Aircraft–wildlife collisions at two major Namibian Airports from 2006–2010

Morgan L. Hauptfleisch[1,2]*, **Nico L. Avenant**[2,3] **& Alton Tsowaseb**[1]

[1]*Department of Nature Conservation, Polytechnic of Namibia, Private Bag 13388, Windhoek, Namibia*

[2]*Centre for Environmental Management, University of the Free State, P.O. Box 399, Bloemfontein, South Africa*

[3]*National Museum, P.O. Box 266, Bloemfontein, South Africa*

Received 29 October 2012. Accepted 25 July 2013

An analysis, the first of its kind in Namibia, was conducted on five years' (2006–2010) Aircraft–wildlife collision (AWC) records from two Namibian airports. These records were compared to AWC reports of three Namibian airlines. Trends in annual and seasonal occurrence of AWCs and species responsible for collisions were investigated. A total of 55 and 73 AWC incidents were reported at Hosea Kutako and Eros airports, respectively. No year-on-year trends in reported AWC incidents could be established, with the highest percentage recorded in the first year (37% of all records). By cross-referencing reports from different entities we estimate that only 19% of incidents were recorded over the study period. Both birds and mammals were involved in AWCs during the period with the two most common species being crowned lapwing (*Vanellus coronatus*) (16% of all incidents at Hosea Kutako and 69% of incidents at Eros) and helmeted guinea fowl (*Numida meleagris*) (9% and 8%, respectively). Unidentified species accounted for, on average, 25% of incidents at Hosea Kutako and 9% at Eros. This analysis provides public and scientific awareness on AWCs as a form of human–wildlife conflict and provides focus for further research into habitat and environmental factors which attract species frequently involved in aircraft collisions. The study sets a baseline of collision frequency against which the success of future airport wildlife minimization efforts can be measured.

Key words: aircraft, wildlife, collision, bird strike, reporting, conflict.

INTRODUCTION

Aircraft–wildlife collisions (AWCs) are a global concern (Allan 2000; Robinson 2000; Froneman 2001; Sodhi 2002; Thorpe 2003; Buurma & Den Haag 2004; IBSC 2006, Blackwell *et al.* 2013), with 42 fatal accidents, 231 human deaths and 80 destroyed aircraft globally as a consequence between 1912 and 2002. Greater flight volumes and increases in wildlife populations (as a result of successful conservation efforts) are increasing the risk of collisions between wildlife and aircraft (Froneman 2000; Robinson 2000; Cleary *et al.* 2006). At Namibia's two major airports, Hosea Kutako (international) and Eros (local), 128 AWC incidents were recorded between 2006 and 2010. Although none led to serious injury or death, two major incidents led to direct costs in excess of N$30 million and N$1 million, respectively (Namibia Airports Company (NAC) unpublished incident reports 2006 and 2010).

In order to reduce the risk of AWCs the International Birdstrike Committee (IBSC) produced a set of nine standards for the control of wildlife hazards at aerodromes (IBSC 2006). Standards number 5, 6 and 7 refer to the recording and reporting of AWC information. This paper addresses the following principles within these standards: (i) ensuring that airports are informed of all collisions reported in their vicinity; (ii) ensuring as far as possible accurate identification of species involved in collisions; and (iii) not using only the total number of collisions as a measure of risk.

Similar research was conducted in east (Nasirwa 2001; Owino *et al.* 2004; Bitebekezi 2007) and west Africa (Oduntan *et al.* 2012). Although bird strike mitigation research has been conducted at airports in South Africa (Anderson & Kok 1990; Byron & Downs 2002; Froneman & van Rooyen 2003; Froneman 2006), very little published research on the extent and frequency of AWCs in southern Africa is available; with only one report providing similar information (by Mundy undated – of bird strikes in Zimbabwe). This is the first study of AWCs in Namibia. The study investigated the number of AWC incidents over time and species involved in incidents. Information on incidents in

*To whom correspondence should be addressed.
E-mail: mhauptfleisch@polytechnic.edu.na

Namibia is incomplete and largely uncollated, a problem this investigation attempted to quantify. By cross-referencing reports from various sources, it comments on the accuracy and reporting diligence of the aviation industry in Namibia over the years 2006–2010.

METHODS

Study area

We sourced AWC data from NAC and three airline operators as collected at Namibia's two largest and busiest airports, Eros and Hosea Kutako International. Hosea Kutako (22°28′S, 17°28′E) is Namibia's primary international airport. Situated approximately 40 km east of Windhoek, the capital city, the airport is the largest of Namibia's nine parastatal airports. A relatively low volume of aircraft (~16 000 flights per year; NAC internal records) use the airport, but most of these flights carry over 100 passengers each to and from various international destinations. Of significance to the problem of aircraft–wildlife collisions is that a high percentage of aircraft using the airport use jet turbine propulsion (pers. obs), making them more vulnerable to engine damage from bird ingestions (Transport Canada 2001). Eros Aerodrome (22°36′S, 17°04′E) is primarily a local destination airport. It is situated in the capital city, Windhoek. This airport carries the highest flight volumes in Namibia (~32 000 flights per year; NAC internal records). Most aircraft using the airport are propeller driven. Both airports are situated in the 'Highland Shrubland' Tree and Shrub Savanna vegetation type (Mendelsohn *et al*. 2002).

AWC records of NAC (Hosea Kutako and Eros Airports)

AWC data were collected by the Chief Fire Officer at each airport in accordance with the IBSC Standards for Aerodrome Bird/Wildlife Control (2006). For the purpose of this analysis NAC AWC records (n = 128) from January 2006 to December 2010 were used.

Species identified in NAC reports were classified according to class and avian species were further classified by size (large >1000 g; medium <1000 g, small <300 g) (following Sowden *et al.* 2007). Mammal species were few (n = 3) and were therefore listed according to frequency of occurrence in collisions.

Internal records of AWC incidents from three airline operators active in Namibia were sourced: Air Namibia (n = 55 records), West Air (n = 39), and Wilderness Air (n = 84). Although the method of reporting differed from NAC, date and species involved in incidents were common to both types, and used in this analysis. Comparisons between NAC and airline reports were possible from 2007 only, when the above-mentioned airlines first started collecting AWC data. Only reports within the vicinity of the two airports (on taxi, take-off, landing or approach) were considered for the analysis.

Statistical analyses were conducted in Statistica®. Pearson product-moment correlation coefficient was used to determine year-on-year trends, NAC-airline reporting corroboration and species-collision correlations.

RESULTS

Analysis of NAC AWC reports

A total of 55 and 73 AWC incidents were recorded at Hosea Kutako and Eros, respectively, over the five-year period. This equated to one collision every 1877 flights at Hosea Kutako, and one every 2777 flights at Eros; or one collision every 43 days at Hosea Kutako and every 31 days at Eros.

A high percentage (not statistically significant as a result of low collision numbers) of all incidents were reported in 2006 in comparison to the following four years (38% and 36% of all, at Hosea Kutako and Eros, respectively) (Fig. 1). No trend was identified for the number of annual incidents at Hosea Kutako, but at Eros airport an increase in the number of reported incidents was found during the last three years, 2008–2010. No correlation in monthly or seasonal occurrence of AWCs could be found between Eros and Hosea Kutako Airports (P > 0.05). At Hosea Kutako and Eros 55% and 44% of collisions occurred during the rainy season (November to April), and 45% and 56% during the dry season (May to October), respectively.

Hosea Kutako recorded incidents with 14 wildlife species, and Eros seven during 2006–2010. Incidents with specific species at the two airports are described in Table 1. Birds were the animal group most involved with AWCs at both airports (54.5% and 90.4%, respectively).

At Hosea Kutako large-sized birds (>1000 g) were involved in 29.1% of all incidents, medium-sized birds in 3.6%, and small birds in 21.8% over the five-year period. The species most often involved in incidents here were the birds crowned lapwing (*Vanellus coronatus*) (small size; 16% of total wildlife incidents) and helmeted guinea fowl

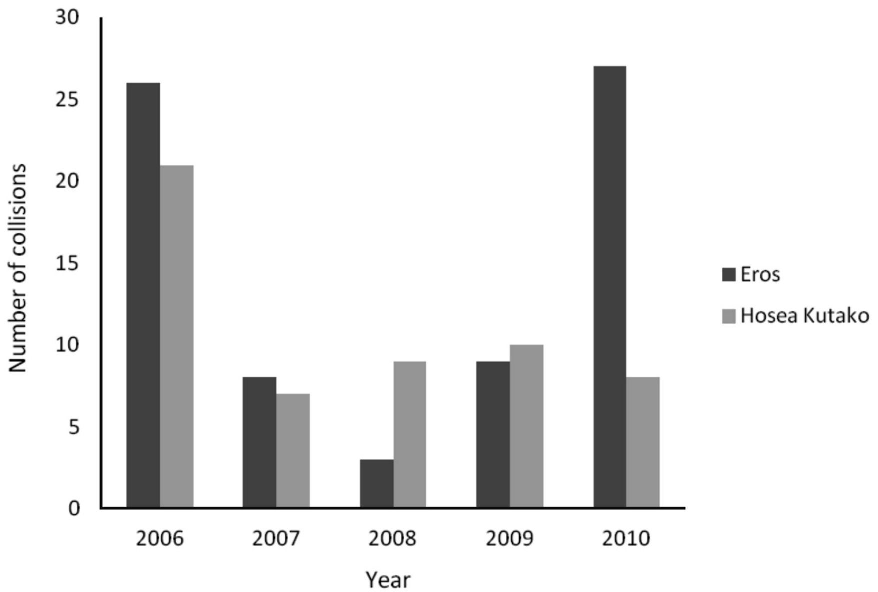

Fig. 1. Number of aircraft–wildlife collision incidents reported at Eros and Hosea Kutako Airports over the five-year period 2006 to 2010 (based on Namibia Airports Company records).

(*Numida meleagris*)(large size; 9%), and the mammals black-backed jackal (*Canis mesomelas)* (9%) and scrub hare (*Lepus saxatilis*) (9%).

At Eros Airport from 2006–2010, 74.4% of all incidents were with small-sized birds, 10.8% with large birds, and 4.1% with medium-sized birds. Crowned lapwing were responsible for two thirds of all incidents. Six incidents (8% of all) occurred with helmeted guinea fowl, followed by one or two incidents with a number of other bird species. No mammal incidents were recorded at Eros Airport.

Collisions with multiple birds were recorded on six occasions at Eros and three occasions at Hosea Kutako. Crowned lapwing were responsible for eight of these nine collisions, with the number of individuals per collision ranging from two to 13. The other multiple bird collision was caused by feral pigeon (*Columba livia*) (3 individuals).

Comparison between AWC records recorded by the Namibian Aircrafts Company and the three airlines

The three airlines, together, recorded 14% fewer incidents ($n = 70$) than NAC ($n = 81$) (Table 2). NAC consistently reported more incidents during the first three years, but no pattern was evident between NAC and any of the three airlines. Sixteen per cent of the AWC incidents recorded by NAC were unidentified (the wildlife species involved were not reported or remained unknown). This percentage was much higher in the airline reports, with 70, 92 and 100% (Air Namibia, West Air and Wilderness Air), respectively, of reports showing the wildlife species involved as unknown.

Air Namibia was responsible for reporting 44% of all collisions at Hosea Kutako and 23% at Eros over the four years, while their annual relative flight volumes contributed 25% (n = 4108) and 7% ($n = 2444$), respectively. This converts to one collision every 2191 flights at Hosea Kutako and one every 888 flights at Eros; or one collision every 97 days at Hosea Kutako and one collision every 133 days at Eros. If Air Namibia's (considered a diligent reporter)(N. Pule, pers. comm.) reporting frequency is extrapolated to all flights at the airports, NAC should be recording one collision every 549 flights at Hosea Kutako (currently every 1877 flights) and one every 194 flights at Eros (currently every 2777 flights). Relative to Air Namibia, it indicates a likelihood that only 25% of all incidents were reported at Hosea Kutako and only 21% at Eros.

DISCUSSION

The lack of a universal frequency measurement unit complicates comparison of the collision frequency with similar studies. In Namibia (this study), for example, flights per incident and days per incident were used. In European studies (e.g. Dekker & Van Gasteren 2005) frequency of

Table 1. Number of aircraft–wildlife collision incidents reported per species at Hosea Kutako International and Eros airports, 2006–2010 (Namibia Airports Company reports).

Species	Hosea Kutako Airport (*n* = 55)		Eros Airport (*n* = 73)	
	Number	%	Number	%
Class Aves	**30**	**54.5**	**66**	**90.4**
Large (>1000 g)				
Helmeted guinea fowl (*Numida melagris*)	5	9.1	6	8.1
Yellow-billed kite (*Milvus aegyptius*)	3	5.5	2	2.7
Secretary bird (*Sagittarius serpentarius*)	3	5.5	0	0
Marabou stork (*Leptoptilos crumeniferus*)	2	3.6	0	0
Abdim's stork (*Ciconia addimii*)	2	3.6	0	0
White-backed vulture (*Gyps africanus*)	1	1.8	0	0
Medium (300–1000 g)				
Southern pale chanting goshawk (*Melierax canorus*)	1	1.8	1	1.4
Black crow (*Corvus capensis*)	1	1.8	0	0
Feral pigeon (*Columbia livia*)	0	0	2	2.7
Small (<300 g)				
Rock kestrel (*Falco rupicolus*)	2	3.6	0	0
Crowned lapwing (*Vanellus coronatus*)	9	16.4	51	68.9
Sparrow (family Passeridae)	0	0	2	2.7
Swallow/swift (family Hirundinidae, Apodidae)	0	0	1	1.4
Burchell's courser (*Cursorius rufus*)	1	1.8	1	1.4
Class Mammalia	**11**	**20.0**	**0**	**0**
Black-backed jackal (*Canis mesomelas*)	5	9.1	0	0
Scrub hare (*Lepus saxatilis*)	5	9.1	0	0
Chacma baboon (*Papio ursinus*)	1	1.8	0	0
Unidentified	**14**	**25.5**	**7**	**9.5**

collisions were measured as flying hours per collisions, and in the U.S.A. and Australia collisions per 10 000 aircraft movements (Steele 2001; Dolbeer 2006). In a comparable study in Africa, also over a five-year period 1986 to 1990 (at Bole International Airport in Ethiopia; Yohannes *et al.* 2000) recorded 33 incidents, which relates to one incident every 55 days, while a study at Oribi Airport in South Africa a collision every 18 days over a one-year period (Byron & Downs 2002) In this study the 55 and 73 AWC incidents over a similar period at Hosea Kutako and Eros, respectively, related to one collision every 44 and 31 days.

Table 2. Number of aircraft–wildlife collision incidents reported by the Namibia Airports Company (NAC), compared with three airlines, 2007–2010.

Airport	Hosea Kutako Airport					Eros Airport				
Reporting entity	NAC	Air Namibia	Wilderness Air	West Air	Mean ± S.D.	NAC	Air Namibia	Wilderness Air	West Air	Mean ± S.D.
2007	7	5	0	0	3 ± 3.6	8	1	1	0	2.6 ± 3.7
2008	9	5	0	0	3.5 ± 4.4	3	0	2	6	2.9 ± 2.5
2009	10	1	1	0	3 ± 4.7	9	3	7	4	5.2 ± 2.8
2010	8	4	4	1	4.5 ± 2.9	27	7	11	7	11.3 ± 9.5
Total	34	15	5	1		47	11	21	17	

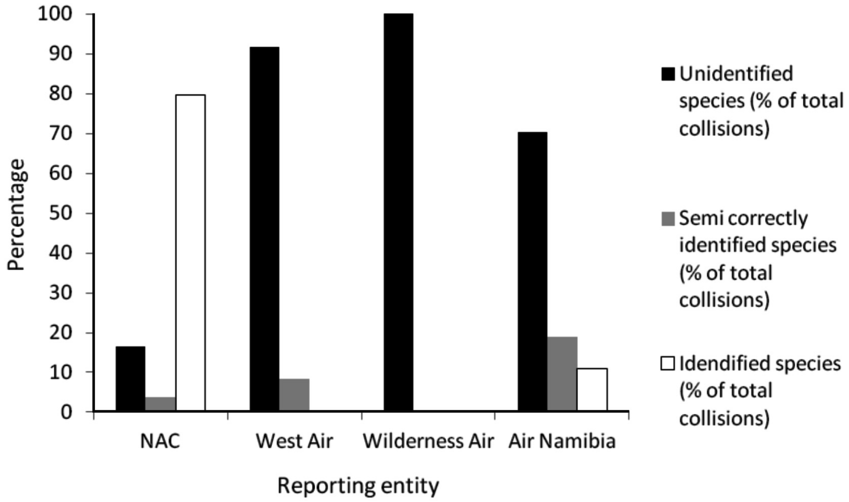

Fig. 2. Identification of species involved in aircraft–wildlife collision incidents reported by the Namibia Airports Company and three airlines.

Although more collisions occurred at Eros, this is expected as it carried more flights (NAC internal records). This does, however, not mean that this relates to a higher monetary or human casualty risk at Eros (IBSC 2006). Eros accommodates mostly smaller (4 to 10 seat) propeller-driven craft which are less vulnerable to engine failures from bird collisions than jet-turbine-driven aircraft (Liebich, 2011). Jet-turbine aircraft with passenger capacity of between 50 and 400 dominate flights at Hosea Kutako – which relatively increases the damage and injury risk. In addition, *c.* 30% of all AWCs at Hosea Kutako is caused by large-sized birds (*vs* <10% at Eros) and 20% by >2 kg mammals (*vs* none at Eros). The 14 species involved in incidents at Hosea Kutako is also high compared to eight at Eros, suggesting that the natural and largely uninhabited ecosystems surrounding Hosea Kutako harbour a greater variety of wildlife compared to the urban surroundings of Eros.

The calculated reporting rate of 25% at Hosea Kutako and 21% at Eros is consistent with that of Wright & Dolbeer (2005) who suggested that less than 20% of all incidents are reported across the U.S.A., as well as that of Barras & Dolbeer (2000) who found that less than 34% of incidents were reported at J.F. Kennedy International Airport over the 13-year period 1979–1998. Possible reasons for this under-reporting may be that collisions are either not detected, or personnel ignore an often laborious reporting process (Linnell *et al.* 1999; Eschenfelder 2001). Further, no 'near miss' incidents were recorded at the Namibian airports, another important indicator in determining risk of AWCs and proactively mitigating it (Klope *et al.* 2009).

Management of the risk of AWCs is severely hampered by the inadequate identification of species involved in incidents. Although NAC staff were able to identify species in the majority of collisions, the high percentage of unidentified species reported by airlines (see Fig. 2) may be a result of reporters needing to concentrate on aircraft control and not being able to identify species, wildlife often not being identifiable after colliding with a large aircraft (particularly turbines fragment and combust remains) and reporters not having enough knowledge of wildlife species. This is consistent with Wright & Dolbeer's (2005) finding that in only 25% of cases the wildlife species are able to be identified by aviation personnel. A lack of coordination between pilots and NAC may further have resulted in wildlife remains not being recovered from runways following collisions.

Of all species identified, crowned lapwing were the most significant contributor to AWC incidents at both Hosea Kutako and Eros airports. This species also dominated incidents at two inland airports in South Africa (Kok & Kok 2002a; Kok 2006). Being a small-sized bird of *c.*185 g (Turpie & Ryan 2005), the risk of a collision with this species causing significant damage to aircraft is relatively low. However, its gregarious habit of occurring in flocks of between 10 and 40 birds (and even up to 100 immediately after the breeding season) (Turpie & Ryan 2005), increases its significance as a risk species (see Sodhi 2002). In this instance, at both airports collisions with multiple crowned lapwing were caused in eight out of every nine recorded incidents. Attracted to short grass and disturbed areas, airport runway verges serve an ideal habitat for this species which is said to avoid areas where grass is taller than 60 mm (Turpie & Ryan 2005). As an insectivore its preferred diet is termites (both *Odontotermes and Hodotermes* in South Africa; Kok & Kok 2002b). Furthermore, the runways and aprons provide ideal habitat for the species' hunt by sight tactic, and the short grass habitat is preferred for nesting.

Helmeted guinea fowl, the second most common species involved in AWC incidents, both at Hosea Kutako and Eros, pose a greater threat to damage and human safety. Its relatively large size and weight (1.38 kg for females; 1.5 kg for males; Ratcliffe 2005), and gregarious habits (occurring in flocks of 15 to 40 birds) makes this species a high risk for causing extensive damage to aircraft and human casualty. Helmeted guinea fowl feed on invertebrates (termites the preferred food item), but it also feeds on plant parts such as seeds and tubers (Nasirwa 2001; Ratcliffe 2005).

Mammalian species accounted for 11 (20%) incidents at Hosea Kutako. This is high compared to the 0% at Eros, and an average of 2.2% in the U.S.A. (Cleary *et al*. 2006). It also highlights the unique situation facing southern African airports surrounded by healthy wildlife populations. Metscher *et al*. (2007) warns that the risk of damage from collisions with mammals should not be underestimated. Five incidents were recorded with black-backed jackal at Hosea Kutako (3 in 2006, 1 in 2008 and 1 in 2009). Management reports (Alexander 2007; SAIEA 2008) identified the uncovered and unfenced landfill site at Hosea Kutako as a possible attractant for this species and other scavengers. Since the closing of the landfill site and improved waste management practices (towards the end of 2009) there have been no jackal sightings near the runway (pers. obs.), indicating that the mitigation measure was effective.

At Eros Airport the increase in AWC incidents from 2008 to 2010 corresponded with an observed increase in crowned lapwing numbers (G. Coetzee pers. comm.). The introduction of grass mowing as a management action is expected to have contributed to their presence as this species are ground-living and prefer short-grass habitat (Kok & Kok 2002b).

Our analyses (≈ no seasonal trend) contradicted the aircraft industry in Namibia's remark that the risk of AWCs were seasonally much higher in the rainy season than in the dry season (R.A. Alexander, W.N. Pule, M. Konings, pers. comm.). If this observation led to vigilance in the wet season and complacency in the latter, it could have had an impact on our data. Owino *et al.* (2004) found significantly more incidents in the Kenyan wet season, while greatest frequency of bird strikes at both Melbourne Airport (Steele 2001) and Dublin Airport (Kelly *et al*. 2001) were observed in autumn. Kelly *et al.* (2001), further, reported that autumn and spring collisions are often with migratory species. The lack of collisions with migratory species at Eros and Hosea Kutako is a possible reason for finding no seasonal collision trend.

CONCLUSION

It is evident that disharmony in reporting of AWCs in Namibia exists among airport staff and airlines. The information provided in reports and the reporting procedure differed for each entity, and it was difficult to determine whether reports from the airlines were captured by airports and *vice versa*. To compound the problem, all airlines did not report incidents to airport personnel. A standardized, industry-wide reporting procedure should be developed, based on IBSC Standard 7 (IBSC, 2006). Near-miss incidents should become a requirement of the standardized reporting procedure in addition to the categories of incidents prescribed in Standard 6. The focus should, further, shift from merely reporting of incidents to demanding analysis of the data from aviation authorities. This will enable airports to mitigate the risk of collisions by removing attractants for species found to commonly collide with aircraft.

REFERENCES

ALLAN, J.R. 2000. The cost of bird strikes and bird strike prevention. Proceedings of the Wildlife Research Center Symposium (pp. 147–153), United States Department of Agriculture, University of Nebraska, Lincoln, U.S.A.

ALEXANDER, R.A. 2007. Report on Wildlife Risks at Hosea Kutako International Airport. Namibia Airports Company, Windhoek, Namibia.

ANDERSON, P.C. & KOK, O.B. 1990. Gonadesiklus van die kroonkiewiet *Vanellus coronatus* op enkele binnelandse lughawens [Gonadal cycle of the crowned plover *Vanellus coronatus* at two inland airports]. *S. Afr. J. Zool.* 25: 54–60.

BARRAS, S.C. & DOLBEER, R.A. 2000. Reporting bias in bird strikes at John F. Kennedy International Airport, New York, 1979–1998. Proceedings of the International Bird Strike Committee IBSC25/WP-SA2, Amsterdam, Netherlands.

BITEBEKEZI, G.K. 2007. The role of community participation in the control of bird hazards at Entebbe International Airport, Uganda. *Ostrich* 78: 131–133.

BLACKWELL, B.F., SEAMANS, T.W., SCHMIDT, P.M., DE VAULT, T.L., BELANT, J.L., WHITTINGHAM, M.J., MARTIN, J.A. & FERNANDEZ-JURICIC, E. 2013. A framework for managing airport grasslands and birds amidst conflicting priorities. *Ibis* 155: 189–193.

BUURMA, L. & DEN HAAG, S. 2004. Bird strikes: local answers to global ICAO questions. *Int. Air. Rev.* 3: 63–67.

BYRON, J. & DOWNS, C.T. 2002. Bird presence at Oribi Airport and recommendations to avoid bird strikes. *S. Afr. J. Wildl. Res.* 32: 49–58.

CLEARY, E.C., DOLBEER, R.A. & WRIGHT, S.E. 2006. Wildlife strikes to civil aircraft in the United States 1990–2005. Other Bird Strike and Aviation Materials, paper 7.

DEKKER, A. & VAN GASTEREN, H. 2005. Eurobase: military bird strike frequency in Europe. Proceedings of the International Bird Strike Committee IBSC27/WP IX-5, Athens, Greece.

DOLBEER, R.A. 2006. Height distribution of birds recorded by collisions with civil aircraft. *J. Wildlife. Manage.* 70: 1345–1350.

ESCHENFELDER, P. 2001. Let no new thing arise: wildlife hazards to aviation. Proceedings of the Bird Strike Committee U.S.A./Canada, Calgary, Canada.

FRONEMAN, A. 2000. Towards the management of bird hazards on South African airports. Proceedings of the International Bird Strike Committee IBSC25/WP-SA5, Amsterdam, Netherlands.

FRONEMAN, A. 2001. Airport wildlife management in Africa. The ACSA-EWT strategic partnership, South Africa. Wings over Africa, Proceedings of the international seminar on bird migration: Research, conservation, education and flight safety. Tel Aviv. Israel.

FRONEMAN, A. & VAN ROOYEN, M. 2003. The successful implementation of a border collie bird scaring program at Durban International Airport, South Africa. Proceedings of the International Bird Strike Committee, Warsaw, Poland.

FRONEMAN, A. 2006. Developing a risk rating system for bird strike occurrences. Bird Strike Committee U.S.A./Canada 8th Annual Meeting, St. Louis, U.S.A.

HOCKEY, P.A.R., DEAN, W.R.J. & RYAN, P.G. 2005. Roberts – Birds of southern Africa, VIIth edn. John Voelcker Bird Book Fund, Cape Town, South Africa.

INTERNATIONAL BIRDSTRIKE COMMITTEE (IBSC). 2006. Recommended Practice No. 1. Standards for aerodrome bird/wildlife control. International Civil Aviation Organisation.

KELLY, T.C.R., BOLGER, M.J., O'CALLAGHAN, A. & BOURKE, P.D. 2001. Proceedings of the Bird Strike Committee U.S.A./Canada, Calgary, Canada.

KLOPE, M.W., BEASON, R.C., NOHARA, T.J & BEGIER, M.J. 2009. Role of near-miss bird strikes in assessing hazards. Internet Center for Human–Wildlife Interactions, University of Nebraska, Lincoln, U.S.A.

KOK, O. 2006. Prey manipulation as a management strategy at an inland South African airport. Proceedings of the Bird Strike Committee U.S.A./Canada annual meeting.

KOK, O. & KOK, O.B. 2002a. Avifauna in grasveld-gemeenskappe op enkele binnelandse lughawens in Suid-Afrika [Avifauna in grassland communities on selected inland airports in South Africa]. *S.-Afr. Tyds. Nat. & Teg.* 21: 4–15.

KOK, O. & KOK, O.B. 2002b. Aspects of the feeding ecology of avifauna at an inland airport, South Africa. Proceedings of the Bird Strike Committee-U.S.A./Canada 4th annual meeting, Sacramento, U.S.A.

LIEBICH, R. 2011. A mechanical engine simulator for development of aero engine failure analysis methods. IUTAM Bookseries 10111: 419–428.

LINNELL, M.A., CONOVER, M.R. & OHASHI, T.J. 1999. Biases in birdstrike statistics based on pilot reports. *J. Wildlife. Manage.* 63: 997–1003.

MENDELSOHN, J., JARVIS, A., ROBERTS, C. & ROBERTSON, T. 2002. Atlas of Namibia: a portrait of the land and its people. David Philip, Cape Town, South Africa.

METSCHER, D.S., COYNE, W.B. & REARDON, J.M. 2007. An analysis of the barriers found in reporting wildlife strike incidents to the FAA National Wildlife Strike Database for civilian aviation. *Int. J. Pro. Av. Tr. & Test. Res.* 1: 38–57.

MUNDY, P.J. Undated. Bird strikes on aeroplanes in Zimbabwe and remedial action. Unpublished report, Department of National Parks, Bulawayo, Zimbabwe.

NASIRWA, O. 2001. Bird migration and bird strike situation in Kenya. Proceedings of the International Seminar on Bird Migration: Research, Conservation, Education and Flight Safety. Tel-Aviv, Israel.

ODUNTAN, O.O., AKINYEMI, A.F. & ABIODUN, O.A. 2012. Assessment of bird strike occurrences and bird species abundance at the Murtala Muhammed International Airport, Lagos. *J. Agric. Sci. Soil Sci.* 2: 223–227.

OWINO, A., BIWOTT, N. & AMUTETE, G. 2004. Bird strike incidents involving Kenya Airways flights at three Kenyan airports, 1991–2001. *Afr. J. Ecol.* 42: 122–128.

RATCLIFFE, C.S. 2005. Helmeted guinea fowl *Numida meleagris*. In: P.A.R. Hockey, W.R.J. Dean & P.G. Ryan (Eds), Roberts – Birds of southern Africa, VIIth edn (pp. 82–83). John Voelcker Bird Book Fund, Cape Town, South Africa.

ROBINSON, M. 2000. Is the possibility of a costly aircraft bird strike growing? Proceedings of the International Bird Strike Committee IBSC25/WP-SA8, Amsterdam, Netherlands.

SODHI, N.S. 2002. Competition in the air: Birds *versus* aircraft. *Auk.* 119: 587–595.

SOUTHERN AFRICAN INSTITUTE FOR ENVIRONMENTAL ASSESSMENT (SAIEA). 2008. Wildlife Control and Reduction Programme for the Namibia Airports Company. Consultants Report for the Namibia Airports Company, Windhoek, Namibia.

SOWDEN, R., KELLY, T. & DUDLEY, S. 2007. Airport bird hazard risk assessment process. Proceedings of the Bird Strike Committee, U.S.A./Canada 9th annual meeting, Kingston, Canada.

STEELE, W.K. 2001. Factors influencing the incidence of bird-strikes at Melbourne Airport, 1986–2000. Proceedings of the Bird Strike Committee U.S.A./ Canada, Calgary, Canada.

THORPE, J. 2003 Fatalities and destroyed civil aircraft due to bird strikes. International Bird Strike Committee Publication, IBSC26/WP-SA 1.

TRANSPORT CANADA. 2001. Sharing the Skies. TP 13549E. Transport Canada, Ottawa, Canada.

TURPIE, J.K. & RYAN, P.G. 2005. Crowned lapwing *Vanellus coronatus*. In: P.A.R. Hockey, W.R.J. Dean & P.G. Ryan (Eds), Roberts – Birds of southern Africa, VIIth edn (pp. 417–419). John Voelcker Bird Book Fund, Cape Town, South Africa.

WRIGHT, S.E. & DOLBEER, R.A. 2005. Percentage of wildlife strikes reported and species identified under a voluntary reporting scheme. Birdstrike Committee U.S.A./Canada, 7th Annual Meeting, Vancouver, Canada.

YOHANNES, E., BEKELE, A. & WOLDU, Z. 2000. Bird strike incidence at Addis Ababa Bole International Airport. *Eth. J. Sci.* 23: 215–229.

Corresponding Editor: M.R. Perrin