1.2 billion.

As airport buffer zones attract birds and other wildlife, airport operators must manage bird strike hazards (Ball et al., 2021; Carswell et al., 2021). They do this by deploying three main strategies: (1) directing bird behavior; (2) modifying habitats, and (3) adjusting cockpit actions for landings and take-offs (Dolbeer, 2011; Metz et al., 2021). Habitat modification involves making the airport less suited to birds by keeping the grass short, eliminating bird attracting plants and insects as well as draining open water areas or wetlands (Steele and Weston, 2021). Airports also deploy sonic booms, predator calls (some even keep predators such as falcons on the property), lasers (at night), and trained dogs (Swaddle et al., 2016). Lastly, some airports employ bird spotters or radar operators who liaise with air traffic control to direct pilots to alternative runways (Allan, 2000; Thorpe, 2003). But the World Birdstrike Association notes that although airports were, or are, initially located on the outskirts of urban areas, encroachment by residential and light industrial developments are now a significant problem. As local municipalities usually determine land-use and zoning (residential, business, and industrial), enterprises wanting quick, easy access to airports are often accommodated. Hence farmlands near airports becoming warehousing sites is a common international phenomenon, despite the risk to both birds and people. Aviation safety and security, largely managed by national government, may not even be consulted. At the same time, tourism, and wildlife protection often fall to different organs of state. Thus, there is seldom cooperation between the various stakeholders, despite the need to mitigate impacts of a collision by adopting wildlife–management planning that considers the risks posed by the wildlife hazards associated with off-airport land.

There is extensive international research on conflicts between aircraft and birds. Much examines management efforts by airports, in terms of habitat management, bird hazard control, and wildlife management (Barras and Seamans, 2002; Blackwell et al., 2009, 2013; DeVault et al., 2009, 2014). In South Africa, the research has similarly centered on bird strikes on the runways and immediate airport surrounds (Byron and Downs, 2002; Viljoen and Bouwman, 2016). This is despite surrounding land-uses attracting birds that can pose a risk to aviation safety. Thus, there is a need for research to expand beyond the perimeter of airports (Dolbeer, 2011; Martin et al., 2011). But as each airport is unique, they must each be individually assessed. It is, therefore, argued here that it is necessary to determine land-uses within the vicinity of the OR Tambo International Airport. Thus, this study assesses the land-use within the ICAO prescribed 13 kilometers (km) radius of the OR Tambo International Airport to identify land-uses listed as incompatible or restricted by the ICAO in terms of bird strikes. The study could assist the Ekurhuleni Metro to effectively manage bird strikes.

LITERATURE REVIEW

The impact of a bird strike varies according to the weight of the bird, the speed of impact, and the number of birds involved (Puneeth and JayaPrakash, 2021). Bird flight paths and the overall nature of their flocking behavior also matter. For example, some airports must deal with big flocks of large and heavy migratory Canada Geese (>3.6 kg). From a South African perspective Spur-winged Geese (*Plectropterus gambensis*) (3.5–5.1 kg) are a problem. It should be noted, however, even a flock of small birds pose threat to aircraft. Likewise, certain activities, such as landfill sites are also a threat, as they attract scavenging birds such as white storks weighing 2.3–4.5 kg (*Ciconia ciconia*) (Arrondo et al., 2021). As a result, landfills should not be located close to airports and this particular land-use activity is classified as high risk. Complicating the issue is that land-use can change over time. Risks posed by differing land-uses can, however, be mitigated (Coccon et al., 2015; Pfeiffer et al., 2018).

Dolbeer (2006, 2011) through the analyses of bird strike data collected over many years, noted that over 70 percent of bird strikes with civil aircraft occurred at just 152 m above ground level and approximately 3 km from the runway. Thus, the 3-kilometer zone around an airport is the highest risk zone for bird strikes. But off-airport strikes are also an issue. Dolbeer (2011) undertook a trend analyses of bird strikes on commercial aircraft > 500 feet above ground level, for the period 1990–2009. The author focussed on Canada Geese (*Branta canadensis*) as this species is most frequently involved in strikes with aircraft in North America. He found risks to commercial aircraft for strikes at > 500 feet are increasing compared to strikes at < 500 feet. He recommends airports to direct attention to sites within 8 km of the airport; that they study movements of those bird species determined to be hazardous and, conduct further research into avian sensory perception, especially the reactions of birds to moving objects (Dolbeer et al., 2021). Similarly, Martin et al. (2011) noted the effectiveness of wildlife-strike mitigation techniques are wholly dependent on the surrounding landscape and the ecology of species involved. The authors noted that airports intercept with the migratory paths of many animals. For example, waterfowl use rivers as migratory pathways even if these rivers are within the airport buffer zone. It is apparent that full collaboration with surrounding landowners, although difficult to achieve, is integral to achieving a reduction in strike rates. Furthermore, a practice of incentives to convert hazardous land-use to more acceptable land-use practices is recommended.

International Civil Aviation Organization Standards

The ICAO formulates standards and recommendations for the aviation industry. Member states (of which South Africa is one) are obligated, through their local civil aviation authority, to adopt and implement measures proposed by the ICAO. The ICAO requires all airports to have a management plan to address both bird and wildlife presence, with several international standards for managing bird strikes, namely ICAO Annex 14 (ICAO, 2013). More so, the standards insist member states adopt measures for discouraging the presence of birds on, but also within, the vicinity of an airport; especially if the birds constitute an aircraft safety hazard. The ICAO has specific advice on land-use where there is a high potential for attracting wildlife. These include food waste disposal, sewage treatment, artificial and natural lakes; abattoirs; fish processing plants; bird sanctuaries, and outdoor theaters.

That said, factors such as specific bird species, the specific site and local environmental conditions all play important roles in the determination of the potential hazard. The effectiveness of airport bird control activities may often be undermined if neighboring land-use practices that attract birds to an area. Thus, the ICAO standard 9.4.4 specifically deals with wildlife strike hazard reductions related to land developments in the vicinity of the aerodrome. The standard recommends that the appropriate authority prevents the establishment of landfill sites (for example), or any other identified source that could attract wildlife to the aerodrome or vicinity. The ICAO (2002), chapter 10 contains guidance for land-use planning in the vicinity of aerodromes, including land-use guidelines for the avoidance of bird hazards. Furthermore, consideration should be given to the location of incompatible land-use even beyond the recommended distance, as such locations could still create bird flyways over airports or across aircraft flight paths. Effective management of land-use is, therefore, necessary to ensure that incompatible land-use is prevented. The ICAO lists specific undesirable land-uses around airports (see **Table 1**). Therefore, successful airport wildlife management programs must embrace the regulation of land-use near airports. Thus, airport authorities and landowners adjacent to airports need to take aviation safety concerns relating to bird strike hazards into consideration when planning land-use in proximity to an airport.

South African Regulations and Standards

In South Africa, the Civil Aviation Regulations (CARS) Licensing and Operation of Aerodromes states that the airport operators must establish an aerodrome environment management program to minimize the potential hazards associated with wildlife (CARS, 2011). Additionally, cognizance of the provisions of the Environment Conservation Act, 1989 (Act No. 73 of 1989) is required. In general, issues within the boundaries of the aerodrome and within a 10 km radius that might affect aerodrome operations negatively, should be addressed. Furthermore, the Minimum Requirements for Waste Disposal by Landfill state that a waste disposal site cannot be located within 3 km from the end of any airport runway or landing strip in the direct line of the flight path and should not be located within 0.5 km of an airport or airfield boundary (DWAF, 2005). Notably, this 0.5 km limit is not aligned to international or local aviation standards.

Bird Strike Research in Africa

Research on airport bird hazards in South Africa is limited. Byron and Downs (2002) conducted research at Pietermaritzburg

TABLE 1 | Land-uses that create potential bird and wildlife hazards for airports (adapted from the ICAO, 2012).

Agricultural activities	Recreational areas
Crops (grains, forage legumes)	Drive-in theaters
Livestock feedlots; pig farms	Golf courses
Pasture lands, Plowing, haying, harvesting	Marinas
Vineyards	Picnic areas
Orchards, berry farms	Outdoor restaurants
	Beaches and racetracks
Food processing	**Wildlife concentration areas**
Abattoirs	Wildlife refuges
Fish processing	Bird feeding stations
Fish-waste outfall	Bird nesting colonies
	Bird roosting sites
	Loafing sites (gulls on flat roofs, parking lots)
Waste facilities	**Natural areas**
Garbage barges	Marshes/swamps/wetlands
Garbage dumps	Mud flats/shorelines
Waste-transfer stations	Bush or woodlots
Landfills holding organic waste	Hedgerow and Riparian habitat
Water bodies	
Sewage lagoons	
Sewage outfalls	
Oxidation ponds	
Storm water retention ponds	
Reservoirs and lakes	

(previously known as Oribi) Airport, one of the smaller airports in South Africa. Martin et al. (2011) explored the effectiveness of wildlife-strike mitigation techniques, concluding that the surrounding landscape and the bird species matters. Furthermore, incentivizing the conversion of hazardous land-use to more acceptable land-use practices was recommended. In the Western Cape, the Ysterplaat Air Force Base bird community was surveyed by Jeffrey and Buschke (2019). The study covered four seasons and birds were categorized in terms of their response to encroaching urban development. They found the overall hazard of bird-aircraft collision remained constant, regardless of bird response. Notably, it was determined that urbanization around the airport complicated the mitigation measures required. In terms of the at-risk bird species, Viljoen and Bouwman (2016) found that African Sacred Ibis (*Threskiornis aethopicus*) and Gray-headed Gulls (*Chroicocephalus cirrocephalus*) pose the biggest threat for bird-aircraft collisions at OR Tambo International Airport, due to their weight and flocking behavior. Their analysis of recorded bird-aircraft collision data for the OR Tambo International Airport for the years 2005–2011 showed that Gray-headed Gulls were involved in 14.2% of collisions, ten times higher than African Sacred Ibis (1.4%). Elsewhere in Africa, there is similarly little published research on bird strikes, despite the estimate that African countries spend over USD $11 million p.a. to mitigate bird strikes (Bird Strike Association of Canada, 2014). By way of example, in Nigeria, Usman et al. (2012) documented bird and wildlife hazard situations, and a much older study by Mundy (2003) in Zimbabwe, focused on bird strikes and then proposed remedial actions. Hauptfleisch and Avenant (2016) examined risk assessment for bird strikes at Namibia's two major airports. With a follow up study by Hauptfleisch et al. (2020) explored bird strike risks in the airspace between Namibian airports and vulture-aircraft collision hotspot areas for small commercial aircraft flight paths.

MATERIALS AND METHODS

Unfortunately, in South Africa, bird species location and number data is mostly limited to that documented by citizen scientists within the context of the Southern African Bird Atlas Project 2 (SABAP2), a project managed by the Animal Demography Unit (ADU) of the University of Cape Town (McKay et al., 2018). That said, reliance on citizen scientists to collect bird data is not unknown internationally (see Uribe-Morfín et al., 2021). To establish which bird species are present in the OR Tambo airport area, SABAP2 data were used. SABAP2 is an ongoing project that commenced in July 2007 and is a follow-up project to SABAP1 which ran from 1987 to 1991. For SABAP1, Quarter-Degree Grid Cells (QDGCs) were the geographical sampling units. QDGCs are grid cells that cover 15 min × 15 min of latitude and longitude respectfully and correspond to the area shown on a 1:50,000 map. For SABAP2 the sampling unit changed to pentad grid cells (or pentads). This finer scale enabled more detailed information on the occurrence of species to be collected. Therefore, SABAP2 is a more accurate reflection of bird distribution. Since 2007 and continuing through until October 2016, a total of 2006 full protocol cards (i.e., 2006 bird surveys lasting a minimum of 2 h to a maximum of 5 days each) have been completed for the OR Tambo airport study area. The study area, specifically a 13 km zone (as prescribed by the ICAO) around OR Tambo airport was the study area for this investigation. Within this 13 km zone 12 pentad grid cells are found. These 12 SABAP2 pentad grid cells form the basis of the bird distribution data. As bird species move freely between these pentad grid cells they could not be used for spatial hazard mapping. The data could, however, be used to identify the most sighted bird species that could pose a potential hazard to aircraft. One pentad grid cell covered 5 min × 5 min of latitude and longitude respectfully. Each pentad is approximately 8 × 7.6 km. as the data have been collected from 2007 onward. There are nine pentads in a QDGC, the data for pentads can, therefore, be combined into QDGC format, and compared to SABAP1 data to detect any large-scale changes in bird distribution.

An analysis of this SABAP2 bird data was undertaken to assign hazard levels to various bird species based on their potential risk to aviation safety. To establish this, the following criteria were used: (a) Species with an average reporting rate of 25% or higher (SABAP2, 2016); (b) Weight and flocking behavior and (c) The Bird Hazard Ranking System designed by Transport Canada (2002). Transport Canada (2002) developed a simple four-level ranking of risk to indicate land-use suitability in primary, secondary and special bird zones. Primary bird hazard zones are those where aircraft are at very low altitudes (take-off and landing) and, thus, have the potential to cause the greatest damage. Secondary bird hazard zones are buffer areas that include various departure and arrival paths, variations in pilot behavior, as well as techniques that factor in the unpredictability of bird behavior. Special bird hazard zones are zones that regularly attract potentially hazardous species even if they are far from an airport. Prime examples here of are golf courses and landfill sites.

The Airport Bird-hazard Risk Analysis Process (ABRAP) (see Transport Canada, 2002) was used to assess the land-use in a 13-kilometer radius surrounding the OR Tambo Airport. The complete ABRAP performs a full risk analysis by utilizing a combination of surrounding land-use, air flight patterns, as well as number and proximity of potentially hazardous bird species. The land-use was determined using a Geographical Information System (GIS) to classify remotely sensed landcover data sets. Land-use surrounding the airport was examined to determine if they are special bird-hazard zones. A GIS map was then produced on current land-use. The ArcMap Analyst Tool-pack, specifically the buffer tool, was used to create vector files depicting the designated buffers surrounding OR Tambo International Airport. Buffers were designated around different land-use types.

Different habitat types were also identified in terms of suitability, based on the overall diversity and number of bird species it could support. The 2014 South Africa Land Cover raster layer was used to identify and extract all noted priority habitat types that have the largest potential of hosting bird species known to collide with aircraft or are home to large densities of birds. An ArcMap spatial analyst tool, Raster Calculator, was used to extract all relevant habitat types within the designated study area. To determine the highest potential risk areas for bird strikes, two factors were utilized: (1) the size of the priority habitat and (2) the distance between patches of priority habitat. Habitats spaced closer together allow for more frequent commuting of birds, thereby increasing the associated risk. To display this relationship, the Kernel Density tool (as part of the ArcMap Spatial Analysts Tool-pack) was used. Kernel Density is useful to identify spatial patterns within the land cover data (Smith et al., 2015). That said, hotspot analysis could have been used to assess density distribution at the local scale, but no profoundly different results would have been produced. The raster layers depicting priority habitat types were converted to point features (i.e., a vector file) using the ArcMap Analysis Tool-pack and assessed using the Kernel Density tool, to highlight areas of concentration. Concentrated areas of priority habitat (i.e., size of habitat) and those spaced close together (i.e., distance between habitats) result in higher Kernel Density factors.

It is acknowledged that the different data sources make use of different resolutions. There is a quarter degree square in SABAP1 and $5' \times 5'$ longitude and latitude for SABAP2. The data were also collected over a different time period with different protocols being used. Notably a spatio-temporal ranking system requires a larger repository of bird data.

RESULTS

To date, a total of 324 bird species has been recorded within the study area and its immediate surroundings (SABAP2, 2016). The bird most frequently recorded is the Laughing Dove (*Streptopelia senegalensis*) at 95.77%, followed closely by the Blacksmith lapwing (*Vanellus armatus*) at 95.52%. The Hadeda Ibis (*Bostrychia hagedash*) is at 91.79%; while the Egyptian Goose (*Alopochen aegyptiacus*) ranked at 86.07%. Also, in the top ten most frequently recorded birds were the African Sacred Ibis (*Threskiornis aethiopicus*) and the Gray-headed Gull (*Larus cirrocephalus*), both were recorded at 84.33%. Thus, many of the high-risk species (Hadeda Ibis, Egyptian Goose, African Sacred Ibis and Gray-headed Gull) were frequently recorded. **Table 2** lists the hazard levels and criteria used to rate species as well as the most hazardous species identified through the Bird Hazard Ranking System (Transport Canada, 2007) in the 13 km vicinity of OR Tambo International Airport. Two primary criteria are noted in the Bird Hazard Ranking System namely; size of the bird species and whether they exhibit flocking or solitary behavior. On the basis, frequency of sighting and size criteria, 6 potentially hazardous species were identified from the SABAP2 data. (All species that rarely cited and are smaller than 50 g are disregarded according to the Bird Hazard ranking system). These species were then ranked according to risk level in **Table 2**.

Based on the above criteria, a subset of species was identified (frequently recorded and having a hazard/risk level of between 1 and 4). The SABAP2 reporting rate, average weight (g) and behavior of each species are shown in **Table 3**.

The SABAP2 data has therefore been used to identify and rank the 6 most hazardous bird species using the Bird Hazard Ranking System. For further hazard identification and spatial hazard mapping these species will have to be monitored in high risk land-use areas. The discussion now moves to the identification of the land-use areas that present the greatest spatial hazard in terms of providing bird habitat. **Figure 1** identifies the land-use types within the 1, 5, 10, and 13 km buffer zones known as bird foraging or roosting habitat. Grassland is shaded green, wetlands shaded red and permanent bodies of water shaded blue. Green areas represent the type of land-use favored by the birds listed in **Table 2**. They are areas of short grass or open areas, such as sports fields, golf courses, and urban smallholdings. Golf courses and areas of short grass attract birds such as the Egyptian Goose

TABLE 2 | A Bird Hazard Ranking System was used to determine the risk level of bird species within the zone of 13 km surrounding OR Tambo International Airport.

Level of risk	Characteristics	Illustrative species
Level 1 (highest)	Very large (>1.8 kg), flocking/solitary	Egyptian goose (2.1 kg) Spur-winged goose (3.5–5.1 kg)
Level 2	Large (1.0–1.8 kg), flocking/solitary	Hadeda ibis (1.25 kg) African sacred ibis (1.5 kg)
Level 3	Medium (300–1,000 g), flocking/solitary	Pied crow (550 g)
Level 4	Small (50–300 g), flocking/solitary	Gray-headed gull (280 g)

TABLE 3 | The SABAP2 reporting rate, known to occur at the OR Tambo International Airport.

Species	Scientific name	SABAP2 average reporting rate (%)	Weight (g)	Flocking behavior	Bird hazard ranking
Egyptian goose	*Alopochen aegyptiacus*	52.0	2.1 kg	Yes	Level 1
Spur-winged goose	*Plectropterus gambensis*	27.1	3.5–5.1 kg	Yes	Level 1
Hadeda ibis	*Bostrychia hagedash*	84.9	1.25 kg	Yes	Level 2
African sacred ibis	*Threskiornis aethopicus*	73.9	1.5 kg	Yes	Level 2
Pied crow	*Corvus albus*	72.8	550 g	Yes	Level 3
Gray-headed gull	*Chroicocephalus cirrocephalus*	75.8	280 g	Yes	Level 4

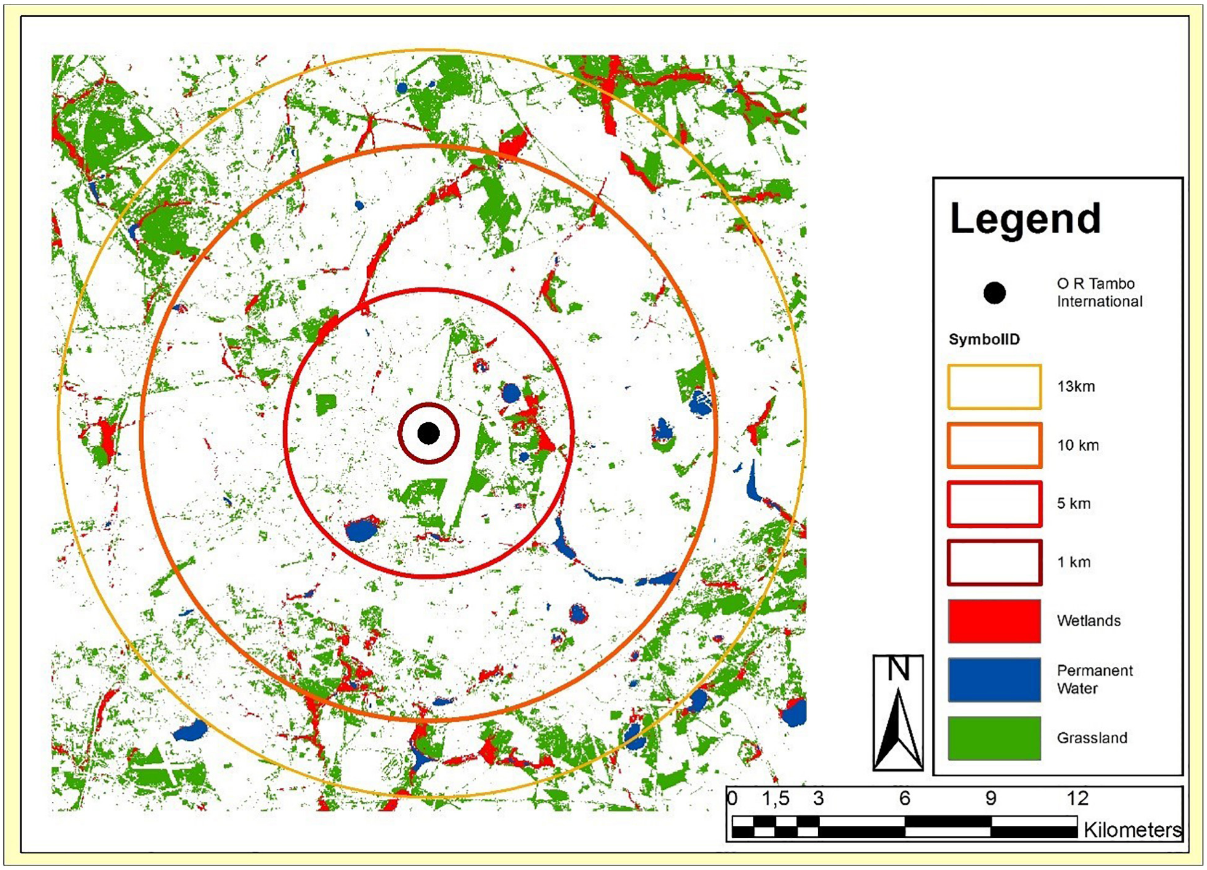

FIGURE 1 | Land-use around OR Tambo International Airport.

(*Alopochen aegyptiacus*), Hadeda Ibis (*Bostrychia hagedash*) and African Sacred Ibis (*Threskiornis aethiopicus*). Golf courses also often have areas that contain dams or streams, which may also encourage hazardous birds to roost and breed such as the Hadeda Ibis (*Bostrychia hagedash*) and African Sacred Ibis (*Threskiornis aethiopicus*). Wetlands and water bodies are also attractive to birds as roosting and nesting sites for species such as the Hadeda Ibis (*Bostrychia hagedash*), African Sacred Ibis (*Threskiornis aethiopicus*), Spur-winged Goose (*Plectropterus gambensis),* Egyptian Goose (*Alopochen aegyptiacus*), and Gray-headed Gull *(Chroicocephalus cirrocephalus)*, especially in Ekurhuleni where birds face a dry winter. Pied Crows (*Corvus albus)* are an opportunistic species that move between various habitats and could be found in any of the abovementioned habitats. While the area immediately surrounding the airport is urbanized, **Figure 1** illustrates that Ekurhuleni is also characterized by many naturally occurring wetlands, farm dams and large dams which are remnants of the gold mining era. Several wetlands are to be found within the 13 km zone of the OR Tambo airport. An area of cultivated land to the northeast of the 13 km zone is another notable area of favorable bird habitat.

The primary bird strike hazard zone is the airport itself and the airspace around the airport runways. The secondary bird strike hazard zone is deemed the 10 km buffer around the airport due to variations in flight departure and arrival paths (see **Figure 2**). **Figure 2** therefore provides a spatial risk map for aircraft safety resulting from the three identified land-uses that serve as bird habitat for high risk bird species. Zones demarcated

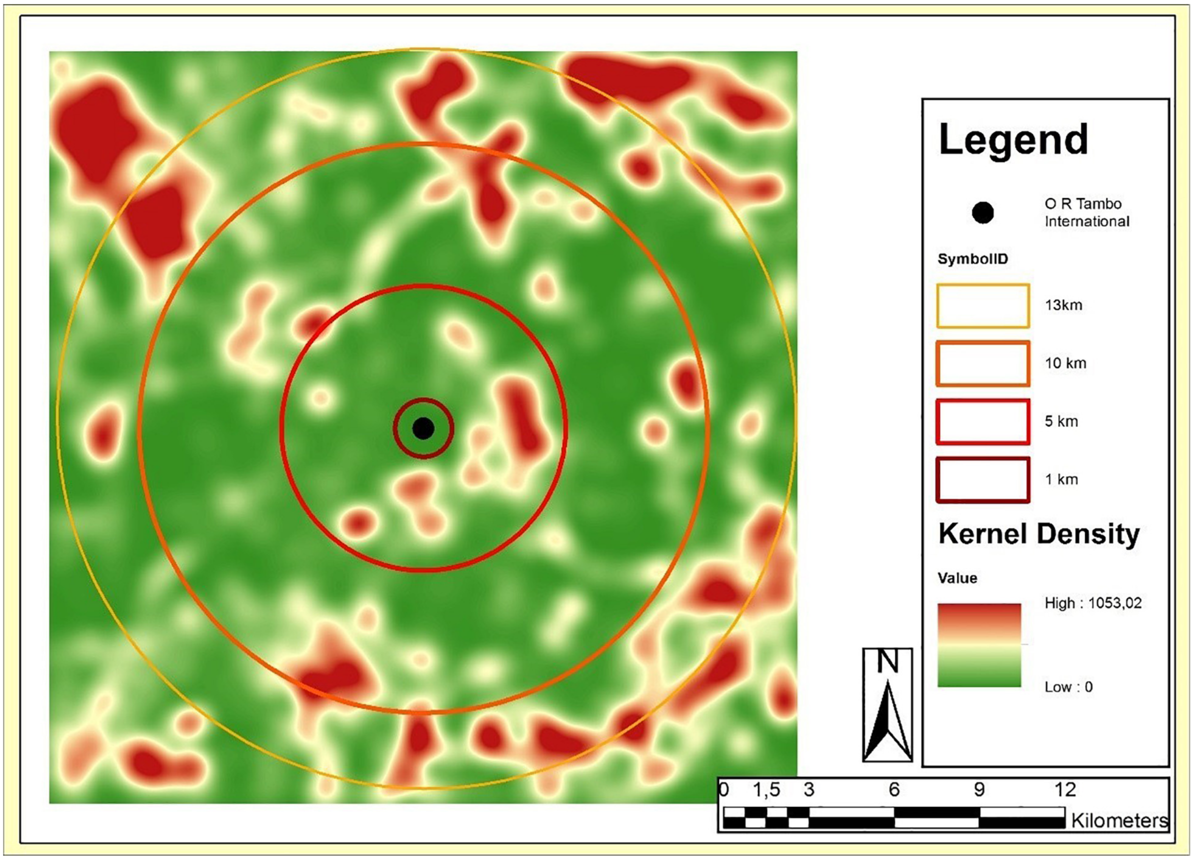

FIGURE 2 | Location of bird strike hazard zone area around OR Tambo International Airport.

as red attract birds and so present potentially hazardous flight paths for aircraft. Red areas support and attract birds and are large contiguous areas, spaced close together. The darker the red, the larger the bird habitats and the closer the different patches are to one another. Additionally, birds may commute between these identified areas posing an additional risk. To determine which areas within the designated buffer poses the highest potential commuting risk, two factors were utilized: (1) The size of the priority habitat and (2) The distance between relevant patches of priority habitat. Habitats spaced closer together allow for more frequent commuting of birds, thereby increasing the associated risk.

ANALYSIS OF RESULTS

It must be noted that these maps present a current view, as the area is subject to ongoing changes in land-use. The data does, however, provide a basis for airport authorities and other stakeholders to devise ways of mitigating the potential of bird strikes. The results indicate that land-use around the OR Tambo International airport supports and attracts the bird species of concern. Thus, the 13 km buffer zone is home to high-risk land-use. Additionally, there is the threat of commuting birds. Part of the challenge is that the original siting of the OR Tambo International Airport failed to take the potential bird-strike risk into account. This is especially true with respect to the numerous water bodies, small rivers and wetlands. While these were not considered a problem by the original engineers who selected the site, the long-term problem of failing to consider wildlife matters is well demonstrated here. Additionally, the failure to make a 13 km buffer zone initially has meant that airport authorities now need to engage with many surrounding private landowners to manage the bird strike. Furthermore, with many different arms of state involved, cooperation across all levels to mitigate the risk will be complex and involve a lot of mediation and negotiation. Added to that is the ongoing urban sprawl that characterizes Gauteng's cities, so that encroachment into the buffer zone will always be a threat. Lastly, the failure of the International Civil Aviation Organization (ICAO) to enforce its standards on OR Tambo is a major concern, as compliance should not be voluntary.

RECOMMENDATIONS AND CONCLUSION

The operator, Airports Company South (ACSA) should become an automatic Interested and Affected Party for all Environmental

Impact Assessments within the prescribed 13 km zone. In this regard, the Department of Environmental Affairs (DEA) must alert ACSA to any proposed land-use activity changes within the 13 km zone. In addition, the City of Ekurhuleni should introduce ongoing monitoring of bird populations in the area to track their movements around the vicinity of the airport. The height-specific protocol used by Viljoen and Bouwman (2016) could be used for an expansion of long-term studies of high-risk bird species. Consideration could also be given to other survey techniques employed at other international airports, such as a dedicated radar for bird detections, used at King Shaka International Airport in Kwa-Zulu Natal, South Africa. While civil aviation standards are followed in South Africa, legislation is required to further ensure aviation safety requirements are aligned to international best practice in respect of land-use and zoning, namely the 13 km zone. In this regard the International Civil Aviation Organization (ICAO) should insist that its regulations are adhered to. Lastly, there is a need for further research on bird hazards at OR Tambo airport. Both the habitat and bird siting data must be collected per habitat as currently the only way to do any research on the matter is using the quarter degree squares dictated by the present data.

The objective of this research was to assess the surrounding landscape of the OR Tambo International Airport to determine if the current land-use practices attract birds known as strike risks. It was found that there are numerous natural and human-altered environments that serve as habitats and food sources for several high-risk species—posing a risk to aircraft. Collectively, the high-risk land-use types identified present a network of habitats within the 13 km demarcated zone. Transition of undesirable land-uses could reduce the risk of aircraft strikes such as the residential development of grassland areas within the 13 km zone. While there is a program to control bird species located at the airport site, management within the entire 13 km zone is needed to effectively address the issue. This will require cooperation between the airport authorities, city planners, affected local businesses in the area, relevant government departments, and representatives from the public. This study serves as a first application of determining bird-strike hazards relating to land-use practices around the OR Tambo International Airport and, the first of its kind on the African continent. The proposal by the Ekurhuleni Metropolitan Municipality to establish African's first Aerotropolis will need the relevant stakeholders to deal with the problem of potential bird strikes if the airport wishes to increase air traffic without compromising safety.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements. Ethical review and approval was not required for the animal study because no animals were handled or treated in any way.

AUTHOR CONTRIBUTIONS

LR and KM undertook the research and prepared the first draft of the manuscript while TM contributed toward the final manuscript preparation. All authors contributed to the article and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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