The use of ecosystem parameters in predicting the risk of aircraft-wildlife collisions at Namibian airports

by

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Declaration

I declare that this thesis, hereby handed in for the qualification of Doctor of Philosophy in Environmental Management in the Faculty of Natural and Agricultural Sciences at the University of the Free State, is my own independent work and that I have not previously submitted the same work for a qualification at another university / faculty. I cede copyright of the thesis in favour of the University of the Free State.

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Summary

Human-wildlife conflict is affecting a number of aspects of society as a result of increased competition for resources such as food and space. To address the complexity, management of human wildlife conflict needs to be innovative to achieve a difficult but possible win-win solution for both humans and wildlife. As an important form of human-wildlife conflict, aircraft-wildlife collisions (AWCs), more commonly known as bird strikes, require even greater imagination and innovation to solve.

AWCs have the potential to cause loss of life to humans, and annual losses in damages as a result of such collisions runs in excess of US$ 3 billion per year to the aviation industry. Due to lack of accurate reporting of AWCs in Namibia (and Africa as a whole) losses have been impossible to quantify locally. In addition to direct damage, airlines, airports and individuals have been litigated in Europe and the USA for indirect damages resulting from AWCs. A number of studies have identified an increasing trend in AWCs globally as a result of higher flight volumes and increases in risk bird populations.

Flight safety in Africa is of concern internationally, and AWCs are an important safety aspect which need to be understood better. Very little empirical research on the extent or causes of AWCs in Africa have been published. At Namibia’s two major airports, Hosea Kutako International and Eros (domestic), 128 AWC incidents were recorded between 2006 and 2010. Although none led to human injury or death, two major incidents lead to costs in excess of N$ 20 million and N$ 1million respectively. Publications on AWC minimisation strategies and techniques on the continent are limited to South Africa and Uganda. This is problematic, as mitigation measures for AWCs in Africa are therefore mostly based on research in foreign ecosystems; while we know that local knowledge of AWC factors, such as bird and mammal population dynamics and climatic seasonality are critical to the success of AWC management.

This study is the first scientific investigation into any aspect of AWCs in Namibia. It aims to understand the relationship between ecosystem components and their effect on the risk of aircraft-wildlife collisions occurring at Hosea Kutako and Eros airports. Monitoring of ecosystem components such as insects and small mammals are useful to airport wildlife management as they are relatively quick and inexpensive tools for determining ecosystem health and functioning and can indicate varying environmental contexts and responses. These ecosystem components and others such as vegetation and avian communities were explored.

The study found that modelling the abovementioned ecosystem factors to predict the risk of AWCs would be marginally accurate, but still useful in understanding the system, as well as the effects of various management actions on that system. Systems modelling was found to have the potential to map the complexity of influences on AWCs and make them understandable to airport management in order to allow more informed decision making and resourcing regarding the management of AWC risk.

The international obligation placed on airport staff to control wildlife hazards in the vicinity of airports is often difficult to fulfil, especially at smaller airports or in countries with inadequate resources and capacity. In addition to this, research into wildlife habitat, species and their habits at airports has predominantly originated in Europe and North America, and hence mitigation measures are most effective in these conditions, and less effective elsewhere. Based on the context of its literature and empirical research, this study proposes a toolkit which was designed to guide airports in Southern Africa to minimise risk of aircraft-wildlife collisions. It is based on the understanding of ecosystems in the vicinity of the two airports on which this study was based, but also on the broader understanding of capacity and resources available to many Southern African countries. It also considers the recommended practices of ICAO, global best practice and promotes a multi-stakeholder management approach.

Key words: Aircraft-wildlife collision, airport habitat, avifauna, bird strike, ecosystem, human-wildlife conflict, multi-stakeholder management, systems modelling, toolkit, wildlife hazard management.

Opsomming

Mens-wildlewe konflik is huidiglik ‘n probleem wat alle aspekte van die samelewing beinvloed as gevolg van verergende kompetisie vir hulpbronne soos voedsel en ruimte. Om hierdie komplekse probleem aan te spreek, moet die bestuur van mens-wildlewe konflik innoverend wees om ‘n moeilike maar wel moontlike wen-wen oplossing vir mens en dier te vind. Vliegtuig-wildlewe botsings (VWBs) is ‘n belangrike vorm van mens-wildlewe konflik en verg nog meer verbeelding en innovering om op te los.

VWBs het die potensiaal om tot menslike lewensverlies te lei, en geldelike verliese weens sulke botsings beloop meer as US$ 3 miljard per jaar vir die globale lugvaartbedryf. Weens ‘n tekort aan akkurate verslagdiening van VWBs in Namibië (en Afrika as geheel) is dit onmoontlik om verliese lokaal te skat. Ongeag direkte verliese, word lugrederye, lughawens en individue voor die hof gedaag om indirekte kostes as gevolg van VWBs te eis. Menigde studies het ‘n globale toename in die volume VWBs gevind as gevolg van meer vlugte en toenames in risiko voël bevolkings.

Vlugveiligheid in Afrika is ‘n internasionale bekommernis, en VWBs is een aspek wat nog swak verstaan word. Weinige empiriese navorsing oor die getalle of oorsake van VWBs in Afrika is al gepubliseer. Op Namibië se twee belangrikste en besigste lughawens, naamlik Hosea Kutako Internasionaal en Eros (plaaslik), is 128 VWB insidente tussen 2006 en 2010 aangemeld. Howel geen tot menslike beserings of lewensverlies gelei het nie, het twee groot insidente tot kostes van meer as N$ 20 miljoen en N$ 1 miljoen gelei. Publikasies oor VWB verminderings strategieë en tegnieke in Afrika is tans beperk tot Suid Afrika en Uganda. Dit veroorsaak probleme, omdat die meerderheid strategieë dus in Europa en Amerika ontwikkel is, vir ekosisteme wat anders as lokale ekosisteme funksioneer. Dit neem nie plaaslike kennis oor voël en soogdier bevolkingsdinamika, en seisoenaliteit in ag nie, faktore wat krities is tot suksesvolle VWB bestuur.

Hierdie studie is die eerste wetenskaplike ontleding van enige aspek van VWBs in Namibië. Dit beoog om die verhouding tussen ekosisteemkomponente en hulle effek op die risiko van VWBs by Hosea Kutako en Eros lughawens te bepaal. Monitering van ekosisteemkomponente soos insekte en klein soogdiere is nuttig vir lughawe wildlewe bestuur omdat hulle relatief goedkoop en vinnige tegnieke behels om ekosisteem gesondheid en funksionering te bepaal, asook omgewingstoestande en reaksies. Hierdie ekosisteemkomponente en ander soos plantegroei en voëlgemeenskappe is as deel van hierdie studie ondersoek.

Die studie het bepaal dat modelering van sekere aspekte van die bogenoemde eksosisteemfaktore tot ‘n laë mate gebruik kan word om die risiko van VWBs te voorspel. Sulke modelering is wel nuttig om die sisteem te kan verstaan, asook die effek van bestuursmetodes op VWB risiko. Daar is gevind dat sisteemmodelering die potensiaal toon om die kompleksiteit van VWB invloede te illustreer, en sodoende hulle verstaanbaar vir lughawebesuur kan maak, wat dan tot meer akkurate besluitneming oor VWB risiko bestuur kan lei.

Die internasionale verpligting wat op lughawe personeel geplaas word om VWBs te verminder is dikwels moeilik om na te kom, veral by kleiner lughawens of in lande waar daar ‘n tekort aan hulpbronne en kapasiteit voorkom. Daarby is navorsing oor VWBs en hulle oorsake meestal in Europa en Amerika uitgevoer, en dus is bestuurstegnieke slegs onder bogenoemde toestande beproef, en heel moontlik minder effektief elders. Hierdie studie stel ‘n hulpmiddel (toolkit) voor om lughawns in Suider Afrika te assisteer in die bestuur van VWBs. Dit word gebasseer op die begrip van ekosisteme in en om die twee studie lughawens, maar ook ‘n wyer begrip van kapasiteit en hulpbronbeskikbaarheid in Suider Afrika as geheel. Dit neem ook die voorgestelde praktyke van ICAO en wêreldwye goeie praktyke in ag, en bevorder ‘n multibelanghebbende bestuurs aanslag.

Sleutelwoorde: Avifauna, ekosisteem, hulpmiddel, lughawe habitat, mens wildlewe konflik, multibelanghebbende bestuur, sisteemmodelering, vliegtuig-wildlewe konflik, wildlewe risiko bestuur.

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List of key terms and abbreviations

Aircraft-wildlife collision (AWC): A collision between an animal and an aircraft. The term is more inclusive than the commonly used aviation term "bird strike".

Airport wildlife control: Measures used to remove or repel wildlife from aircraft manoeuvring areas at or near airports. These measures may be non lethal (e.g. dogs, sonic deterrents) or lethal (culling or poisoning).

ATC: Air Traffic Controller. Responsible for controlling the manoeuvring of aircraft in its mandated airspace.

AWC risk: A measure of the likelihood of a collision between an aircraft and an animal and the possible consequence of such a collision (Anagnostopoulos 2003, Allan 2006).

Bird strike: An aviation term for a collision between an aircraft and avian species. The term is more commonly used than AWC as birds account for the vast majority of collisions (Dolbeer & Wright 2008).

EIA: Environmental Impact Assessment. A process of identifying and predicting the effect of activities on the environment, and recommending mitigating measures for such effects.

Extraordinary event management: In the context of this study it refers to the management of sudden bird flocking events or migrations caused by unpredictable climatic or other factors.

IBSC: International Bird Strike Committee. A voluntary organisation supported by the airline industry to provide guidance on the management of AWC risk. In June 2012 it transformed into the World Birdstrike Association.

ICAO: International Civil Aviation Organisation tasked to regulate civil aviation (including airports; ICAO, 1991) under the Chicago Convention on International Civil Aviation of 1944(6) to which Namibia is a signatory.

Multi-stakeholder management: Collective management of a problem (in this case AWCs) by involving all affected and causal groups or individuals. The process was found to greatly enhance the identification and mitigation of root causes of AWCs (Leshem & Froneman 2003, Bitebekezi 2007).

NAC: Namibia Airports Company. Parastatal company responsible for the operation of Namibia's eight most strategic airports.

Sensitivity analysis: A process of testing the effects on subtle changes in model parameters on the output of the model (Starfield & Bleloch 1986).

Systems thinking: Systems thinking (or systems dynamics, and modelling) attempts to address problems which are complex (Sterman 2001; Barlas 2007; Senge *et al.* 1994). Senge (2006) defines systems thinking as a discipline of seeing wholes, while Costanza *et al.* (1993) describe it as a tool to understand the interrelationships and interconnectedness of exchanges in energy, information and matter (natural or anthropogenic).

WARN: Wildlife and Aircraft Research Namibia project – A project developed in 2009 as an outcome of this PhD study to provide guidance and scientific input into AWC management in Namibia. It is funded by the NAC and has established a bird strike centre at Eros airport.

Wildlife or AWC hazard: The species or attractant of species that are likely to be an AWC risk (ICAO 1991,IBSC 2006).

Veld: A Southern African colloquial term for rangeland, pasture or grassland.

SETTING THE CONTEXT

CHAPTER 1: INTRODUCTION

Human-wildlife conflict is increasing globally as wildlife populations increase in urban and rural environments, mainly resulting from successful conservation actions (Messmer 2000, Conover 2002, Messmer 2009) and the expansion of urban areas (Conover *et al.* 1995, Morzillo & Mertig, 2011). This results in increased competition for resources such as food and space (Kaplan *et al.* 2011). Temby (2004) recognised wildlife collisions with aircraft as one of the most serious and costly problems relating to human-wildlife conflicts. Management of human-wildlife conflict is a complex discipline (Ruiz & Moreira 1986, Treves *et al.* 2006, Dickman 2010) which relies on balancing human wellbeing with wildlife populations (Messmer 2000) and understanding the drivers of the conflict (Dickman 2010). It has evolved from managing animal damage, or so-called problem animal control, to a holistic and interdisciplinary science which considers root causes of conflicts (whether anthropogenic, climatic or biological) and attempts to address these causes rather than "control" wildlife (Dickman 2010). To address the complexity, control or management of human wildlife conflict needs to be innovative (Dickman 2010, Kaplan *et al.* 2011) and holistic (Avenant *et al.* 2006) in order to achieve a difficult but possible win-win solution for both humans and wildlife (McShane *et al.* 2011). It further needs to consider the possible collateral or non-target effects of control measures on ecosystems (Morzillo & Mertig 2011).

Aircraft-wildlife collisions (AWCs) are a global concern. Thorpe (2003) reported 42 fatal accidents, 231 human deaths and 80 destroyed aircraft in the world's aviation sector as a result of AWCs between 1912 and 2002, while Dolbeer *et al.* (2012) cited 229 human deaths and 210 destroyed aircraft since 1988 alone. In the USA the annual cost of damage and delays have been estimated at US$ 1.2 billion (Allan 2000), while Short *et al.* (2000) estimated it between US$3 and 4 billion per anum. Satheesan & Satheesan (2000) found that vultures alone (of which one species, *Gyps africanus,* was identified as a high risk in Chapter 3 of this study) resulted in the loss of 21 lives and 33 aircraft from 1955 to 1999. Lack of accurate records made it impossible to estimate losses for Namibia, or Africa as a whole. Aircraft downtime of 723 535 hours as a result of aircraft-wildlife conflict was reported in the

USA alone between 1990 and 2010 (Dolbeer *et al.* 2012). Of additional concern to airports and airlines is civil and criminal litigation which may result from injury or loss of life caused by AWCs (MacKinnon 2001, Matijaca 2001, Dale 2009).

The volume of collisions are increasing (Eschenfelder 1999, Short *et al.* 2000, Cleary *et al.* 2006, Messmer 2009, Keirn *et al.* 2010, Dolbeer *et al.* 2012) as a result of greater wildlife numbers resulting from conservation efforts (Conover 2002, Cleary *et al.* 2006, Messmer 2009), increasingly altered ecosystems (Messmer 2009), faster and quieter aircraft and engines (Godin 1994, Buurma & Den Haag 2004, Keirn *et al.* 2010, Thompson 2010) and increased flight volumes (Robinson 2000, Keirn *et al.* 2010). To compound the problem global climate change is resulting in altered habitats (Jeltsch *et al.* 2010), wildlife distributions and migration patterns (Zalakevicius 2000, Mawdsley 2009) and hence different bird collision risks compared to previous decades. All considered, Robinson (2000) and Thompson (2010) predict a major global catastrophe in the short or medium term.

Airport operation (including safety) is globally regulated under the Chicago Convention on International Civil Aviation of 1944(6). Volume 1 (Aerodrome design and operations) of the convention places a responsibility on aerodromes to manage wildlife hazards at airports and in the immediate vicinity. Provisions related to this are specified in part 3 (Bird Control and Reduction) of the Airports Services Manual (Doc 9137 (3) Bird control and reduction). The document prescribes that airports approach wildlife management comprehensively, identifying and systematically reducing wildlife hazards through a wildlife management plan or programme (Kaczynska-Adamczyk 2011). In Africa, the Africa Civil Aviation Commission (AFCAC) is responsible for oversight of policy and technical issues related to civil aviation on the continent. Although aviation safety is an important priority of AFCAC (Abeyratne 1998), it remains a major performance concern for the continent (IATA 2013). No specific provisions in Namibian civil aviation legislation regarding wildlife control or reduction are in existence. The development thereof is in progress, and this study provided input into the process (Directorate of Civil aviation personal communication June 2013). Notwithstanding, the risk of civil and or criminal liability for airlines, airports or individuals is a possibility in any country around the world (Matijaca 2001, Battistoni 2009, Dale 2009).

At Namibia’s two major airports, Hosea Kutako International and Eros (domestic), 128 AWC incidents were recorded between 2006 and 2010. Although none led to serious injury or death, two major incidents lead to direct costs in excess of N$ 30 million and N$ 1 million, respectively (NAC unpublished incident reports 2006 and 2010).

The International Civil Aviation Organisation (ICAO), of which Namibia is one of 190 signing countries, recognises collisions between aircraft and wildlife (birds in particular) as a priority safety risk (Buurma & den Haag 2004, IBSC 2006). Also in Namibia, greater flight volumes and increases in wildlife populations are leading to increased risks of collisions between wildlife and aircraft (Froneman 2000, Robinson 2000, Cleary *et al.* 2006).

MacKinnon (2001) notes that AWCs are not "an act of God". Causes are often anthropogenic and should therefore be managed. With safety being a priority concern for world aviation (Abeyratne 1998) managing the risk posed by AWCs is of vital importance at all airports. In order to reduce this risk the International Bird Strike Committee (IBSC) was formed which has produced a set of nine standards for the control of wildlife hazards at aerodromes (IBSC 2006). The standards refer to:

i) Management responsibility for management of AWCs and their minimisation;
ii) Management of features attracting wildlife to an airport, and maintenance of records of such management actions;
iii) Presence of trained and equipped wildlife controllers on an airport;
iv) Species specific equipment and devices to deter wildlife must be available at an airport, and staff must be trained in their use;
v) Regular monitoring of wildlife sightings and control actions taken at an airport must be conducted;
vi) Classification of collision incidents must be standardised as a) confirmed strikes, b) unconfirmed strikes, and c) serious incidents;
vii) Standard recording and reporting of AWC incidents, and the use of information from such reporting;
viii) Regular wildlife risk assessments must be undertaken; and
ix) Management of a 13km radius around an airport to minimise wildlife attractants.

In this respect, Allan & Orosz (2000) concisely summarises wildlife management at airports as modifying wildlife behaviour in order to reduce the numbers that enter the airport operating environment.

The parastatal Namibia Airports Company Ltd (NAC) is responsible for the operation of eight Namibian airports, including the Hosea Kutako International Airport (Namibia's largest airport) and Eros Aerodrome (highest volume of flights in Namibia). Both airports comply with the standards to some degree, as discussed at various points in this study.

Very little empirical research on the extent or management of AWCs in Africa has been published. Research on the frequency of AWCs and species responsible for collisions was conducted in east Africa (Nasirwa 2001, Owino *et al.* 2004, Bitebekezi 2007) and west Africa (Oduntan *et al.* 2012). Bird strike mitigation research has been conducted at airports in South Africa (Anderson & Kok 1990, Byron & Downs 2002, Froneman & van Rooyen 2003, Froneman 2006). Publications on AWC minimisation strategies and techniques on the continent are limited to South Africa and Uganda. This is problematic, as solutions to AWCs in Africa are therefore mostly based on research in foreign ecosystems; while we know that local knowledge of AWC factors, such as bird behaviour, is critical to the success of AWC management (Buurma & Den Haag 2004).

This study is the first ecological investigation into any aspect of AWCs in Namibia. It aims to understand the relationship between ecosystem components and their effect on the risk of aircraft-wildlife collisions occurring at Hosea Kutako and Eros airports. Linkages between ecosystem components such as vegetation structure and condition, bird occurrences, insect abundance and diversity, and small mammal abundance and community structure at these airports were explored, an approach seldom adopted when considering AWC risk (Soldatini *et al.* 2010). Airports are peculiar habitats (Soldatini *et al.* 2010) that provide niches and ecosystem services such as shelter, nesting sites, water and primary food supply (grass / vegetation, insects, small mammals and carrion) (Soldatini *et al.* 2010). In reading the philosophy and principles of Island Biogeography (MacArthur & Wilson 1967, Triantis 2011), much value can be gained in viewing airports as islands, with unique ecosystems influenced by "offshore" processes. Monitoring of ecosystem components such as insects and small mammals are useful to airport wildlife management as they are relatively quick and inexpensive tools for determining ecosystem health and functioning (Kaiser *et al.* 2009, Avenant 2011), and can indicate varying environmental contexts and responses (De Graaff 1974, Ferreira & Avenant 2003). Particularly small mammals are valuable prey and predator species, as well as dispersers of seed, soil nutrient and aeration benefactors as well as habitat modifiers (Avenant 2000, Avenant 2005, Witmer 2011). Baker & Brooks (1981), for example, found population fluctuations in predatory raptors in response to meadow vole (*Microtus pennsylvanicus*) in Canada.

The effect of anthropogenic factors such as surrounding land use, airport wildlife control measures and airport infrastructure were also considered. The relationship between the abovementioned factors was represented in this study in a system dynamics model. While spatial models are used to monitor and predict the risk of aircraft wildlife collisions in the USA and Europe based on local knowledge of wildlife presence, densities, migration patterns, and historical birdstrike data (e.g. Lovell & Dolbeer 1999, Dolbeer *et al.* 2000, Shamoun-Baranes *et al.* 2008), this study includes (as far as could be established) the first attempt to describe the risk of AWCs using systems modelling.

The accuracy of any systems model is dependent on an understanding of the relationship that the components of the model have on each other. This study examines the following components of the model in this regard:

- Historical AWC statistics including species involved in collisions, frequency of collisions at different flight phases, seasonal variation in collisions, and the constancy and accuracy of reporting;
- Ecosystem components:
  - Vegetation condition and structure;
  - Insect abundance and diversity based on feeding functional groups;
  - Small mammal abundance, diversity and community structure; and
  - Bird abundance and diversity.
- Anthropogenic components:
  - Volumes of flights;
  - Types of aircraft and their vulnerability to AWCs; and
  - Land use on properties surrounding the airports.

Using the model and its components as guidance, the study makes practical suggestions regarding effective mitigation of AWCs at the airports. The suggestions are presented as a toolkit for AWC management.

1.1 Study goal and objectives

In order to focus the study, a goal and five objectives were formulated.

Goal:

To use ecological research as a basis for developing management tools for the aviation industry in Namibia; in other words, address the root causes of aircraft wildlife collisions to reduce the risk of aircraft wildlife collisions.

Objectives:

i) Identify causes of AWCs taking into account historical AWC incidents at the two airports;
ii) Identify ecological and anthropogenic factors which influence the presence of wildlife at the airports;
iii) Develop a systems dynamics model illustrating the relationship between the abovementioned factors and their influence on the risk of AWCs at the airports;
iv) Use the model to test the impact of mitigation measures on the risk of AWCs; and
v) Develop a practical AWC management toolkit based on knowledge gained in the preceding four objectives and available international literature.

1.2 Philosophy and approach

This study was conducted in fulfilment of the degree *Philosophiae Doctor* in the discipline of Environmental Management. As far as possible scientific rigour was pursued, however the lack of previous research in this field, particularly in Africa, made it difficult to rely on hypotheses and methodologies within the field of AWC management. In order to produce effective wildlife management tools for airports, the study considers broad sustainability aspects (social, bio-physical and economic), as they are primary drivers of ecosystem change in postmodern society (Brown & Havstad 2004). Stakeholder engagement [a cornerstone of effective environmental management (Calabash 2006) and a vital part of any human-wildlife conflict study (Dickman 2010)] formed an integral part of the study. Chapter 8 (A multi-stakeholder approach to mitigate the risk of aircraft-wildlife collisions at Namibian airports) describes this approach in more detail. The study responded to and addressed hazards identified by the Namibian Wildlife Hazard Management Forum which consisted of the following entities:

- NAC;
- Namibian Directorate of Civil Aviation;
- Airlines Operators Association of Namibia;
- National Museum of Namibia;
- Southern African Institute for Environmental Assessment;
- Namibia Animal Rehabilitation and Research Centre;
- Air Namibia;
- West Air;
- Air Berlin;
- South African Airways;
- British Airways (Comair); and
- The Polytechnic of Namibia.

In addition, this study was partially guided by the international wildlife hazard management community, through interaction with the International Bird Strike Committee, now known as the World Bird Strike Association.

Innovation is required to manage a complex human wildlife conflict such as collisions between aircraft and wildlife (Dickman 2010, Kaplan *et al.* 2011). Therefore, much of the study applies methodology (e.g. ecological index of rangelands, SaGraSS insect assessment, small mammal community assessment) and solutions (e.g. Systems modelling and Toolkit) not used previously in the management of AWCs. Through the systems model (Chapter 6) the study attempts to test the veracity of various AWC control measures; this aspect is still largely lacking in human wildlife conflict globally (Dickman, 2010). All of this assists in testing assumptions of the correct approach to AWCs.

On the advice of Buurma & Den Haag (2004), Martin *et al.*(2011) and McShane *et al.* (2011) the study used a multi-scaled approach, with ecological research at a local scale (two Namibian airports and surrounding areas), the development of a multi-stakeholder mitigation strategy to address the AWC problem, a regional (southern African) scale in developing a toolkit for the management of the problem, and a global scale in the application of systems modelling in order to predict the effects of various factors on the risk of AWCs.

1.3 Value of the study

The study resulted in the following outputs:

- An understanding of the extent of, and species involved in AWCs at Namibia's major airports. No previous analysis of AWC records or reports had been conducted in Namibia. This chapter also provided the baseline AWC situation at the airports, on which the subsequent chapters and recommendations were based (see Chapter 2);
- An understanding of the ecosystems at the study airports, a first (as far as could be determined) for airports in arid African savannas, and the effect of AWC control measures on these ecosystems;
- A systems model capable of describing contributing factors to AWCs predicting the changes in the risk of AWCs as a result of a number of ecological and anthropogenic parameters (Chapter 6);
- A management toolkit for the effective management of the AWC problem at southern African airports (Chapter 7);
- Improved awareness of AWCs and their management in Namibia, as well as AWCs as a research discipline (Appendix 1);
- A research entity (the Wildlife and Aircraft Research Namibia, WARN project), operational since 2009 (see Appendices 1, 2 and 3); and
- On-the-job training for six students completing the National Diploma in Nature Conservation (Natural Resource Management) at the Polytechnic of Namibia, 2009-2013.

Use and implementation of the above outputs contributed to more proactive and effective management of AWCs at Hosea Kutako and Eros airports (Chapter 8, Appendix 1).

1.4 Study sites

Namibia is a country of 824 292 m^2 situated on the Atlantic Coast of southern Africa (Figure 1.1). With a population of only 2.1 million (GRN 2011) it is one of the most sparsely populated countries in the world, with relatively high biodiversity and high levels of species endemism (Griffin 1998). Since its independence in 1990, the country has had a particularly enabling developmental environment but has failed to fully achieve its development objectives (Marope 2005). One particular reason for this has been a shortage of skills and knowledge required to compete with the international market (Marope 2005). Namibia's Vision2030 (GRN 2004) highlights the improvement of transport infrastructure (including specifically airports) as a key objective to achieving its 2030 development goals. With a shortage of the necessary skills this is a particularly difficult task.

Considering the above, compliance with international standards at Namibian airports has been challenging. Although Hosea Kutako and Eros are Namibia's two largest airports, they are still relatively small by international standards. Limited available human and other resources (a common problem at smaller airports - DeVault *et al.* 2009) dictate that airport emergency services (Fire and Rescue) are delegated the responsibility to manage wildlife collision risks, supported and guided by airport operations management (Personal observation October 2007 - February 2011)(Chapter 8).

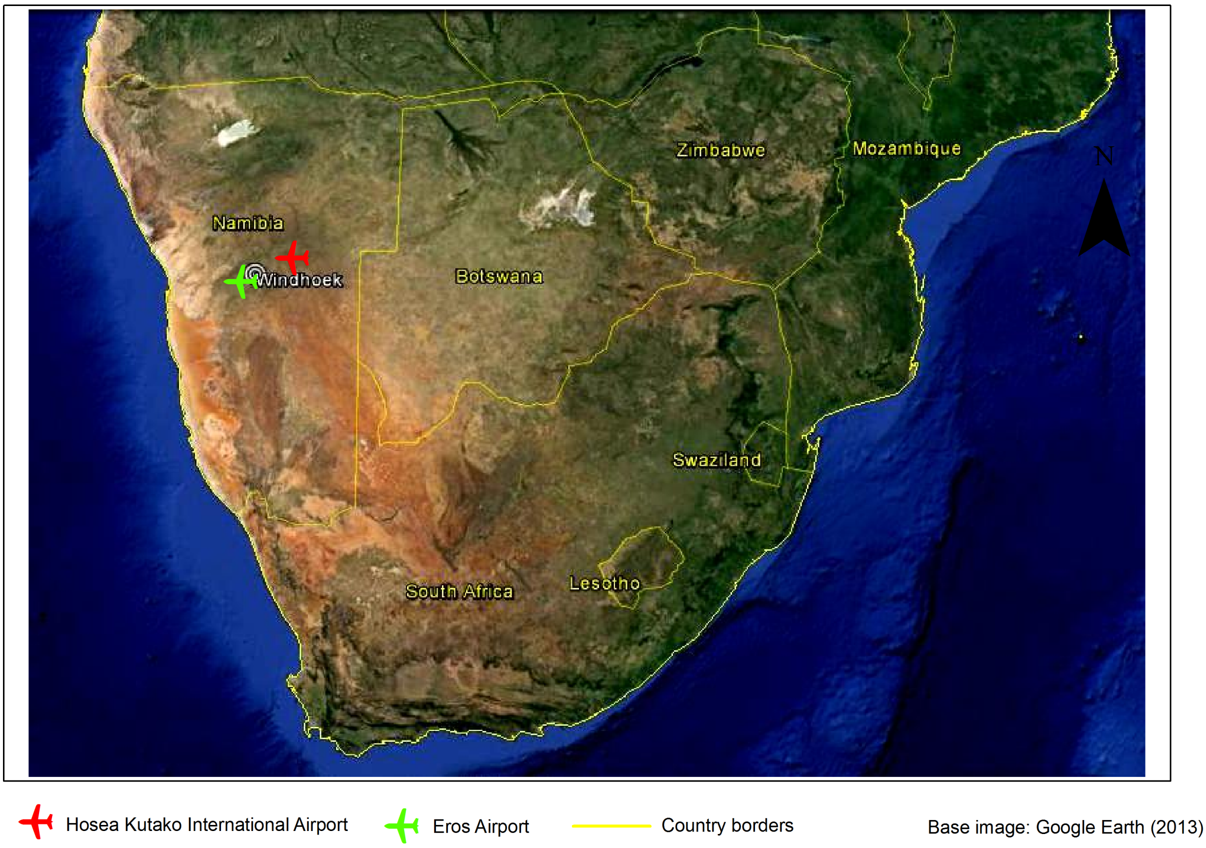


Figure 1.1: Map of southern Africa specifying the two study airports.

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. Its main runway length is 4.575 km making it capable of allowing safe take-off and landing of all sizes and capacity of aircraft. A relatively low volume of aircraft (+/- 16 000 flights per year) (NAC pers. comm.) use the airport, but most of these flights carry over 100 passengers each to and from various international destinations. The airport is situated in a rural setting, surrounded by commercial cattle and game farms (Figure 1.2a). Of significance to the problem of aircraft-wildlife collisions is that a high percentage of aircraft using the airport use jet turbine propulsion which, according to MacKinnon (2001), is more vulnerable to damage from birds then propeller driven aircraft.

Eros Aerodrome (22°36'S; 17°04'E) is mostly a local destination airport. It is situated in the capital city of Windhoek, surrounded on three sides by suburban and business properties, and by the Windhoek Golf course on the other (Figure 1.2b). This airport carries the highest flight volumes in Namibia (+/- 32 000 flights per year) (NAC pers.comm.). Most aircraft using this airport are propeller driven.

Both airports are situated in the "Highland Shrubland" Tree and Shrub Savanna vegetation type (Mendelsohn *et al.* 2002) which is characterised by low unpredictable rainfall (350-400 mm)(Mendelsohn *et al.* 2002). Dominant woody species include a number of *Acacia* species (e.g. *Acacia mellifera, Acacia hebeclada, Acacia hereroensis*) while climax grass species are dominated by *Anthephora pubescens*, *Brachiaria nigropedata*, and *Heteropogon contortus* (Joubert *et al.* 2008).

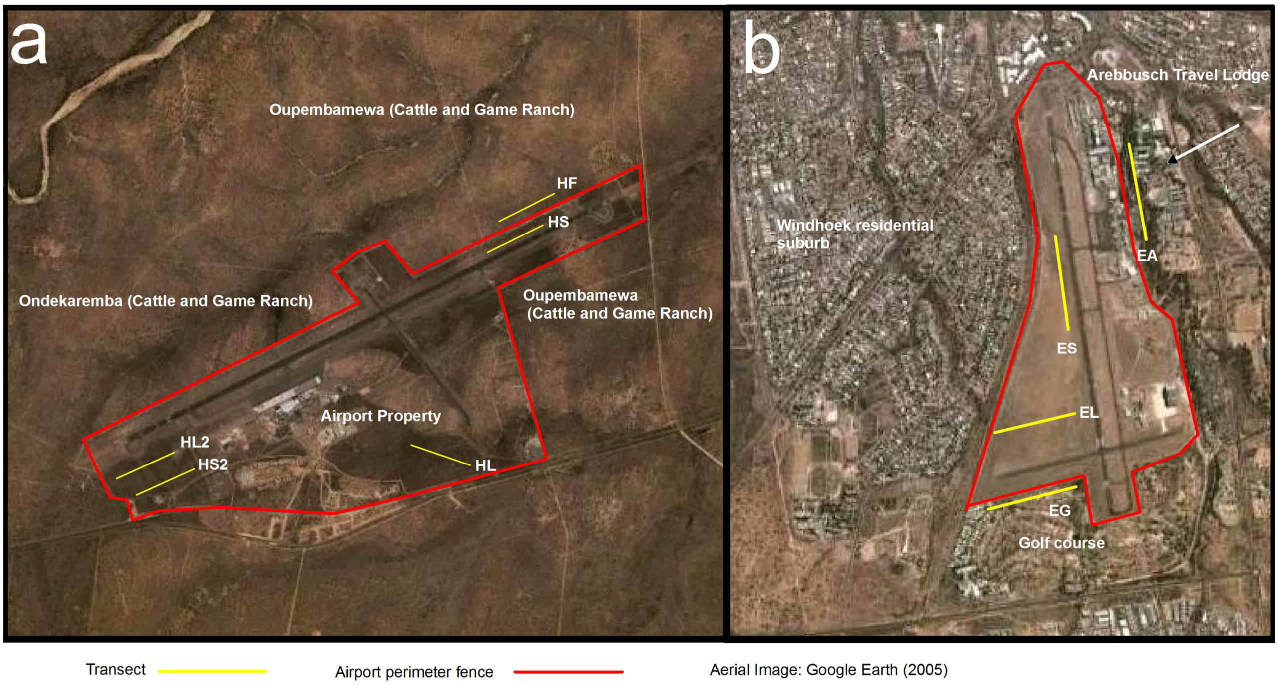


Figure 1.2: Maps of the study area and transects at a) Hosea Kutako and b) Eros.

At each airport ecosystem components (Chapters 3, 4 and 5) were assessed in the following land uses:

At Hosea Kutako:

- HF: The cattle and game farm Oupembamewa, directly to the north of the airport (see Figure 1.2a);
- HL: Grassland area on the airport property adjacent to the secondary runway (where no grass mowing takes place but woody vegetation is removed);
- HL2: Grassland area on the airport property to the southwest of the main runway where no grass mowing takes place and woody vegetation is removed;
- HS: Grassland area on the airport property adjacent to the main runway where grass is mown annually in addition to woody vegetation removal(at the most common landing and takeoff area); and
- HS2: Grassland area on the airport property adjacent to the main runway where grass is mown annually in addition to woody vegetation removal (in close proximity to HL2).

At Eros airport:

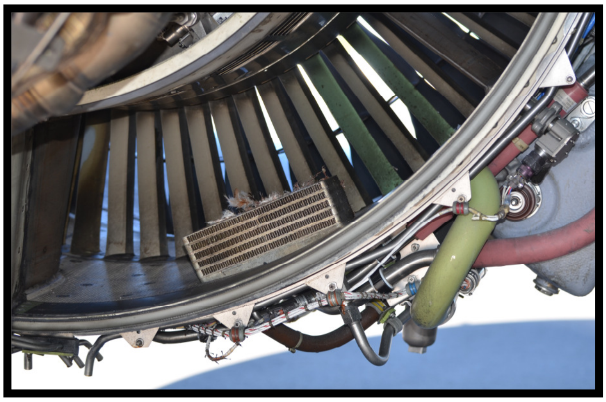
- EA: Arebbusch Travel Lodge: A tourism accommodation facility along the Arebbusch river adjacent to the airport (See Figure 1.2b) dominated by riparian woody vegetation such as *Acacia karroo, Acacia erioloba* and *Ziziphus mucronata*;

- EG: The Windhoek Golf Course directly to the south of the main and secondary runways of the airport. Ecosystem components were assessed in the golf course "rough" dominated by natural grassland which is unmown and unwatered;
- EL: On airport grassland area adjacent to the secondary runway (see Figure 1.2b) which is not mown, but woody vegetation is removed;
- ES: On airport grassland adjacent to the main runway (at the most common take-off and landing area) which is mown annually.

1.5 Assumptions and limitations

- Reporting of the extent of AWCs is poor in Namibia and as a result reporting biases may have resulted.
- This study focused largely on diurnal wildlife hazards as the two airports are operated largely during daylight hours.
- The two study sites have a low volume of aircraft movements compared to many other airports globally. This may result in some management recommendations being difficult to implement at higher volume airports.

THEME 1: THE EXTENT OF AIRCRAFT WILDLIFE COLLISIONS IN NAMIBIA



CHAPTER 2: AIRCRAFT WILDLIFE COLLISIONS AT TWO MAJOR NAMIBIAN AIRPORTS FROM 2006-2010

Abstract

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 that make use of the specific airports. 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 the 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 minimisation efforts can be measured.

2.1 Introduction

Aircraft Wildlife collisions (AWCs) are a global concern (Solman 1976, 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, Dolbeer *et al.* 2012). 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 have lead to direct costs in excess of N$ 30 million and 1 million, respectively (Namibia Airports Company (NAC) unpublished incident reports 2006 and 2010). Flight volumes at the other seven commercial airports in Namibia are very low (NAC records), and no formal AWC reporting system was in place at the time of this investigation.

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). In order to comply with these standards the airports employ control measures to reduce wildlife collisions. These include regular runway inspections, driving away of wildlife with vehicles and gas cannons, and vegetation management actions which are further evaluated in Chapter 5. 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 of incidents in 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, the period for which data were available before implementation of the management measures addressed in this study.

2.2 Methodology

2.2.1 Study area

AWC data was 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. The second study site was Eros Aerodrome (22°36'S; 17°04'E), primarily a local destination airport serving the local tourism and commerce industries. 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).

2.2.2 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 were identified from visual sightings as well as remains following collisions. Where remains were not identifiable from visual inspection, or where reporters were unable to identify the wildlife responsible for collisions, the species was noted as unidentified. Species identified in NAC reports were classified according to class and avian species were further classified by size (large > 1000g; medium > 300g <1000g, small < 300g). (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 correlate the collision frequency per year (month on month), NAC records with the three airline reports, and species with collision frequency.

2.3 Results

2.3.1 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)(Figure 2.1). 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.

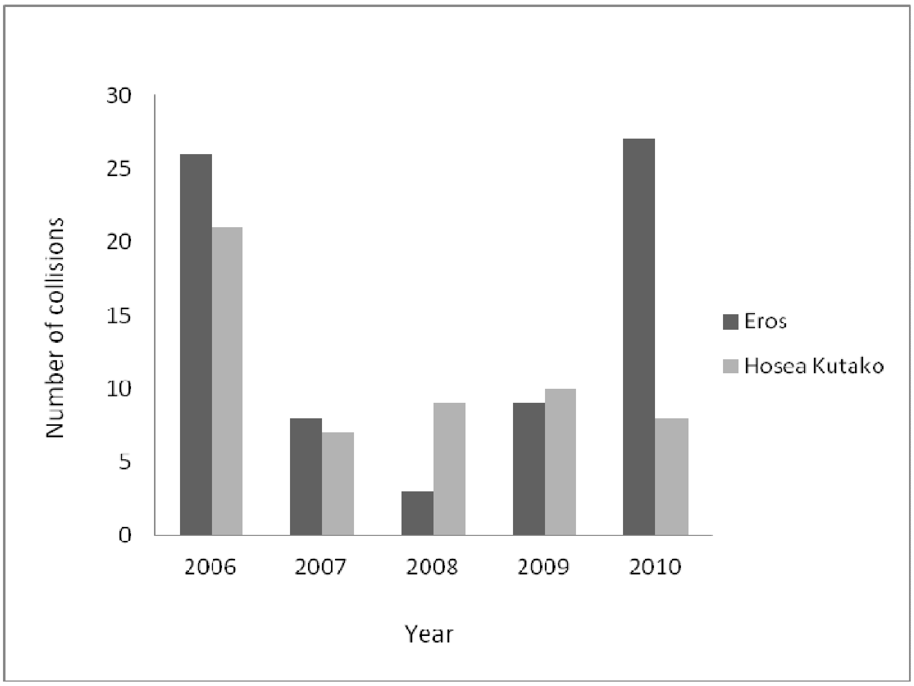


Figure 2.1: The number of Aircraft Wildlife Collision incidents reported at Hosea Kutako and Eros Airports over the five year period 2006 to 2010 (based on Namibia Airports Company records).

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 2.1. 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 5 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 *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 1 or 2 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 2 to 13. The other multiple bird collision was caused by Rock Dove (*Columba livia*) (3 individuals).

Table 2.1: The 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 abdimii*)	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
Rock Dove (*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**

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

The three airlines, together, recorded 14% less incidents (n= 70) than NAC (n=81) (Table 2.2). NAC consistently reported more incidents during the first three years, but no pattern was evident between NAC and any of the three airlines. Sixteen percent 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.

Table 2.2: The 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.	NAC	Air Namibia	Wilderness Air	West Air	Mean.
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	

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.

2.4 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 collisions were measured as flying hours per collisions, and in the USA 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 indicated 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..

Although more collisions occurred at Eros, this is expected as it carried more flights (NAC internal records). This does, however, not mean that it 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 AWC's 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 the 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 USA, 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. The US reporting rate was found have increased to 39% (Dolbeer *et al.* 2009) due to awareness efforts as well as improvements in reporting forms and methods. Possible reasons for this underreporting 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 Figure 2.2) may be a result of reporters needing to concentrate on aircraft control and not being able to indentify 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.

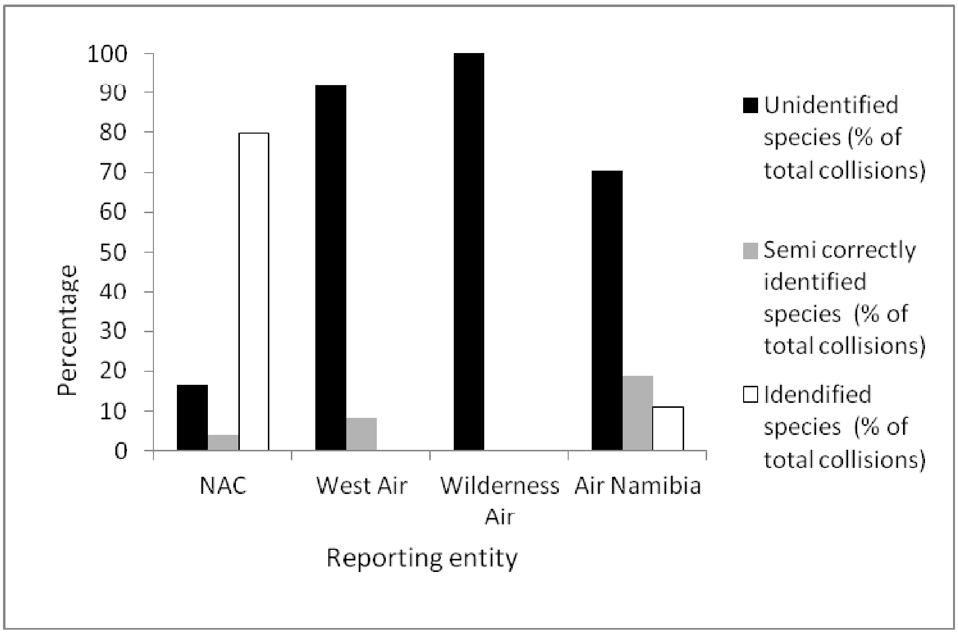


Figure 2.2: Identification of species involved in Aircraft Wildlife Collision incidents reported by the Namibia Airports Company and three airlines.

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, DeVault *et al.* 2011). In this instance, at both airports collisions with multiple Crowned Lapwing were the cause 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 60mm (Turpie & Ryan 2005). As an insectivore its preferred diet are 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%) of incidents at Hosea Kutako. This is high compared to the 0% at Eros, and an average of 2.8% in the USA (Dolbeer *et al.* 2012). 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, while Dolbeer & Wright (2009) find two deer species to be among the most damage causing wildlife. 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, Hauptfleisch 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.

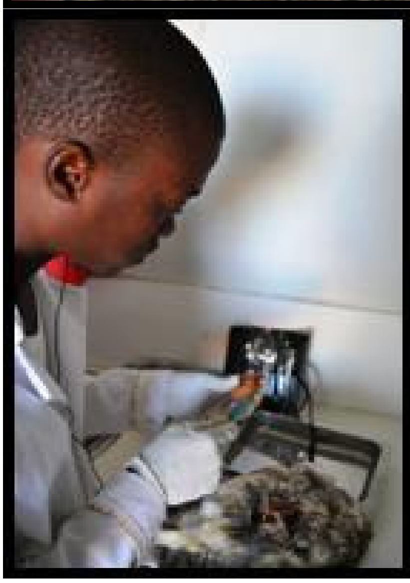
At Eros Airport the increase in AWC incidents from 2008 to 2010 corresponded with an observed increase in Crowned Lapwing numbers (G. Coetzee pers. comm.). The introduction of grass mowing as a management action is expected to have contributed to their presence as this species are ground-living and prefer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

2.5 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 standardised, industry-wide reporting procedure should be developed, based on IBSC Standard 7 (IBSC 2006). Near-miss incidents should become a requirement of the standardised 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.

THEME 2: THE STUDY OF ECOSYSTEM PARAMETERS AT NAMIBIAN AIRPORTS



CHAPTER 3: COMBINING COLLISION HISTORY, PILOT PERCEPTION, AVIFAUNAL SURVEY AND RISK ASSESSMENT TO DETERMINE PRIORITY AVIAN RISK AT AIRPORTS

Abstract

A risk assessment which included a proposed risk weighting methodology was conducted at Hosea Kutako and Eros airports which estimated the probability of an accident / collision as well as the consequence of such a collision. This required surveys of bird occurrence frequencies at both airports. The results of the risk assessment for each airport was compared to actual aircraft wildlife collision (AWC) incidences for each species, frequency of occurrence of birds at the airports and pilot perceptions of species risk, in order to find whether risk assessment and pilot perception are reliable measures of potential AWC incidence. *Gyps africanus* (White-backed Vulture) and *Numida meleagris* (Helmeted Guinea Fowl) were the highest risk species at both airports. They were also, after *Vanellus coronatus* (Crowned Lapwing), the species most often encountered by pilots. AWC records showed that *V. coronatus* and *N. meleagris* were the most frequently struck birds at both airports. The study illustrates how combining risk assessment, pilot perception and AWC history can benefit management plans at airports through the identification of priority bird species.

3.1 Introduction

The International Civil Aviation Organisation (ICAO), with Namibia as one of the 190 signing countries, recognises collisions between aircraft and wildlife (mostly birds - hence the aviation term “bird strike”) as a priority safety risk (Buurma & den Haag 2004, IBSC 2006). Globally birds account for a very high percentage of aircraft-wildlife collisions (AWCs) (Barras & Seamans 2002) (an average of 97 to 98% in the USA - Cleary *et al.* 2006, DeVault *et al.* 2008, Dolbeer & Wright 2008). At the two Namibian study sites birds are responsible for 54.4% and 90% of the identified collision incidents at Hosea Kutako and Eros, respectively (Chapter 2). Greater flight volumes and increases in bird populations, as a result of successful conservation efforts, has led to an increased risk of collisions between wildlife and aircraft in recent times (Froneman 2000, Robinson 2000, Cleary *et al.* 2006). Not all avifauna however pose a hazard to aircraft, and Carter (2001) and Soldatini *et al.*

(2010) have suggested that a risk assessment can help prioritise management actions needed to treat wildlife risks at airports.

Avifaunal surveys are considered a useful tool in determining the risk posed by bird species to aircraft in the vicinity of an airport (Anagnostopoulos 2003, Allan 2006, Sowden *et al.* 2007, Soldatini *et al.* 2010). These birds are attracted to habitats in the airport surrounds (Kennamer *et al.* 1999, Blackwell *et al.* 2013) meaning that the birds can be viewed as merely the symptom of the true AWC problem.

As discussed in Chapter 1, this chapter, as well as Chapters 4 and 5 specifically investigated some of the ecosystem components and their effect on AWCs. Avifauna, being the primary cause of collisions (Dolbeer & Wright 2008, Dolbeer 2011) are therefore an obvious ecosystem component to consider. The objectives of this study were to determine which avian species occur at the two study airports, and how frequently they are encountered. It further compares this aspect to the species involved in collisions (as established in Chapter 2). It proposes a risk rating method (by combining risk assessment aspects used in other similar studies, and tests the results of this method by comparing them to pilot perception of risk avian species at the airports, and AWC history).

3.1.1 Study area

Namibia is known for its diversity of avifauna with 644 bird species recorded (Robertson *et al.* 1998). Species richness for birds has been recorded as 135 and 130 for the Hosea Kutako and Eros Quarter degree squares, respectively (Coninfo 2009). Hosea Kutako is situated in a rural setting, surrounded by commercial cattle and game farms. Eros is an urban airport, surrounded on three sides by suburban and business properties, and by the Windhoek Golf course on the other. Both airports are situated in the "Highland Shrubland" Tree and Shrub Savanna vegetation type (Mendelsohn *et al.* 2002) which is characterised by low unpredictable rainfall (350-400 mm) (Mendelsohn *et al.* 2002). Dominant woody species include a number of *Acacia* species (e.g. *Acacia mellifera, Acacia hebeclada, Acacia hereroensis*) while climax grass species are dominated by *Anthephora pubescens*, *Brachiaria nigropedata*, and *Heteropogon contortus* (Joubert *et al.* 2008).

3.2 Methodology

3.2.1 Recording of AWCs, 2006-2010

AWC data are collected by the Chief Fire officer at each airport in accordance with the IBSC Standards for Aerodrome Bird/Wildlife Control (2006). The following incidents involving wildlife are recorded:

a) Reported bird strikes – where a collision between a bird and an aircraft has been reported;
b) Urgent action taken to prevent a collision with wildlife identified as an immediate, direct, threat (e.g. Air Traffic Control calling on NAC personnel to chase / shoot wildlife on runways/ aprons);
c) Reported evasive action by airline operators or aviators to prevent an AWC.

For the purpose of this analysis we used the 128 NAC AWC records reported from January 2006 to December 2010. Birds were responsible for 54.5% and 90.4% of AWCs at Hosea Kutako and Eros, respectively; mammals for 20% and 0% respectively; and unidentified taxa for 25.5% and 9.5% respectively (Chapter 2).

3.2.2 Pilot interviews

Face-to face interviews (n=40) were conducted between January and March 2011 with pilots who frequent both airports. They were asked to list the five species which they perceive to pose the greatest risk of AWCs in the vicinity of Hosea Kutako and Eros. This risk included both the probability of collision and the consequence of a collision with an identified species. Total number of times a species was mentioned was taken as a percentage of pilots interviewed, providing a representation of each species as a percentage of pilots.

3.2.3 Avifaunal surveys

Avian sightings (species, number in group and behaviour) were recorded on fixed routes of 13.96 km at Hosea Kutako and 6.55 km at Eros, using Nikon Monarch 8x45 binoculars. The strip count method for wildlife census was used (Bothma 2002). This method was found to be simple and practical for obtaining accurate estimates of birds (Viljoen 2002) and is particularly successful in open habitats (Bothma 2002). FAO (2007) cites it as one of the most common methods to determine bird species composition and density. It is the easiest and most efficient survey technique for airport personnel to be able to replicate. The surveys (n=40 at Hosea Kutako and n=43 at Eros) took approximately 2 hours and were (similar to the methodology used in Constantin & Floyd 1991) conducted on the boundary service road with a consistent view of all runways and taxiways. Other methods, such as point counts (Anagnostopoulos 2003) (often used when terrain makes strip counting impossible, FAO (2007), Air Traffic Control tower surveys (Lensink *et al.* 2000), and panorama scans (Poot *et al.* 2000) were found to produce inaccurate scores in an area where birds were less concentrated. Following Servoss *et al.* (2000), small non-flocking species were not recorded as their impact on AWC risk was considered negligible, and time taken in identifying these species could result in more important species being missed in the survey. Small flocking species were recorded, even though DeVault *et al.* 2011 found that collisions with multiple birds seemed to only increase the likelihood of damage to aircraft if bird body mass exceeded 1 125 g.

3.2.4 Avian risk assessment

In general, risk assessment attempts to rate the risk of a hazard based on its likelihood to occur, and the consequence of its occurrence (Vincoli 2006, Hauptfleisch 2009). This has been modified to suit AWC hazards by subjecting avian species occurrence at airports to factors based on specific characteristics of birds. In this study, species occurrence frequency were subjected to a risk assessment adapted from Short *et al.* (2000), Davis *et al.* (2002), Anagnostopoulos (2003), Lykos *et al.* (2005), Zakrajsek & Bissonette (2005) Allan (2006), Sowden *et al.* (2007) and Dao-De *et al.* (2010). Characteristics of avian species identified at each airport were weighted according to the following (weighting score provided in brackets) to determine a risk rating (RR):

- Frequency of occurrence (FO): <20% (1); 20-40% (2); 41-60% (3); 61-80% (4); >80% 5;
- Maximum mass (MM): <50g (1); 51-300g (2); 301-1000g (3); 1001- 1800g (4); >1800g (5);
- Flocking behaviour (FB): solitary (1); loose flocks (2); tight flocks (3);
- Foraging strategy (FS): on the ground (1); from a perch (2); from flight (3);
- Flight dynamics (FD): rapid and direct (1); slow / meandering / hovering (2).

Maximum mass was noted as the mass of an adult male individual as found by Hockey *et al.* 2005. Flocking behaviour, foraging strategy and flight dynamics was determined from observations during the 83 bird surveys, as well as species information in Hockey *et al.* 2005[1].

Total risk rating was calculated by adding the weighting of each of the above factors (RR = FO+MM+FB+FS+FD), following Short *et al.* (2000), Davis *et al.* (2002), Anagnostopoulos (2003), Allan *et al.* (2003),Allan (2006) and Sowden *et al.* (2007).

3.2.5 Reaction of birds to manoeuvring aircraft

The reaction of birds to taking off or landing aircraft was observed for five days at each airport during 2010. Birds within 100m of taking off or landing (not taxiing) were identified, and their reaction (changed behaviour) to these aircraft were noted. Reaction was classified as no change in behaviour, avoidance by flight, or avoidance by non-flight movement (running, hiding, ducking). Air Traffic Control (ATC) tower surveys (Lensink *et al.* 2000), and panorama scans (Poot *et al.* 2000) were used at Eros and Hosea Kutako respectively. As each airport only has one main runway (see Figure 3.1) and relatively consistent prevailing winds, observations were limited to the main landing and takeoff points on each runway (Figure 3.1). Behaviour of birds within this area was noted for 30 seconds before landing or takeoff of an aircraft. Reaction was defined as change in behaviour with the aircraft approaching, and passing the bird.

[1] Hockey *et al.* 2005 is the seventh edition of the Robert's Birds of southern Africa. The publication is recognised to be the definitive review of all literature related to each of southern Africa's bird species.

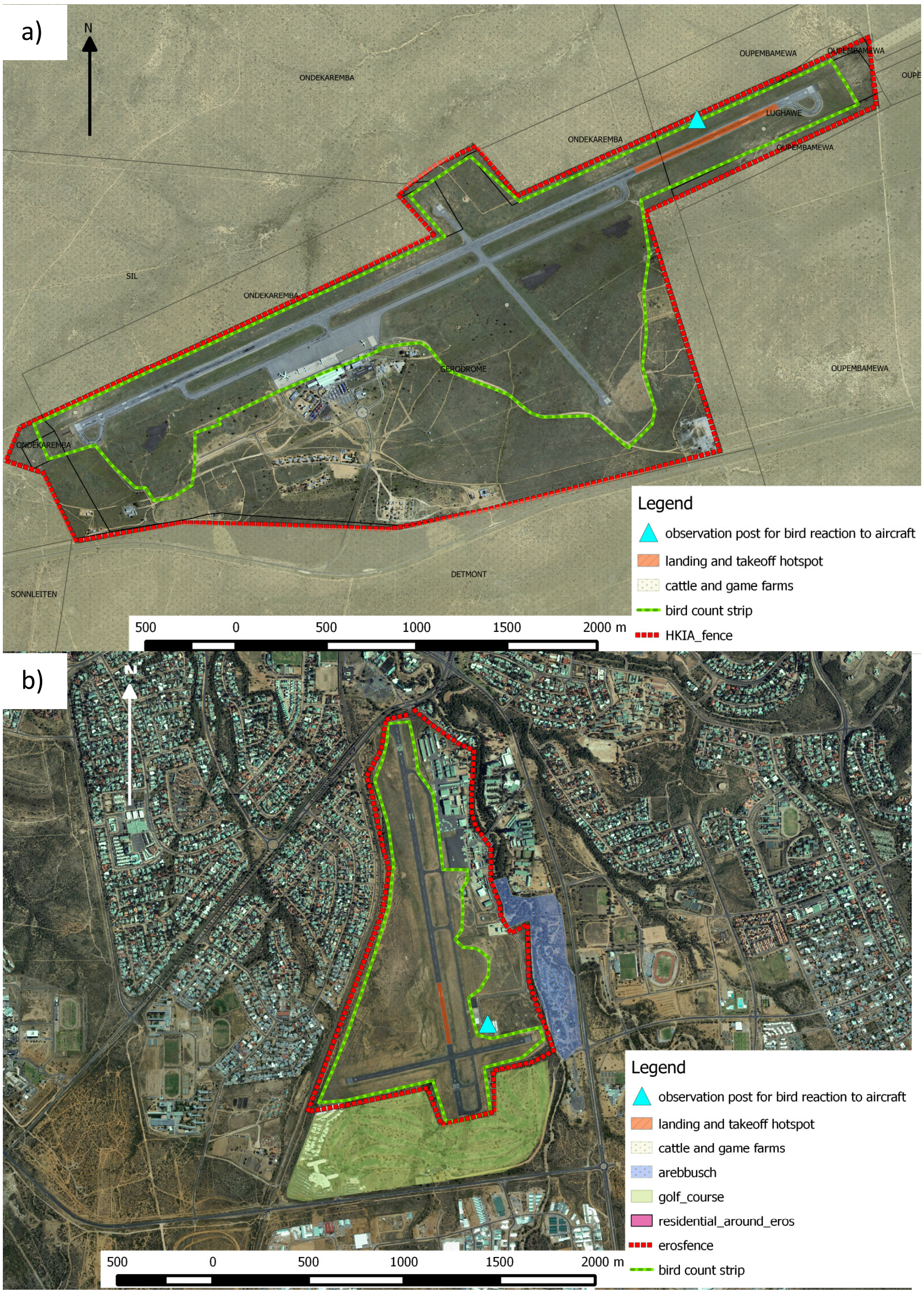


Figure 3.1: Study area of a) Hosea Kutako and b) Eros showing strip count routes (green), behavioural observation spots (blue triangles) and main take-off and landing spots (orange areas).

3.2.6 Statistical analyses

Normality of data was determined with Shapiro-Wilk's W test. Comparison of normally distributed data was conducted using the Chi square test. For non-normally distributed data standard nonparametric tests (Mann-Whitney-U test for two way and Kruskal-Wallis for multiple analysis of variance when comparing avian species occurrences), were used. The Pearson Product Moment correlation was used to correlate selected ecosystem parameters, transects (land use) and airports (Hosea Kutako, Eros). All statistical analyses were completed using the computer program Statistica ® for Windows version 10 (StatSoft Inc. 2011), and the 95% confidence level ($p<0.05$) was regarded as statistically significant for all tests.

3.3 Results

3.3.1 Avifauna responsible for AWC incidents between 2006 and 2010

A review of AWC collisions at or in the vicinity of the two airports for 2006-2010 identified the bird species responsible at both airports (Table 3.1). A total of 14 avian species or groups were responsible for AWCs at the two airports. The species most often involved at Hosea Kutako were *Vanellus coronatus* (Crowned Lapwing; 30% of incidents) and *Numida meleagris* (Helmeted Guinea Fowl; 16.7%). *Milvus aegyptius* (Yellow-billed Kite), *Sagittarius serpentarius* (Secretary Bird), *Leptoptilos crumeniferus* (Marabou Stork), *Ciconia abdimii* (Abdim's Stork) and *Falco rupicolus* (Rock Kestrel) were all involved with >5% of those incidents that involved birds.

Table 3.1. The relative contribution of identified bird species to AWCs at Hosea Kutako International and Eros airports (summarised from Namibia Airports Company reports, 2006-2010).

Species	Hosea Kutako Airport		Eros Airport	
	Number	%	Number	%
Large (>1000 g)				
Helmeted Guinea Fowl (*Numida meleagris)*	5	16.7	6	9.1
Yellow-billed Kite (*Milvus aegyptius*)	3	10.0	2	3.0
Secretary Bird (*Sagittarius serpentarius*)	3	10.0	0	0
Marabou Stork (*Leptoptilos crumeniferus*)	2	6.7	0	0
Abdim's Stork (*Ciconia addimii*)	2	6.7	0	0
White-backed Vulture (*Gyps africanus*)	1	3.3	0	0
Medium (300-1000 g)				
Southern Pale Chanting Goshawk (*Melierax canorus)*	1	3.3	1	1.5
Black Crow (*Corvus capensis*)	1	3.3	0	0
Rock Dove (*Columbia livia)*	0	0	2	3.0
Small (<300 g)				
Rock Kestrel (*Falco rupicolus)*	2	6.7	0	0
Crowned Lapwing (*Vanellus coronatus*)	9	30.0	51	77.4
Sparrow (Family Passeridae)	0	0	2	3.0
Swallow/swift (Family Hirundinidae, Apodidae)	0	0	1	1.5
Burchell's Courser (*Cursorius rufus*)	1	3.3	1	1.5
Total	30	100	66	100

At Eros Airport *V. coronatus* was responsible for 77.3% of incidents involving birds. Six incidents (9.1% of all) occurred with *N. meleagris,* followed by 1 or 2 incidents with a number of other bird species.

At Hosea Kutako large birds (mass >1 kg) were responsible for 53.4% of all bird incidents, medium sized birds (mass between 300 g and 1 kg) for 6.6%, and small birds (mass <300 g) for 40%. At Eros large birds were responsible for 12.1% of bird incidents, medium sized birds for 4.5% and small birds for 83.4%.

Collisions with multiple birds were recorded on 6 occasions at Eros and three occasions at Hosea Kutako. *V. coronatus* were responsible for 8 of the 9 collisions with multiple birds ranging from 2 to 13 individuals per collision. The other multiple bird collision was caused by Rock Dove *Columba livia* (3 individuals).

Results of the birds identified by individual pilots as the top five risk species (in some cases classified roughly according to families or sub-families (e.g. Stork - Ciconiidae ; Eagle – Accipitridae: Aquilinae; Falcon/ Goshawk – Falconidae , Accipitridae: Melieraxinae; Dove / Pigeon - Columbidae; Swallow / Swift- Hirundinidae, Apodidae) are summarised in Table 3.2. In total 18 avian species or groups were identified as highest risks by them. Here, *V. coronatus* was listed the most (by 62.5% of pilots), followed by *N. meleagris* (50%). Other important species groups listed were vultures (32.5%) and swallows/swifts (27.5%). Eight (20%) of the pilots interviewed were not able to comment as they could not identify bird species.

Table 3.2: Bird species perceived by pilots to pose the highest risks to aircraft at Hosea Kutako and Eros airports (n=32).

Identification	Classification	Number (and percentage) of pilots listing the specific species
Large (>1000 g)		
Helmeted Guinea Fowl	Species: *Numida meleagris*	20 (50%)
Yellow-billed Kite	Species: *Milvus aegyptius*	4 (10%)
Pelican	Species: *Pelecanus onocrotalus*	3 (7.5%)
Stork	Family: Ciconiidae	5 (12.5)
Egyptian Goose	Species: *Alopochen aegyptiaca*	3 (7.5)
Eagle	Family: Accipitridae	1 (2.5%)
Vulture	Family: Accipitridae	13 (32.5%)
Medium (300-1000 g)		
Falcon	Family: Falconidae	3 (7.5%)
Cape Crow	Species: *Corvus capensis*	
Dove or Pigeon	Family: Columbidae	4 (10%)
Small (<300 g)		
Rock Kestrel	Species: *Falco rupicolus*	4 (10%)
Crowned Lapwing	Species: *Vanellus coronatus*	25 (62.5%)
Pale-winged Starling	Species: O*nychognathus nabouroup*	2 (5%)
Fork-tailed Drongo	Species: *Dicrurus adsimilis*	2 (5%)
Swallow/Swift	Family: Hirundinidae / Apodidae	11 (27.5%)
Spotted Thick-knee	Species: *Burhinus capensis*	1 (2.5%)
Bronze-winged Courser	Species: *Rhinoptilus chalcopterus*	1 (2.5%)
Black-shouldered Kite	Species: *Elanus caeruleus*	1 (2.5%)

3.3.2 Avifaunal surveys

Overall, 34 species were recorded during the 83 surveys (Table 3.3); 21 at Hosea Kutako and 24 at Eros. Eleven species (32% of all) were recorded at both airports. A significantly lower number of sightings of all species recorded was found at Eros compared to Hosea Kutako ($H_{1,83}$ = 61.43, $p<0.001$).

Table 3.3: Frequency of occurrence of avifauna at Hosea Kutako and Eros airports, 2011-2012.

Species	Hosea Kutako Airport (n=40 surveys)	Eros Airport (n=43 surveys)
Large (>1000 g)		
Helmeted Guinea Fowl *(Numida meleagris)*	17 (42.5%)	9 (20.9%)
Martial Eagle (*Polemaetus bellicosus*)	-	3 (7.0%)
Yellow-billed Kite (*Milvus aegyptius*)	-	3 (7.0%)
Egyptian Goose (*Alopochen aegyptiaca)*	-	3 (7.0%)
Secretary Bird (*Sagittarius serpentarius*)	3 (7.5%)	-
Tawny Eagle (*Aquila rapax*)	3 (7.5%)	-
Black-headed Heron (*Ardea melanocephala*)	7 (17.5%)	-
Northern Black Korhaan (*Afrotis afraoides*)	7 (17.5%)	-
Red-crested Korhaan (*Lophotis ruficrista*)	1 (2.5%)	-
White-backed Vulture (*Gyps africanus*)	1 (2.5%)	1 (2.3%)
Medium (300-1000 g)		
Southern Pale Chanting Goshawk (*Melierax canorus*)	18 (45%)	1 (2.3%)
Cape Crow (*Corvus capensis*)	37 (92.5%)	-
Pied Crow (*Corvus albus*)	1 (2.5%)	-
Black-shouldered Kite (*Elanus caeruleus*)	31 (77.5%)	2 (4.7%)
Greater kestrel (*Falco rupicoloides*)	4 (10%)	-
Grey Turaco (*Corythaixoides concolor*)	8 (40%)	-
Rock Dove (*Columba livia*)	-	9 (20.9%)
Red-billed Spurfowl (*Pternistis adspersus*)	1 (2.5%)	1 (2.3%)
Small (<300 g)		
Rock Kestrel (*Falco rupicolus*)	9 (22.5%)	7 (16.3%)
Crowned Lapwing (*Vanellus coronatus*)	12 (30%)	31 (72.1%)
Cape Glossy Starling (*Lamprotornis nitens*)	-	9 (20.9%)
Burchell’s Starling (*Lamprotornis australis*)	14 (35%)	-
Lilac-breasted Roller (*Coracias caudatus*)	20 (50%)	9 (20.9%)
Laughing Dove (*Streptopelia senegalensis*)	-	7 (16.3%)
White-browed Sparrow-weaver (*Plocepasser mahali*)	-	7 (16.3%)
Fork-tailed Drongo (*Dicrurus adsimilis*)	-	5 (11.6%)
Blacksmith Lapwing (*Vanellus armatus*)	-	4 (9.3%)
Cape Turtle Dove (*Streptopelia capicola*)	29 (72.5%)	4 (9.3%)
African Grey Hornbill (*Tockus nasutus*)	3 (7.5%)	3 (7.0%)
Southern Yellow-billed Hornbill (*Tockus leucomelas*)	8 (20%)	2 (4.7%)

Species	Hosea Kutako Airport (n=40 surveys)	Eros Airport (n=43 surveys)
Pale-winged Starling (*Onychognathus nabouroup*)	-	2 (4.7%)
Namaqua Sandgrouse (*Pterocles namaqua*)	-	1 (2.3%)
Bronze-winged Courser (*Rhinoptilus chalcopterus*)	-	1 (2.3%)
Acacia Pied Barbet (*Tricholaema leucomelas*)	-	1 (2.3%)

Corvus capensis (Cape Crow) dominated the sightings at Hosea Kutako (observed during 92.5% of surveys) while regular sightings of *Elanus caeruleus* (Black-shouldered Kite; 77.5% of surveys) and *Streptopelia capicola* (Cape Turtle Dove; 72.5% of surveys) were also recorded. *Numida meleagris* (Helmeted Guinea Fowl) , *Melierax canorus* (Southern Pale Chanting Goshawk), *Corythaixoides concolor* (Grey Turaco), *Lamprotornis australis* (Burchell's Starling) and *Coracias caudatus* (Lilac-breasted Roller) were recorded during more than 33% of the surveys, and *Vanellus coronatus* (Crowned Lapwing) during 30% of surveys. At Eros, *V. coronatus* (Crowned Lapwing) dominated sightings (observed during 72.1% of surveys), with *N. meleagris* (Helmeted Guinea Fowl), *C. caudatus* (Lilac-breasted Roller), *Lamprotornis nitens* (Cape Glossy Starling) and *Columba livia* (Rock Dove) recorded on 20.9% of surveys, each.

On occasions when *V. coronatus* were present at both airports, there were significantly more individuals at Eros than at Hosea Kutako ($H_{1,44}$ = 9.30, p<0.05). This was also the case with *M. canorus* (Southern Pale Chanting Goshawk) ($H_{1,19}$ = 4.56, p <0.05) and *C. caudatus* (Lilac-breasted Roller) ($H_{1,28}$ = 15.22, p <0.001).

3.3.3 Risk Analysis

The only species rated as high risk at both airports were *G. africanus* (risk rating = 14 at Hosea Kutako and 14 at Eros) and *N. meleagris* (risk rating = 13 at Hosea Kutako and 12 at Eros).

The risk analysis for Hosea Kutako International Airport is described in Table 3.4. Six avian species were rated as high risk (RR ≥11, or >60% of the highest possible score of 18). These are *G. africanus* (rating = 14), *C. capensis* (rating = 13), *N. meleagris* (rating = 13), *E. caeruleus* (rating = 12), *S. serpentarius* (rating = 11) and *M. canorus* (rating = 11).

The risk rating at Eros also produced six high risk species (Table 3.4). These species are *G. africanus* (rating = 14), *N. meleagris* (rating = 12), *P. bellicosus* (rating = 11), *M. aegyptius* (rating = 11), *A. aegyptiaca* (rating = 11) and *V. coronatus* (rating = 11).

Table 3.4: Avian species risk analysis for Hosea Kutako International and Eros airports. Weightings are indicated in brackets; Risk Rating = the weightings of Frequency + Mass + Flocking behaviour + Foraging behaviour + Flight behaviour (adapted from Short *et al.* 2000, Davis *et al.* 2002, Anagnostopoulos 2003, Allan 2006 and Sowden *et al.* 2007).

Species	**Occurrence frequency (%) Hosea Kutako**	**Occurrence frequency (%) Eros**	**Mass (kg)**	**Flocking behaviour**	**Foraging behaviour**	**Flight behaviour**	**Risk Rating Hosea Kutako**	**Risk Rating Eros**
Large (>1000 g)								
White-backed Vulture (*Gyps africanus*)	2.5 (1)	2.3 (1)	5.5 (5)	Tight flocks (3)	In flight (3)	Soaring (2)	14	14
Helmeted Guinea Fowl *(Numida meleagris)*	42.5 (3)	20.9 (2)	1.4 (4)	Tight flocks (3)	On ground (1)	Slow (2)	13	12
Secretary Bird (*Sagittarius serpentarius*)	7.5 (1)	0 (0)	4 (5)	Loose flocks (2)	On ground (1)	Slow (2)	11	Not present
Tawny Eagle (*Aquila rapax*)	7.5 (1)	0 (0)	1.6 (5)	Solitary (1)	From perch (2)	Rapid (1)	10	Not present
Black-headed Heron (*Ardea melanocephala*)	17.5 (1)	0 (0)	0.51 (3)	Solitary (1)	On ground (1)	Slow (2)	8	Not present
Northern Black Korhaan (*Afrotis afraoides*)	17.5 (1)	0 (0)	0.77 (3)	Solitary (1)	On ground (1)	Slow (2)	8	Not present
Red-crested Korhaan (*Lophotis ruficrista*)	2.5 (1)	0 (0)	0.68 (3)	Solitary (1)	On ground (1)	Slow (2)	8	Not present
Martial Eagle (*Polemaetus bellicosus*)	0 (0)	7.0 (1)	4.0 (5)	Solitary (1)	From perch (2)	Soaring (2)	Not present	11
Yellow-billed Kite (*Milvus aegyptius*)	0 (0)	7.0 (1)	0.68 (3)	Loose flocks (2)	In flight (3)	Meandering (2)	Not present	11

Species	Occurrence frequency (%) Hosea Kutako	Occurrence frequency (%) Eros	Mass (kg)	Flocking behaviour	Foraging behaviour	Flight behaviour	Risk Rating Hosea Kutako	Risk Rating Eros
Egyptian Goose (*Alopochen aegyptiaca*)	0 (0)	7.0 (1)	2.1 (5)	Loose flocks (2)	On ground (1)	Slow (2)	Not present	11
Medium (300g – 1000 g)								
Cape Crow (*Corvus capensis*)	92.5 (5)	0 (0)	0.5 (3)	Loose flocks (2)	On ground (1)	Slow (2)	13	Not present
Black-shouldered Kite (*Elanus caeruleus*)	77.5 (4)	4.7 (1)	0.26 (2)	Solitary (1)	In flight (3)	Hovering (2)	12	9
Southern Pale Chanting Goshawk (*Melierax canorus*)	45 (3)	2.3 (1)	0.9 (3)	Loose flocks (2)	From perch (2)	Rapid (1)	11	9
Grey Turaco (*Corythaixoides concolor*)	20.0 (1)	0 (0)	0.27 (2)	Tight flocks (3)	From perch (2)	Slow (2)	10	Not present
Pied Crow (*Corvus albus*)	2.5 (1)	0 (0)	0.55 (3)	Loose flocks (2)	On ground (1)	Slow (2)	9	Not present
Red-billed Spurfowl (*Pternistis adspersus*)	2.5 (1)	2.3 (1)	0.47 (3)	Loose flocks (2)	On ground (1)	Slow (2)	9	9
Greater Kestrel (*Falco rupicoloides*)	10.0 (1)	0 (0)	0.28 (2)	Solitary (1)	In flight (3)	Rapid (1)	8	Not present
Small (<300 g)								
Rock Kestrel (*Falco rupicolus*)	22.5 (2)	16.3 (1)	0.23 (2)	Loose flocks (2)	In flight (3)	Rapid (1)	10	9
Lilac-breasted Roller (*Coracias caudatus*)	50.0 (3)	20.9 (2)	0.11 (2)	Solitary (1)	From perch (2)	Slow (2)	10	9
Cape Turtle Dove (*Streptopelia capicola*)	72.5 (4)	9.3 (1)	0.15 (2)	Solitary (1)	On ground (1)	Slow (2)	10	7
Crowned Lapwing (*Vanellus coronatus*)	30.0 (2)	72.1 (4)	0.19 (2)	Loose flocks (2)	On ground (1)	Slow (2)	9	11
Burchell's Sandgrouse (*Pterocles burchelli*)	32.5 (2)	0 (0)	0.2 (2)	Loose flocks (2)	On ground (1)	Slow (2)	9	Not present
Burchell's Starling (*Lamprotornis australis*)	35.0 (2)	0 (0)	0.11 (2)	Loose flocks (2)	On ground (1)	Slow (2)	9	Not

Species	Occurrence frequency (%) Hosea Kutako	Occurrence frequency (%) Eros	Mass (kg)	Flocking behaviour	Foraging behaviour	Flight behaviour	Risk Rating Hosea Kutako	Risk Rating Eros
								present
African Grey Hornbill (*Tockus nasutus*)	7.5 (1)	7.0 (1)	0.17 (2)	Solitary (1)	From perch (2)	Slow (2)	8	8
Southern Yellow-billed Hornbill (*Tockus leucomelas*)	20.0 (1)	4.7 (1)	0.21 (2)	Loose flocks (2)	On ground (1)	Slow (2)	8	8
Laughing Dove (*Streptopelia capicola*)		16.3 (1)	0.1 (2)	Loose flocks (2)	On ground (1)	Rapid (1)	Not present	7
White-browed Sparrow-weaver (*Plocepasser mahali*)	0 (0)	16.3 (1)	0.05 (1)	Loose flocks (2)	On ground (1)	Slow (2)	Not present	7
Pale-winged Starling (*Onychagnathus nabouroup*)	0 (0)	4.7 (1)	0.1 (2)	Loose flocks (2)	On ground (1)	Rapid (1)	Not present	7
Bronze-winged Courser (*Rhinoptilus chalcopterus*)		2.3 (1)	0.16 (2)	Solitary (1)	On ground (1)	Slow (2)	Not present	7
Fork-tailed Drongo (*Dicrurus adsimilis*)		11.6 (1)	0.05 (1)	Solitary (1)	From perch (2)	Rapid (1)	Not present	6
Acacia Pied Barbet (*Tricholaema leucomelas*)		2.3 (1)		Solitary (1)	On ground (1)	Rapid (1)	Not present	5

3.3.4 Comparison of collision records, avifaunal surveys, risk rating and pilot perception

Table 3.5 compares AWC incidence, avian species frequency of occurrence, risk rating and pilot perception for Hosea Kutako and Eros airports. No significant correlation could be found between AWC incidence and frequency of occurrence at Hosea Kutako ($r = 0.18$, $n = 38$, $p > 0.05$), while at Eros the relationship correlated significantly ($r = 0.85$, $p < 0.01$). The correlations between pilot perception and percentage AWC incidence was significant at both airports (Hosea Kutako: $r = 0.82$, $n = 38$, $p < 0.05$; Eros: $r = 0.74$, $n = 38$, $p < 0.05$), as well as the correlations between pilot perception and risk rating (Hosea Kutako: $r = 0.25$, $n = 38$, $p < 0.05$; Eros: $r = 0.42$, $n = 38$, $p < 0.05$). No significant correlation could be found for the relationship between risk rating and frequency of AWC incidence (Hosea Kutako: $r = 0.21$, $n = 38$, $p > 0.05$; Eros: $r = 0.21$, $n = 38$, $p > 0.05$).

Table 3.5: Consolidated table of various avian parameters for Hosea Kutako International and Eros airports, Windhoek, Namibia.

Species	Hosea Kutako			Eros			
	% of AWC incidents (2006-2010)	Frequency of occurrence	Risk analysis rating	% of AWC incidents (2006-2010)	Frequency of occurrence	Risk analysis rating	Percentage of pilots perceiving the species as one of the five highest risk species
Large (>1000 g)							
White-backed Vulture (*Gyps africanus*)	3.3%	2.5%	14	0%	2.3%	14	32.5%
Helmeted Guinea Fowl *(Numida meleagris)*	16.7%	42.5%	13	9.1%	20.9%	12	50%
Secretary Bird (*Sagittarius serpentarius*)	3%	7.5%	11	0%	0%	Not rated	0%
Marabou Stork (*Leptoptilos crumeniferus*)	6.7%	0%	Not rated	0%	0%	Not rated	(Stork)
Abdim's Stork (*Ciconia abdimii*)	6.7%	0%	Not rated	0%	0%	Not rated	12.5%
Martial Eagle (*Polemaetus bellicosus*)	0%	0%	Not rated	0%	7%	11	(Eagle)
Tawny Eagle (*Aquila rapax*)	0%	7.5%	10	0%	0%	Not rated	2.5%
Yellow-billed Kite (*Milvus aegyptius*)	10%	0%	Not rated	2.7%	7%	11	10%
Black-headed Heron (*Ardea*	0%	17.5%	8	0%	0%	Not rated	0%

Species	Hosea Kutako % of AWC incidents (2006-2010)	Frequency of occurrence	Risk analysis rating	Eros % of AWC incidents (2006-2010)	Frequency of occurrence	Risk analysis rating	Percentage of pilots perceiving the species as one of the five highest risk species
melanocephala)							
Egyptian Goose (*Alopochen aegyptiaca)*	0%	0%	Not rated	0%	7%	11	7.5%
Northern Black Korhaan (*Afrotis afraoides*)	0%	17.5%	8	0%	0%	Not rated	0%
Red-crested Korhaan (*Lophotis ruficrista*)	0%	2.5%	8	0%	0%	Not rated	0%
Pelican (*Pelecanus onocrotalus)*	0%	0%	Not rated	0%	0%	Not rated	7.5%
Medium (300 g – 1000 g)							
Southern Pale Chanting Goshawk (*Melierax canorus*)	3.3%	45%	11	1.4%	2.3%	9	(Falcon or goshawk) 7.5%
Cape Crow (*Corvus capensis*)	3.3%	92.5%	13	0%	0%	Not rated	0%
Pied Crow (*Corvus albus*)	0%	2.5%	Not rated	0%	0%	Not rated	0%
Black-shouldered Kite (*Elanus caeruleus*)	0%	77.5%	12	0%	4.7%	9	2.5%
Greater Kestrel (*Falco rupicoloides*)	0%	10%	8	0%	0%	Not rated	0%
Grey Turaco (*Corythaixoides concolor*)	0%	40%	10	0%	0%	Not rated	0%
Rock Dove (*Columba livia*)	0%	0%	Not rated	3%	20.9%	9	(Dove or Pigeon) 10%
Red-billed Spurfowl (*Pternistis adspersus*)	0%	2.5%	9	0%	2.3%	9	0%
Small (<300 g)							
Crowned Lapwing (*Vanellus coronatus*)	30%	30%	9	77.4%	72.1%	11	62.5%
Rock Kestrel (*Falco rupicolus*)	6.7%	22.5%	10	0%	16.3%	9	10%
Cape Glossy Starling (*Lamprotornis nitens*)	0%	0%	Not rated	0%	20.9%	9	0%
Burchell's Starling (*Lamprotornis australis*)	0%	35%	9	0%	0%	Not rated	0%

Species	Hosea Kutako			Eros			
	% of AWC incidents (2006-2010)	Frequency of occurrence	Risk analysis rating	% of AWC incidents (2006-2010)	Frequency of occurrence	Risk analysis rating	Percentage of pilots perceiving the species as one of the five highest risk species
Lilac-breasted Roller (*Coracias caudatus*)	0%	50%	10	0%	20.9%	9	0%
Blacksmith Lapwing (*Vanellus armatus*)	0%	0%	Not rated	0%	9.3%	8	0%
African Grey Hornbill (*Tockus nasutus*)	0%	7.5%	8	0%	7.0%	8	0%
Southern Yellow-billed Hornbill (*Tockus leucomelas*)	0%	20.0%	8	0%	4.7%	8	0%
Namaqua Sandgrouse (*Pterocles namaqua*)	0%	0%	Not rated	0%	2.3%	8	0%
Burchell's Sandgrouse (*Pterocles burchelli*)	0%	32.5%	9	0%	0%	Not rated	0%
Laughing Dove (*Streptopelia senegalensis*)	0%	0%	Not rated	0%	16.3%	7	0%
White-browed Sparrow-weaver (*Plocepasser mahali*)	0%	0%	Not rated	0%	16.3%	7	0%
Cape Turtle Dove (*Streptopelia capicola*)	0%	72.5%	10	0%	9.3%	7	0%
Pale-winged Starling (*Onychognathus nabouroup*)	0%	0%	Not rated	0%	4.7%	7	5%
Burchell's courser (*Cursorius rufus*)	3.3%	0%	Not rated	1.5%	0%	Not rated	0%
Bronze-winged Courser (*Rhinoptilus chalcopterus*)	0%	0%	Not rated	0%	2.3%	7	2.5%
Fork-tailed Drongo (*Dicrurus adsimilis*)	0%	0%	Not rated	0%	11.6%	6	5%
Acacia Pied Barbet (*Tricholaema leucomelas*)	0%	0%	Not rated	0%	2.3%	5	0%
Sparrow (unidentified)	0%	0%	Not rated	2.7%	0%	Not rated	0%
Swallow / swift (unidentified)	0%	0%	Not rated	1.4%	0%	Not rated	27.5%
Spotted Thick-knee (*Burhinus capensis*)	0%	0%	Not rated	0%	0%	Not rated	2.5%

3.3.5 Reaction of birds to aircraft

The reaction of 11 resident avian species to aircraft in the manoeuvre of landing and taking off is illustrated in Table 3.6 and Figure 3.2, indicating that the majority of observations found that manoeuvring did not have any impact on the behaviour of the birds (x = 90.51% ± 14.61). Some observations found birds to actively avoid planes by aerial flight (x = 8.53% ± 4.26), while very few observations (x = 0.96% ± 1.72) found birds to avoid aircraft by moving away on foot, ducking or hiding.

Of the 930 *V. coronatus* observations (representing 87.2% of all sightings) the birds did not react to aircraft 812 times (87.3%), demonstrated an aerial avoidance response in 102 (11.0%) cases, and demonstrated a running avoidance response in 16 (1.7%) aircraft manoeuvres. A significant majority ($\chi_c{}^2{}_{11,2} = 20.42$, $p < 0.001$) of the birds observed (within 100m of runways) showed no change in their behaviour when passed by taking off or landing aircraft.

Table 3.6: Reaction of eleven avian species to aircraft during surveys at Hosea Kutako and Eros airports, 2011 and 2012.

Species	No reaction % (n)	Aerial avoidance response % (n)	Ground avoidance response % (n)
Crowned Lapwing (*Vanellus coronatus*)	87.3% (812)	11.0% (102)	1.7% (16)
Blacksmith Lapwing (*Vanellus armatus*)	58.8% (20)	32.4% (11)	8.8% (3)
Rock Dove (*Columba livia*)	93.5% (29)	6.5% (2)	0% (0)
Red-footed Falcon (*Falco vespertinus*)	100% (28)	0% (0)	0% (0)
Rock Kestrel (*Falco rupicolus*)	89.3% (25)	10.7% (3)	0% (0)
Southern Pale Chanting Goshawk (*Melierax canorus*)	100% (9)	0% (0)	0%(0)
Martial Eagle (*Polemaetus bellicosus*)	100%(7)	0%(0)	0%(0)
Cape Glossy Starling (*Lamprotornis nitens*)	100% (3)	0% (0)	0% (0)
Black-shouldered Kite (*Elanus caeruleus*)	66.7% (2)	33.3% (1)	0% (0)
Yellow-billed Kite (*Milvus aegyptius*)	100% (3)	0% (0)	0% (0)
Namaqua Sandgrouse (*Pterocles namaqua*)	100% (2)	0% (0)	0% (0)

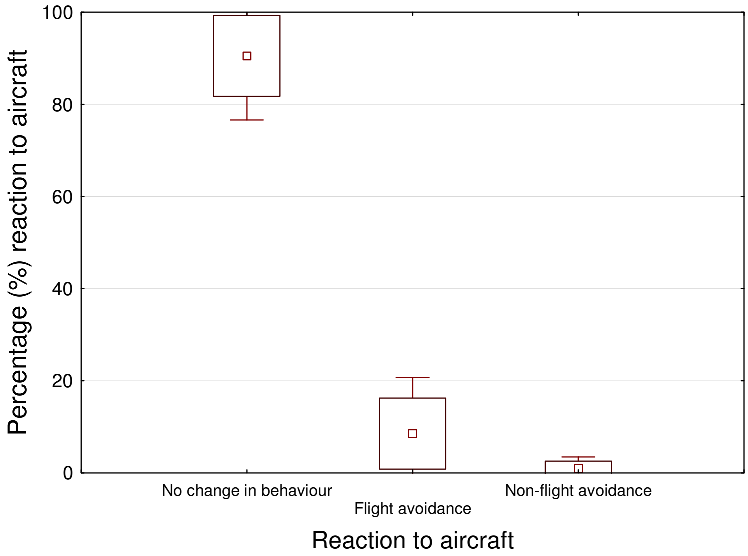


Figure 3.2: Reaction of 11 avian species to aircraft take-off and landing at Hosea Kutako and Eros Airports. See text for detail on the species included. (Inner square = mean, box = 2x standard error, whisker = 2x standard deviation).

3.4 Discussion

This study highlighted uniqueness of airports' avian diversity. Even though the two airports are within the same vegetation type, and separated by less than 50 km, no correlation between the species composition and frequencies of occurrence could be found. The composition and condition of the ecosystem often affects which birds occur there (Furnes & Campuysen 1997), even at a local scale (Soini 2006). Findings of diversity and abundance of small mammals (Chapter 4) arthropods and vegetation (Chapter 5) confirm the uniqueness of ecosystems at the two airports. It further supports the findings by Godin (1994), Deacon & Rochard (2000), Dekker (2000) and DeVault *et al.* (2009) stating that no two airports are exactly alike. Although species such as gulls and Canada Geese pose a common hazard at many airports (Servoss *et al.* 2000, Brown *et al.* 2001, Dolbeer & Wright 2009, RNLAF 2009), studies of avifaunal species occurrence at airports in Australia (Steele 2001), Europe (Lensink *et al.* 2000, RNLAF 2009) and the USA (Constantin & Floyd 1991) showed very few common species or occurrence patterns. A contributing factor (as suggested Chapter 4 and Chapter 5) is surrounding land use, with Hosea Kutako being surrounded by farmland and wilderness, while Eros is in urban surrounds. Blair (1996) and Clergeau *et al.* (2001) found bird diversity in urban areas to be different to surrounding landscapes as a result of artificial woody vegetation diversity and water provision in towns and cities not found in surrounding landscapes. This is supported by Korpimaki (2008) who also found that urban birds even showed changed behaviour when compared to rural areas.

Migratory species, identified to be a particular AWC risk by Nasirwa (2001), were not found at the current study sites, and are not expected to be frequently encountered. One exception is however *Phoenicopterus roseus* (Greater Flamingo). This species is known to migrate between wetlands in southern Africa (e.g. Walvis Bay and Etosha in Namibia and Makgalakgadi and Sua Pans in Botswana) (McCuloch *et al.* 2003) and their habits of migrating at night in large numbers (Henschel 2012) (Hockey *et al.* 2005) could pose a risk to aircraft en route to the two study sites.

3.4.1 Risk species

Although the categorisation of risk factors is common to accepted practice (Short *et al.* 2000, Davis *et al.* 2002, Anagnostopoulos 2003 Allan 2006 and Sowden *et al.* 2007) the subjective weighting assigned to each category seemed to produce an expected list of high risk species which correlated to pilot perception. It does however require further testing before it can be recommended for general use. The species identified as high risk at Hosea Kutako and Eros airports are highlighted below, according to their mass, behaviour and ecology:

<u>Ground foraging species</u>

Numida meleagris (Helmeted Guinea Fowl) falls under the top three most common species involved in AWC incidents at both airports. Its relatively large size and weight (1.38 kg for females; 1.5 kg for males - Hockey *et al.* 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 possible human casualty. *N. meleagris* feeds on invertebrates (highlighting the importance of the airport arthropod study in Chapter 5), but it also feeds on seeds, tubers and weed plants (Hockey *et al.* 2005). Elsewhere in Africa, Nasirwa (2001) reported four collisions with this species in Kenya.

Vanellus coronatus (Crowned Lapwing) have been the most significant contributor to AWC incidents at both Hosea Kutako and Eros airports. The species is common in southern Africa, but little is known of its ecology (Kok & Anderson 1989). 62.5% of the pilots questioned see this species as one of the five highest risk species at the study sites, and it was identified in 72.1% and 30% of surveys at Eros and Hosea Kutako, respectively. This species has also dominated incidents and sightings at two inland airports in South Africa (Kok & Kok 2002b, Kok 2006), and other lapwing species were found to be a significant AWC risk in Europe (Bell 1999, Poot *et al.* 2000). Being a small sized bird of 185 grams on average (Hockey *et al.* 2005), the risk of significant damage to aircraft following a collision with one individual of this species 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 - Hockey *et al.* 2005), increases its significance as a risk species (as also applied by Sodhi 2002, Dolbeer & Wright 2009, DeVault *et al.* 2011). In this instance, at both airports, collisions with multiple *V. coronatus* were reported in eight out of every nine 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 60mm (Hockey *et al.* 2005). Its preferred diet are termites (both *Odontotermes* and *Hodotermes*, Family: Hodotermitidae) (Kok & Anderson 1989, Kok & Kok 2002b). *V. coronatus*'s habit of becoming habituated to aircraft movement is illustrated by individuals ignoring aircraft landing and taking off in 87.3% of observed aircraft movements (n=930). This factor leads to habituated individuals possibly being less "flighty" and therefore less likely to collide with aircraft. The surrounding golf course and mown road verges (with less predation risk than surrounding areas) hosts a healthy population of this species (personal observations 2008-2012). The limited observations of this study suggest that culling of *V. coronatus* individuals may be counterproductive, as this could result in in-migration of inexperienced individuals likely to be more skittish, resulting in an increased risk of collisions. This factor is taken into account when determining AWC risk in the systems model (see Chapter 6) but would require a dedicated study of innate behaviour followed by marking and observation of resident individuals at the airport.

Corvus capensis (Cape Crow) was the most commonly observed bird species at Hosea Kutako, but absent from Eros. Despite its common occurrence at Hosea Kutako, no records of AWCs were recorded. A study of a related species, *Corvus brachyrhynchos* (American Crow) (Mukherjee *et al.*2013), found it to display a superior cognitive ability when avoiding traffic on roads compared to other species. *C. capensis* may display a similar learning ability to avoiding aircraft at Hosea Kutako. As with most Corvidae this species has a varied diet, from invertebrates to fruit (Hockey *et al.* 2005). At Hosea Kutako they were most commonly seen on the taxiway verges feeding in mown grass. Dean *et al.* (2006) observed this species utilising road verges in the semi-arid parts of South Africa, which are also mostly mown. This indicates that *C. capensis* may be attracted by mowing.

<u>Raptors (Order: Falconiformes)</u>

Raptors are often identified as a risk around airports, presumably as a result of their large size and their often soaring / hovering movements (Servoss *et al.* 2000). They have also been involved in many collisions with aircraft worldwide (Baker & Brooks 1981, Anderson *et al.* 1999, Garland *et al.* 2009). Many of them predate on a number of the small mammal species, which highlights the importance of small mammal surveys at airports (see Chapter 4; also suggested in Washburn *et al.* 2011). In the current study, seven raptor species were identified as high risk (5 at Hosea Kutako; 3 at Eros). Four of these are discussed below.

Gyps africanus (White-backed Vulture) was identified as a high risk species at both airports. Although rarely observed at Hosea Kutako and Eros (see Table 3.3), a collision with an aircraft in 2010 resulted in damage of approximately US$ 106 000 (P. Keil, West Air, pers. comm. 2011). Only 32.5% of the pilots questioned have seen the species on at least one of the airports, indicating that the probability of colliding with *G. africanus* is relatively low. As a result of its gregarious habits and large size (5.5 kg; Hockey *et al.* 2005), however, a result of a collision with this species is likely to have aircraft crippling consequences. This species feeds exclusively on carrion (Hockey *et al.* 2005, Boshoff & Boshoff 2007). The global *G. africanus* population is under threat (Koenig 2006). Locally, feeding areas (mostly for livestock carcasses; Anderson & Anthony 2005) are being reduced through bush encroachment and changes in land use (Monadjem & Garcelon 2005), and improved regional livestock management has reduced the availability of food (Monadjem *et al.* 2004). Local vulture conservation activities include protection of nesting sites, encouraging landowners to leave dead animals in the field, and the establishment of vulture restaurants (Monadjem *et al.* 2004, Anderson & Anthony 2005). These factors may, however, increase the risk of vulture collisions around especially Hosea Kutako. While vulture restaurants have been found to improve juvenile survival, and provide an eco-tourism opportunity for landowners who establish them, it may also lead to vultures adjusting their normal foraging range (Anderson & Anthony 2005) and the attraction of Corvid (Stork) species. The presence of a vulture restaurant on a farm 7km from Hosea Kutako (22º 21.8948' S; 17º 22.7708' E) is, therefore, likely to increase the risk of AWCs, and should be addressed (see also Wolter 2008).

Sagittaruis serpentarius (Secretary Bird) was only recorded at Hosea Kutako (always a single pair, found during 7.5% of surveys). This species was not identified by the pilots, possibly as a result of its habits of foraging in the grass (Hockey *et al.* 2005), and not using perches which are likely to make it more visible to pilots. No collision incidents have been recorded with this species but, as with *G. africanus*, its large size could result in severe consequences to aircraft. Mundy (undated) found Secretary Birds foraging at Harare Airport, and corroborated the risk identified during the current study.

Milvis aegyptius (Yellow-billed Kite) is an intra-Africa migrating subspecies of the Black Kite (*M. m. migrans)*. It was recorded in 7% of surveys at Eros only, and was identified as a risk by 10% of pilots. Despite its low occurrence, one AWC incident involving this species has been reported at Eros airport (Hauptfleisch *et al.* 2013). Large flocks of the gregarious *M. m. migrans* (Black Kite), a summer Paleacrtic migrant, often together with *M. m parasitus* have been sighted elsewhere in Namibia (Komen 2009). Management guidance for this flocking behaviour has been included in the Airport Toolkit (Chapter 7) in the event of it taking place near an airport. This species has, between 1984 and 2000, been involved in 27 collisions with aircraft in Kenya (Owino *et al.* 2004).

Elanus caeruleus (Black-shouldered Kite) has been rated a high risk species at Hosea Kutako as a result of the high frequency of sightings (77% of surveys) and its habit of hovering and swooping for prey (Hockey *et al.* 2005). This species has not been involved with AWCs at any of the two airports under study. Chapter 4 explains the high abundance of its preferred prey *Rhabdomys pumilio* (Hockey *et al.* 2005) a probable reason for its presence at the airport.

<u>Waterfowl</u>

Alopochen aegyptiaca (Egyptian Goose) was the only waterfowl species identified as a high risk for AWCs (Hockey *et al.* 2005), and then only at Eros. The species is a known nuisance at golf courses in South Africa (Sampson 2012), and is most probably attracted to the relatively safe nesting and foraging areas provided by the water hazards on the neighbouring golf course.

3.4.2 Pilot perception as an indicator of risk species

When comparing all data variables (AWC incidents, avifaunal surveys, pilot perceptions and species risk analysis) (Table 3.5), 80% of the identified high risk species (risk rating of 11 or higher) were also perceived by pilots to be species of concern. This indicates that pilot perception may be an effective indicator of AWC risk, making communication between pilots and airport wildlife control staff critical to identify and mitigate AWC risk timeously at airports where no formal risk assessment has been done. If the risk rating process (see Table 3.4) could also include extent of damage from previous incidents (= AWC records) as used by Dolbeer *et al.* (2000), it would likely provide an even closer correlation. AWC reports at the airports (for 2006-2010) did not record this aspect accurately. Linnell *et al.* (1999) and Flavio (2011) however warns that pilot perception is biased, as pilots show less acuity to birds while in critical phases of flight, such as takeoff and landing, and therefore this should not be the sole indicator of AWC risk.

3.4.3 Frequency of occurrence of bird species as an indicator of collision risk

A comparison between the results of avifaunal surveys and AWC records has shown that the frequency of occurrence of species at airports is not necessarily an indicator of which species collide with aircraft. Here, behaviour, mode of feeding, flight speed and reaction of birds to aircraft (see 3.4.4 below) may play a more important role.

3.4.4 Relationship between AWC incidence frequency and collision risk

The lack of correlation between AWC incidence and collision risk is expected as collision risk includes not only the likelihood of a collision but also the consequence of such a collision.

3.4.5 Birds becoming habituated to aircraft movements

Habituated resident bird populations potentially pose a lower AWC risk as a result of their ability to “learn” not to take flight when aircraft manoeuvre nearby. Figure 3.2 demonstrates that a significant majority of birds observed during this study did not alter their behaviour on encountering aircraft. Lensink *et al.* (2000) found similar results in a study where only 1.3% of bird movements were caused by aircraft movements. This indicates that these mostly resident birds learn in some way not to fear aircraft, and not to react, or react more appropriately. This may suggest why Burger (1985) and Linnell *et al.* (1996) found proportionally higher collisions between aircraft and juvenile (less experienced) birds. Kelly *et al.* (2001) found birds to possess a sophisticated memory capable of learning. This learning ability helps them identify aircraft, avoid them if necessary, and to be less flighty if aircraft do not pose a direct physical threat. Similar habituation (or learning) was described by Conomy *et al.* (1998), Kuzir & Muzinic (1998), Soldatini *et al.* (2008) and Mukherjee *et al.*(2013).

The culling of habituated individuals may therefore increase the risk of collisions through creating the improved opportunity for immigration of unhabituated individuals (as suggested in Chapter 6). The risk assessment methodology used in this study does not consider the ability of species to become habituated, an aspect that may influence the likelihood of collisions. As the cognitive ability of avian species is likely to be varied (Kelly *et al.* 2001,Mukherjee *et al.*2013) this aspect will require species specific behavioural research before it can be incorporated into a risk assessment process. Stankowich & Blumstein (2005) caution that species reaction to threats differ between species, as well as for the speed, approach angle, cryptic weaponry, and sound of the perceived threat.

3.5 Conclusions and recommendations

This study proposes a weighting system for inclusion in accepted AWC risk assessment methodology. The results of the risk assessment correlated closely to pilot risk perception, but not to AWC history or frequency of occurrence of bird species. The risk analysis rated six species (*G. africanus*, *C. capensis*, *N. meleagris*, *E. caeruleus*, *S. serpentarius*, and *M. canorus*) as high risk at Hosea Kutako International Airport, and six species at Eros Airport (*G. africanus*, *N. meleagris*, *P. bellicosus*, *M. aegyptius*, *A. aegyptiaca* and *V. coronatus*). The fact that only two species were rated as high risk at both airports supports the findings of Chapter 4 and Chapter 5 that although the airports are in close proximity to one another, their ecosystems and AWC risk are quite different.

By combining the four variables (risk rating, pilot perception and avian species occurrence) an improved picture of avian dynamics for Hosea Kutako and Eros could be obtained. Observations on habituation and behaviour of specific species also greatly added to this understanding, and motivated for further investigation regarding their inclusion in risk assessment analyses. The fact that pilot perception was found to be highly accurate in predicting AWC risk species or groups, may play an important role in management plans for southern African airports where no formal risk assessments have been done, as it provides a rapid view of AWC risk. Habituation of birds at airports meant that birds most frequently observed at the airports were not necessarily more likely to collide with aircraft.

From the above conclusions it is recommended that the risk assessment methodology (including weighting) proposed in this study be tested at other airports, and correlated to AWC frequency, pilot perception and bird species occurrence. A factor for the consequence of collisions needs to be included in AWC records, and for this to be achieved the airports need to more accurately record damage caused, or change in flight path etc. for each AWC. It is further recommended that factors affecting the occurrence of the high risk species found in this study be addressed by NAC management as a matter of priority.

CHAPTER 4: AIRCRAFT WILDLFIE COLLISIONS AT NAMIBIAN AIRPORTS: SMALL MAMMAL COMMUNITY VARIABLES AS AN INDICATOR OF RISK

Abstract

Understanding ecosystems within and surrounding airports can help to determine the causes and possible mitigation measures for collisions between aircraft and wildlife, a serious safety concern for the global aviation industry. Small mammal communities are an important component of the semi arid savanna ecosystems of Namibia, its productivity and its ecosystem integrity. This study compared the abundance and diversity of small mammals (rodents and small insectivores) between Namibia's two main airport properties (one urban and one rural) as well as between various land uses surrounding the airports over two years. A total of 2150 small mammals (3 orders, 11 species) were captured over four trapping seasons; 1570 at Hosea Kutako International Airport and 580 at Eros Airport. Small mammal abundance was significantly higher in the growing season than in the non-growing season. The dominant nocturnal and diurnal species at both airports were *Mastomys coucha* and *Rhabdomys pumilio,* respectively. Mowing of grass at the airports to reduce the risk of aircraft wildlife collisions resulted in a significant reduction of small mammal abundance at Hosea Kutako during the non-growing season, indicating that annual mowing was effective but insufficient to reduce the overall abundance of mammal prey species for raptors. Small mammal numbers were significantly higher at Hosea Kutako airport compared to the cattle and game farming land use surrounding the airport, while no differences in small mammal densities or diversity was found in different land uses at, and surrounding Eros. The study suggests that the fence around Hosea Kutako provides a refuge for small mammals from most flightless predators, resulting in higher densities of prey species for raptors. It also indicates that surrounding land use results in altered ecosystem function and productivity, an important consideration when identifying wildlife attractants at airports.

4.1 Introduction

Aircraft Wildlife collisions (AWCs), more commonly known as bird strikes, are a global safety and financial concern to the aviation industry (Allan 2000, Robinson 2000, Froneman 2001, Sodhi 2002, Thorpe 2003, Buurma & Den Haag 2004, IBSC 2006, Blackwell *et al.* 2013). The majority of AWCs occur within 13km of the take-off and landing, below an altitude of 2000ft (IBSC 2006, Dolbeer 2006). At Namibia's two busiest airports Hosea Kutako (international) and Eros (local), 128 AWC incidents were recorded between 2006 and 2010 (Hauptfleisch *et al.* 2013). Although none led to serious injury or death, two major incidents have lead to direct costs in excess of N$ 30 million and 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). Standard 2 refers to the management of features attracting wildlife to an airport and standard 9 to the management of a 13 km radius around an airport to minimise wildlife attractants. Indeed, land use and land management at and in the vicinity of airports has been purported to have a distinct influence on risk of aircraft-wildlife collisions (Blackwell *et al.* 2013, Schmidt *et al.* 2013). This study has relevance to both these standards as small mammals are an important attractant for raptors and other predators (Baker & Brooks 1981, Witmer & Fantinato 2003, Witmer 2011), two of the groups which have been identified as responsible for AWCs at Hosea Kutako and Eros (see Chapter 2). The study also considered small mammal abundance and diversity at the airports to surrounding land uses.

Airports are unique and often productive habitats providing niches and ecosystem services such as shelter, nesting sites, water and primary food supply (grass / vegetation, insects, small mammals and carrion) (Soldatini *et al.* 2010). As such, airports can be viewed as islands with unique ecosystems, influenced by "offshore" processes such as surrounding land use (MacArthur & Wilson 1967). The monitoring of small mammals as an ecosystem component may be most useful to airport wildlife management as it has been described as a relatively quick and inexpensive tool for determining ecosystem health and functioning (Avenant & Cavallini 2007, Avenant *et al.* 2008, Avenant 2011), and can indicate varying environmental contexts and responses (De Graaff 1974, Ferreira & Avenant 2003, Avenant *et al.* 2008, Golley *et al*. undated). Some small mammal species' abundance may be indicative of the primary productivity of ecosystems (Avenant 2011), but they are also valuable prey and predator species, dispersers of seed, soil nutrient and aeration benefactors, and habitat modifiers that can determine vegetation composition through selective utilization of seeds and other reproductive plant parts (Malan & Crowe 1996, Avenant 2000, Perrin & Bodbijl 2001, Avenant 2005, Witmer 2011). This makes them a causal and indicative group likely to indirectly affect the risk of aircraft-wildlife collisions (AWCs) at airports. Where Baker & Brooks (1981) found population fluctuations in predatory raptors in response to meadow vole *Microtus pennsylvanicus* in Canada, however, Barras *et al.* (2000) could not find any correlation between small mammal densities and raptor densities at JF Kennedy Airport; an indication that the relationship between raptors and small mammals is not necessarily a simple one. Nevertheless, the management of rodent populations through habitat augmentation or population control has been recommended to reduce raptor numbers at airports (Witmer & Fantinato 2003, Witmer 2011). Avenant *et al.* (2008) and Avenant (2011) describe the use of small mammals as indicators of ecosystem integrity in South African grasslands. In arid and semi-arid environments (as is the case with the Namibian study sites) Hoffman & Zeller (2005) found an understanding of small mammal community structure to be important in recommending practical ecosystem management guidelines.

This study compares small mammal abundance and diversity under different land uses and vegetation management regimes within a 13km radius of Namibia's two largest and busiest airports, Hosea Kutako (international) and Eros (national). The small mammals considered were those of the orders Rodentia, Eulipotyphla and Macroscelidea small enough to be caught in standard small-mammal traps. They are known prey for a variety of raptor species, e.g. Black-shouldered Kite, Secretary Bird, Greater Kestrel and Tawny Eagle (Hockey *et al.* 2005), that frequent the two study sites (Chapter 4). No analysis of small mammal density or diversity has been published for any African airport.

4.1.1 Study sites

Both airports are situated in the "Highland Shrubland" Tree and Shrub Savanna vegetation type (Mendelsohn *et al.* 2002) which is characterised by low unpredictable rainfall (350-400 mm)(Mendelsohn *et al.* 2002) which falls mostly during the summer months from October to

April resulting in a distinct growing season (GS) and non-growing season (NG). Dominant woody species include a number of *Acacia* species (e.g. *Acacia mellifera, Acacia hebeclada, Acacia hereroensis*) while climax grass species are dominated by *Anthephora pubescens*, *Brachiaria nigropedata*, and *Heteropogon contortus* (Joubert *et al.* 2008). The study sites fall on the edge of the Kalahari desert, characterised by substrates of deep sandy soils (Mendelsohn *et al.* 2002).

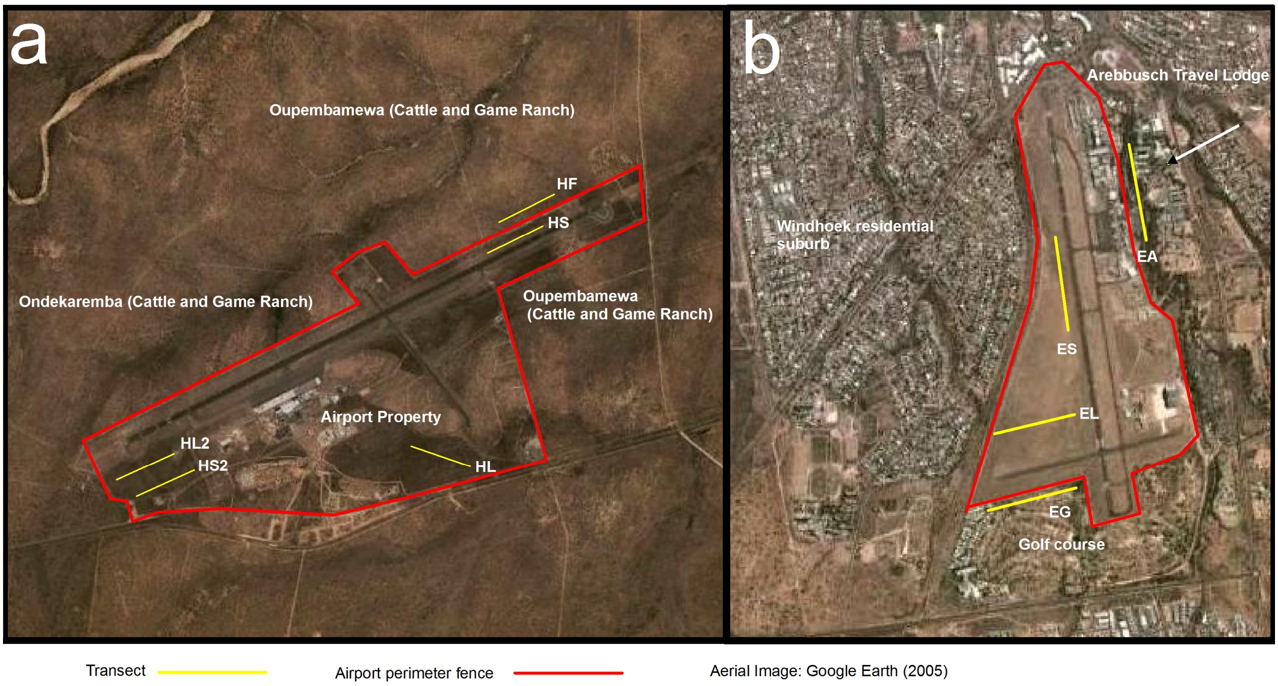


Figure 4.1: Maps of the study area and transects at a) Hosea Kutako and b) Eros.

4.2 Methodology

Small mammals were trapped in order to determine the abundance and diversity of rodents, shrews and elephant shrews (Orders Rodentia, Eulipotyphla and Macroscelidea, respectively). Single line transects were laid out in representative areas of similar environmental characteristics (soil type, topography), but different land use or vegetation management, both within and around the two airports. At Hosea Kutako these were i) two areas within the airport where grass was not disturbed (labelled HL and HL2), ii) two areas where grass was mown annually (HS and HS2), and iii) one area in the neighbouring game and cattle ranch (HF) (Figure 4.1a). At Eros they were i) an area within the airport where grass was not disturbed (EL), ii) an area within the airport where grass was mown annually

(ES), iii) a neighbouring golf course "rough" (EG), and iv) the neighbouring Arebbusch urban travel lodge (EA) (Figure 4.1b).

Linear transects were preferred to grids as space utilization at airports are relative to runways, causing airport properties to be largely linear with long narrow ecotones. Larger areas are also covered with the same number of traps laid out in a transect (Pearson & Ruggiero 2003), increasing the opportunity to trap more species as these are not homogenously distributed over an area (Avenant 2011).

Mark-recapture sampling was conducted at the end of the dry non-growing season (in September 2010 and September 2011) and the end of the wet, growing season (in March 2011 and March 2012) (Mendelsohn *et al.* 2002). One hundred well ventilated Sherman-like stainless steel box traps (7.6 x 7.6 x 25.4 cm) were spaced 5 m apart on a single 495 m line transect in each habitat (following Avenant 1996, 2000, 2003, 2011, Avenant & Cavallini 2007, Avenant *et al.* 2008 and Seamans *et al.* 2007). The traps were baited with a mixture of peanut butter, rolled oats, sunflower oil and a meaty extract, Bovril®. Each trap was checked for successful trappings and re-baited at dawn and dusk for four consecutive days, in order to consistently sample diurnal and nocturnal small mammal species (following Muck & Zeller 2006 in similar habitat in Namibia, and Avenant 2011 in South African grasslands). Captured specimens were identified, sexed and marked with fur pattern clippings to ensure identification of retrapped individuals. Mortalities were donated to the collection of the National Museum of Namibia.

The term "trap night" was used to describe one trap which was set for a 24 h-period (Rowe-Rowe & Meester 1982). Three measures of abundance were used, *viz.* trap success (an indication of density), variety (≈ species richness, or the number of species), and diversity. Trap success (or percentage success) is the number of small mammals captured/100 trap nights. This was to avoid "trap happy" individuals from influencing density estimates. Variety is the number of species collected, and diversity was calculated using the Shannon information index (Spellerberg & Fedor 2003, Magurran 2004).

Normality of data was determined with Shapiro-Wilk's W test, and the Wilcoxon matched pairs test for two way comparison were used to compare trap success and species richness across land uses in specific seasons. All statistical analyses were completed using the computer program Statistica® for Windows version 10 (StatSoft Inc. 2011), and the 95% level ($p<0.05$) was regarded as statistically significant for all tests.

4.3 Results

4.3.1 Abundance

A total of 2 150 individual small mammals were captured over the four trapping seasons (1 570 at Hosea Kutako, 580 at Eros) (Table 1), with considerable differences between transects and between seasons in the same transects, at both airports (Figure 4.2). This excluded the retrapped individuals which contributed a fair percentage to the total number of catches (16.18% at Hosea Kutako; 9.80% at Eros). This contribution by retraps was commonly more pronounced at the end of the non-growing season (23.11% ± 25.77%, vs. 12.68% ± 9.46% at the end of the growing seasons).

Of the total number of individuals, 1 317 were trapped in the growing seasons and 833 in the non-growing seasons (Table 1). This phenomenon, where more individuals were trapped at the end of the growing season than at the end of the following non-growing season, repeated itself at eight and five of the nine transects, respectively. Significantly more small mammals were caught at the end of the first growing season (GS1) than at the end of the following non-growing season (NG1); from the end of the second growing season (GS2) to the end of the second non-growing season (NG2), total number of individuals trapped stayed unchanged (630 to 635, respectively).

Table 4. 1: Percentage contribution of small mammal species trapped on different land uses in and surrounding Hosea Kutako and Eros airports. The numbers of individuals trapped are in brackets. GS, growing season; NGS, non-growing season.

		Hosea Kutako					**Eros**			
Season	**Species**	**Farm (HF)**	**Un-mown (HL)**	**Un-mown2 (HL2)**	**Mown (HS)**	**Mown 2 (HS2)**	**Travel lodge (EA)**	**Golf course (EG)**	**Un-mown (EL)**	**Mown (ES)**
	Order – Rodentia									
GS 1	*Desmodillus auricularis*	-	-	1.26 (2)	-	-	-	-	-	8.33(1)
NGS 1		-	-	-	-	-	-	-	-	-
GS 2		2.86 (1)	1.05 (1)	-	-	-	-	-	-	-
NGS 2		-	-	-	-	-	-	-	-	-
GS 1	*Gerbilliscus leucogaster*	5.08 (3)	8.14 (14)	6.92 (11)	-	16.67 (12)	-	8.43 (7)	-	-
NGS 1		12.5 (2)	9.52 (10)	40.48 (17)	-	66.67 (2)	-	-	-	-
GS 2		17.14 (6)	1.05 (1)	5.56 (6)	5.0 (6)	12.82 (10)	-	4.55 (3)	8.51 (8)	20 (4)
NGS 2		7.14 (1)	2.94 (7)	16.25 (26)	-	33.33 (1)	-	-	4.13 (5)	-
GS 1	*Mastomys coucha*	30.51 (18)	13.95 (24)	20.75 (33)	18.82(16)	31.94 (23)	60 (3)	60.24 (50)	40 (16)	66.67(8)
NGS 1		-	3.81 (4)	21.43 (9)	-	-	-	30 (3)	25 (1)	100 (3)
GS 2		25.71 (9)	4.21 (4)	16.67(18)	17.8 (21)	7.69 (6)	25 (4)	39.39(26)	29.79(28)	75 (15)
NGS 2		35.71 (5)	8.82 (21)	9.38(15)	57.14 (4)	-	-	24.44(22)	26.45(32)	-
GS 1	*Mus musculus*	-	-	-	-	-	-	-	-	-
NGS 1		-	-	-	-	-	-	-	-	-
GS 2		-	-	5.56 (6)	-	-	-	-	-	-
NGS 2		-	-	-	-	-	-	-	-	-
GS 1	*Mus indutus*	-	-	-	-	-	-	-	5 (2)	8.33 (1)
NGS 1		-	1.9 (2)	4.76 (2)	100 (1)	-	-	-	50 (2)	-
GS 2		-	-	-	-	-	-	-	-	-
NGS 2		-	-	0.63 (1)	-	-	-	-	-	-
GS 1	*Rhabdomys pumilio*	45.76 (27)	68.6 (118)	69.81 (111)	70.59(60)	51.39 (37)	20 (1)	27.71 (23)	55 (22)	16.67(2)
NGS 1		12.5 (2)	75.24 (79)	33.33 (14)		33.33 (1)	92.86 (13)	60 (6)		
GS 2		54.29(19)	93.68 (89)	72.22 (78)	73.73(87)	78.21 (61)	75 (12)	54.55 (36)	61.7 (58)	5 (2)

		Hosea Kutako					Eros			
Season	**Species**	**Farm (HF)**	**Un-mown (HL)**	**Un-mown2 (HL2)**	**Mown (HS)**	**Mown 2 (HS2)**	**Travel lodge (EA)**	**Golf course (EG)**	**Un-mown (EL)**	**Mown (ES)**
NGS 2		57.14 (8)	88.24(210)	73.75 (118)	42.86 (3)	66.67 (2)	100 (2)	74.44 (67)	53.72(65)	-
GS 1	*Saccostomus campestris*	3.39 (2)	6.4 (11)	0.63 (1)	7.06 (6)	-	-	-	-	-
NGS 1		25 (4)	2.86 (3)	-	-	-	-	-	25 (1)	-
GS 2		-	-	-	2.54 (3)	1.28 (1)	-	-	-	-
NGS 2		-	-	-	-	-	-	-	0.83 (1)	-
GS 1	*Thallomys paedulcus*	-	-	-	-	-	-	-	-	-
NGS 1		-	-	-	-	-	7.14 (1)	-	-	-
GS 2		-	-	-	-	-	-	-	-	-
NGS 2		-	-	-	-	-	-	-	-	-
	Order -Eulipotyphla -									
GS 1	*Crocidura sp1*	1.69 (1)	0.58 (1)	0.63 (1)	-	-	-	-	-	-
NGS 1		-	-	-	-	-	-	-	-	-
GS 2		-	-	-	0.85 (1)	-	-	-	-	-
NGS 2		-	-	-	-	-	-	-	-	-
GS 1	*Crocidura sp2*	-	-	-	1.18 (1)	-	-	-	-	-
NGS 1		-	-	-	-	-	-	-	-	-
GS 2		-	-	-	-	-	-	-	-	-
NGS 2		-	-	-	-	-	-	-	-	-
	Order – Macroscelidea									
GS 1	*Elephantulus intufi*	13.56 (8)	2.33 (4)	-	2.35 (2)	-	-	3.61 (3)	-	-
NGS 1		50 (8)	6.67 (7)	-	-	-	-	10 (1)	-	-
GS 2		-	-	-	-	-	-	1.52 (1)	14.88(18)	-
NGS 2		-	-	-	-	-	-	1.11 (1)	-	-
	Totals									
GS 1	Numbers trapped	59	172	159	85	72	4	83	40	12
NGS 1		16	105	42	1	3	14	10	4	3
GS 2		35	95	108	118	78	16	66	94	20

		Hosea Kutako					**Eros**			
Season	**Species**	**Farm (HF)**	**Un-mown (HL)**	**Un-mown2 (HL2)**	**Mown (HS)**	**Mown 2 (HS2)**	**Travel lodge (EA)**	**Golf course (EG)**	**Un-mown (EL)**	**Mown (ES)**
NGS 2		14	238	160	7	3	2	90	121	0
GS 1	Species richness	6	6	6	5	3	2	4	4	4
NGS 1		4	6	4	1	2	2	3	3	1
GS 2		4	4	4	5	4	2	4	3	3
NGS 2		3	2	4	2	2	1	3	4	0
Total		7	8	8	8	4	3	4	6	5
GS 1	Shannon diversity	1.91	1.49	1.27	1.28	1.45	1.37	1.43	1.22	1.42
NGS 1		1.75	1.33	1.74	0	0.92	0.37	1.30	1.52	0
GS 2		1.57	0.42	0.98	1.18	1.02	0.81	1.30	1.25	0.99
NGS 2		1.26	0.62	1.11	0.99	0.92	0	0.89	1.65	0

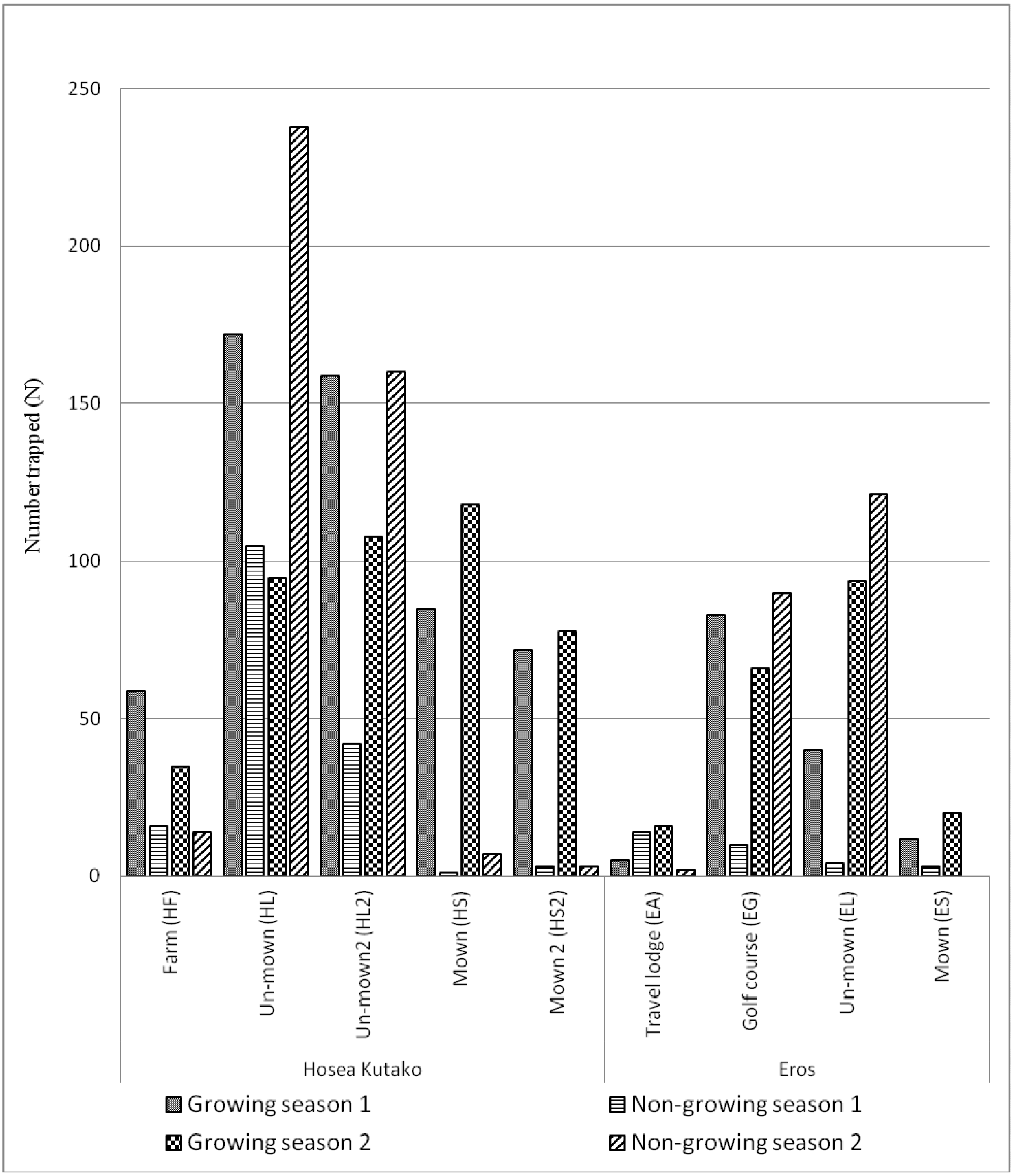


Figure 4.2: Total numbers of small mammal individuals caught per transect and season on the nine standard 495 m line transects.

At the end of the growing season the mean trap success was, in the first year only, significantly higher at Hosea Kutako compared to the non-growing season ($p<0.05$; Figure 4.3); at Eros mean trap success did not differ between any growing season and the following non-growing season.

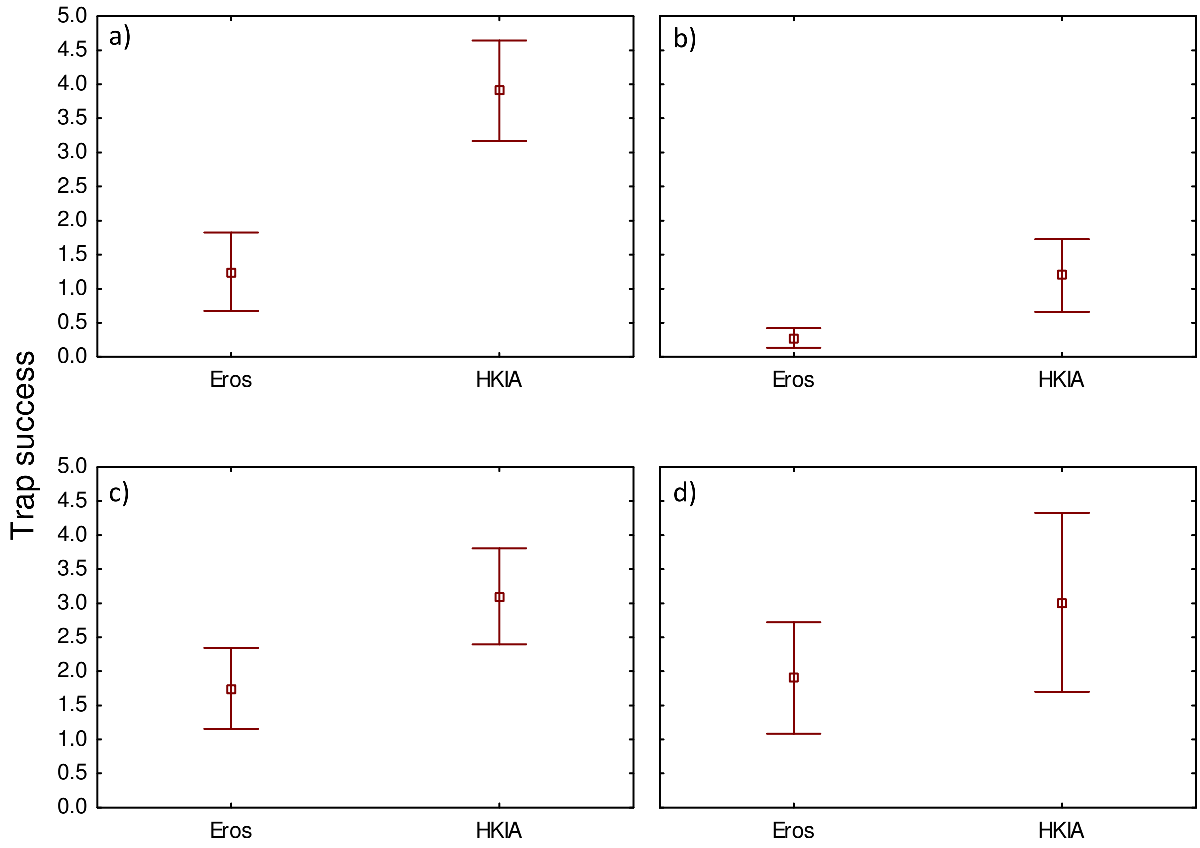


Figure 4.3: The mean (indicated with 95% confidence intervals) small mammal trap success at the end of each growing (GS and GS2) and non-growing (NG1 and NG2) seasons, respectively, for a) Growing season 1, GS1; b) Non-growing season 1, NG1; c) Growing season 2, GS2; d) Non-growing season 2, NG2.

Per individual transect, mean daily trap success at Hosea Kutako in the first growing season (GS1) was highest in the two unmown transects (HL = 24.57 ± 9.22; HL2 = 22.71 ± 3.50), followed by the two mown transects (HS = 12.14 ± 4.22; HS2 = 10.29 ± 5.02). The game and cattle farm (HF) showed the lowest trap success at the Hosea Kutako study site (HF = 8.43 ± 4.24)(Figure 4.4a). This was significantly lower than HL ($Z = 2.37$, $p<0.05$), HL2 ($Z = 2.37$, $p<0.05$) and HS ($Z = 2.20$, $p<0.05$). Further significant differences were observed between HL and HS ($Z = 2.20$, $p<0.05$), HL and HS2 ($Z = 2.37$, $p<0.05$), HL2 and HS ($Z = 2.37$, $p<0.05$), HL2 and HS2 ($Z = 2.37$, $p<0.05$). The pattern was similar in the first non-growing season with mean trap success highest in the two unmown transects (HL = 15.00 ± 2.38, HL2 = 6.00 ± 5.42). During this season, however, no significant difference in trap success could be found between the game and cattle farm and the two on-airport mown transects (HF = 2.29 ± 2.36; HS = 0.14 ± 0.38; HS2 = 0.43 ± 0.79)(Figure 4.4b). The difference was significant between HL and HS (Z = 2.37, p<0.05), HL and HS2 (Z = 2.37, p<0.05), HL2 and HS (Z = 2.37, p<0.05), HL2 and HS2 (Z = 2.37, p<0.05), HF and HL (Z = 2.37, p<0.05) and HF and HL2 (Z = 2.37, p<0.05).

At the end of the second growing season at Hosea Kutako (Figure 4.4c) one mown transect (HS) had the highest mean trap success (16.86 ± 7.47) followed by the two unmown transects (HL 13.57 ± 10.53; HL2 = 15.43 ± 4.08,). As in the first growing season the farm (HF) had the lowest mean trap success (5.00 ± 2.71). Differences were significant between HL2 and HS2 (Z = 2.37, p<0.05) and HS and HS2 (Z = 2.21, p<0.05). HF again had a significantly lower trap success than HL (Z = 2.03, p<0.05) and HL2 (Z = 1.99, p<0.05). At the end of the second non-growing season (Figure 4.4d) the two unmown transects again had the highest mean trap success (HL = 34.00 ± 13.79: HL2 = 22.86 ± 3.29), followed by the cattle and game farm (HF = 2.00 ± 2.77). The two mown transects had the lowest mean trap success (HS = 1.00 ± 1.73; HS2 = 0.43 ± 0.79). HL had significantly higher trap success than HS (Z = 2.37, p<0.05) and HF (Z= 2.37, p<0.05). HL2 had a significantly higher trap success than HS (Z = 2.37, p<0.05). No other differences were significant.

At Eros, trap success was highest at the end of the first growing season (GS1) at the golf course (EG = 11.86 ± 7.17) and lowest at the Travel Lodge (EA = 0.71 ± 1.50)(Figure 4.4a). There were significant differences between EA and EG (Z = 2.37, p <0.05) as well as EA and EL (Z = 2.37, p <0.05). A Further significant difference was found between EG and ES (Z = 2.37, p <0.05). At the end of the first non-growing season (NG1) mean trap success was highest at the Travel Lodge (EA = 2 ± 2) and lowest at the on-airport mown transect ES (0.43 ± 0.79)(Figure 4.4b). There were significant differences between EA and EG (Z = 2.20, p <0.05), EA and EL (Z = 2.37, p<0.05), EA and ES (Z = 2.03, p< 0.05), EG and ES (Z = 2.37, p<0.05) and EL and ES (Z = 2.37, p<0.05). After the second growing season (GS 2) mean trap success was highest in the on-airport mown transect EL (13.43 ± 5.41) and lowest in the on airport unmown transect ES (2.86 ±2.61). The off airport transects resulted in mean trap success of 9.43 ±5.47 at the golf course (EG) and 2.29 ±1.50 at the Travel Lodge EA (Figure 4.4c). There were significant differences only between EG and ES (Z = 2.03, p< 0.05). After the second non-growing season (NG2) mean trap success was again highest in the on-airport mown transect EL (17.29 ± 5.25) and lowest in the on airport unmown transect where no small mammals were trapped (Figure 4.4d). There were significant differences between EA and EG (Z = 2.20, p<0.05), EA and EL (Z = 2.20, p<0.05), EA and ES (Z = 2.02, p<0.05), EG and ES (Z = 2.02, p<0.05) and EL and ES (Z = 2.02, p<0.05).

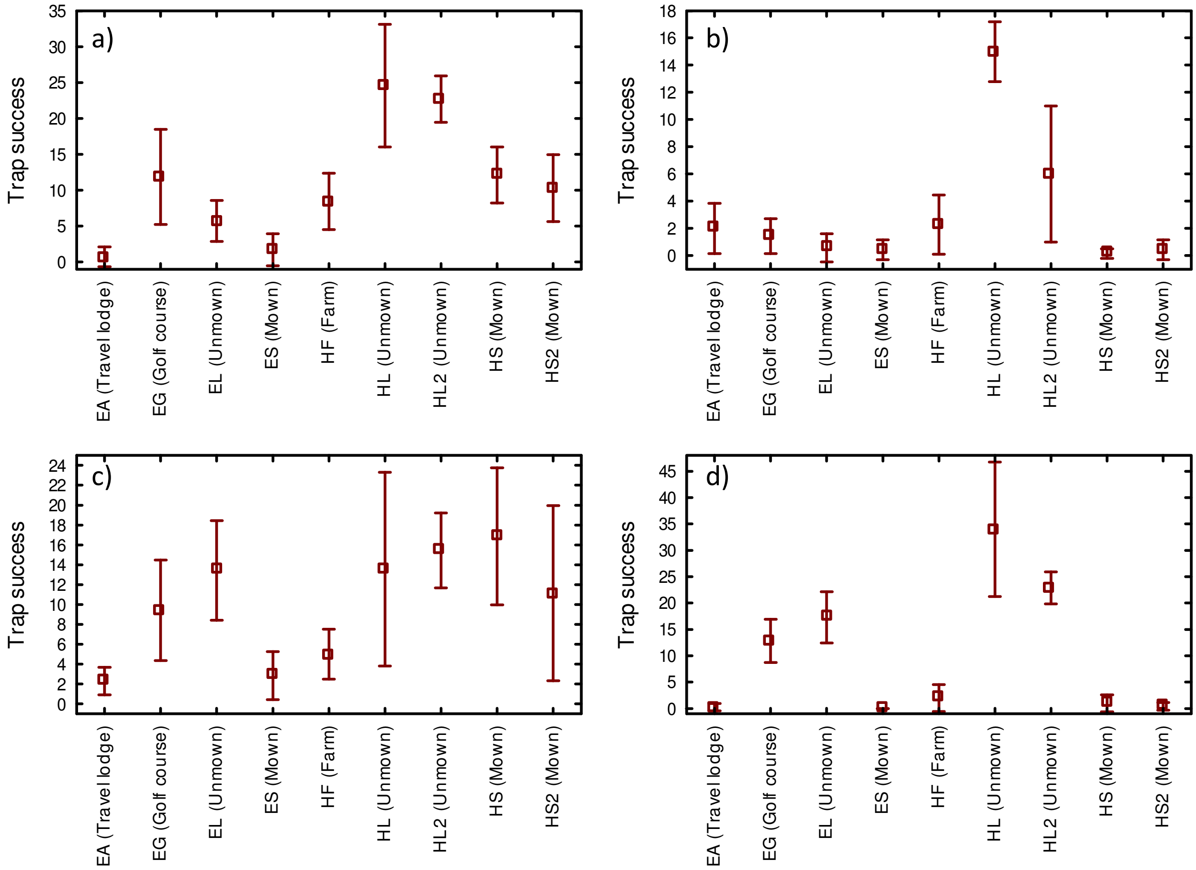


Figure 4.4: Mean daily small mammal trap success per transect at the end of four consecutive seasons. a) Growing season 1, GS1; b) Non-growing season 1, NG1; c) Growing season 2, GS2; d) Non-growing season 2, NG2. Box = 25% to 75% , whiskers = variance.

4.3.2 Species composition and richness

In total 11 species of small mammal were recorded (Table 1). This includes eight rodents (*Desmodillus auricularis, Mastomys coucha, Mus musculus, Mus indutus, Rhabdomys pumilio, Saccostomus campestris, Gerbilliscus leucogaster*, *Thallomys paedulcus*), one elephant shrew (*Elephantulus intufi*) and two unidentified shrews of the genus *Crocidura*. All of the above species besides *T. paedulcus* were trapped at Hosea Kutako; at Eros *Mus musculus* and the two species of *Crocidura* were not detected.

Except for the most common species *R. pumilio, M. coucha* and *G. leucogaster*, notable differences were observed where and when specific species were found (Table 1). For example, at Hosea Kutako: *D. auricularis* was only found at unmown sites, and also only at the end of the growing season; 80% of the *Mus indutus* individuals was found at unmown sites, at the end of the non-growing season; the commensal *M. musculus* was only found at unmown site HL2, relatively close to the freight store (Figure 4.1a). *Crocidura* sp.1 was found in unmown habitats, except at HS where a drainage line cuts through the habitat. Relatively large numbers of *E. intufi* and *S. campestris* were collected, in a range of habitats, at both airports; in contrast, only one individual of *T. paedulcus* could be trapped (on the banks of a dry riverbed at the Arebbusch Travel Lodge next to Eros Airport).

Both the dominant diurnal and nocturnal species, *R. pumilio* and *M. coucha* respectively (Table 1), were commonly trapped at all transects, at both airports. With both these species similar fluctuation curves were observed almost throughout and at all transects (Table 1; Figure 4.5 and 4.6), with numbers higher at the end of the growing season than at the end of the non-growing season.

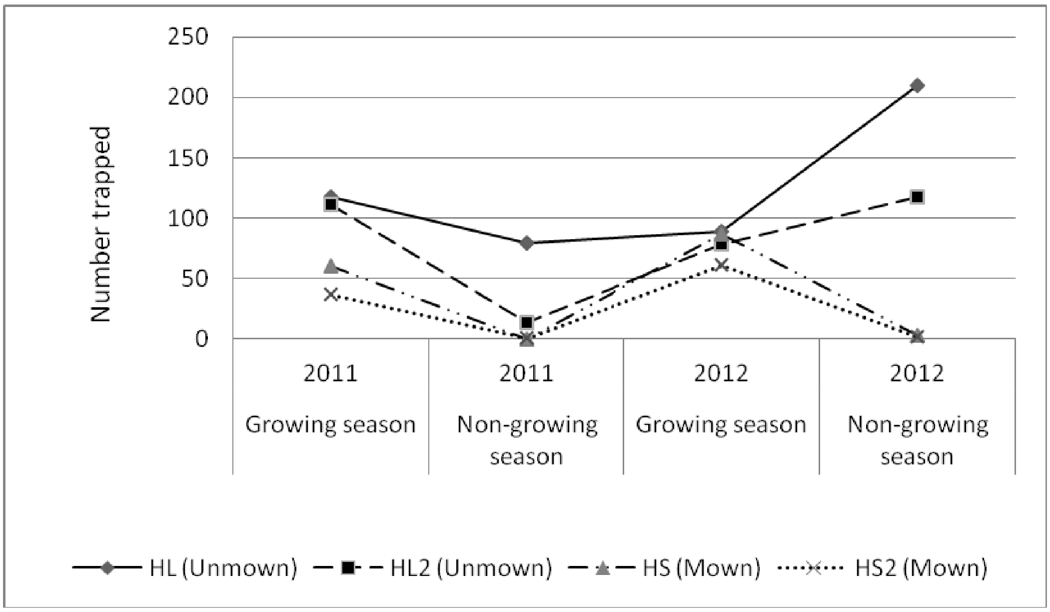


Figure 4.5: The number of *Rhabdomys pumilio* individuals trapped on standard transects at two mown and two unmown habitats at Hosea Kutako International Airport.

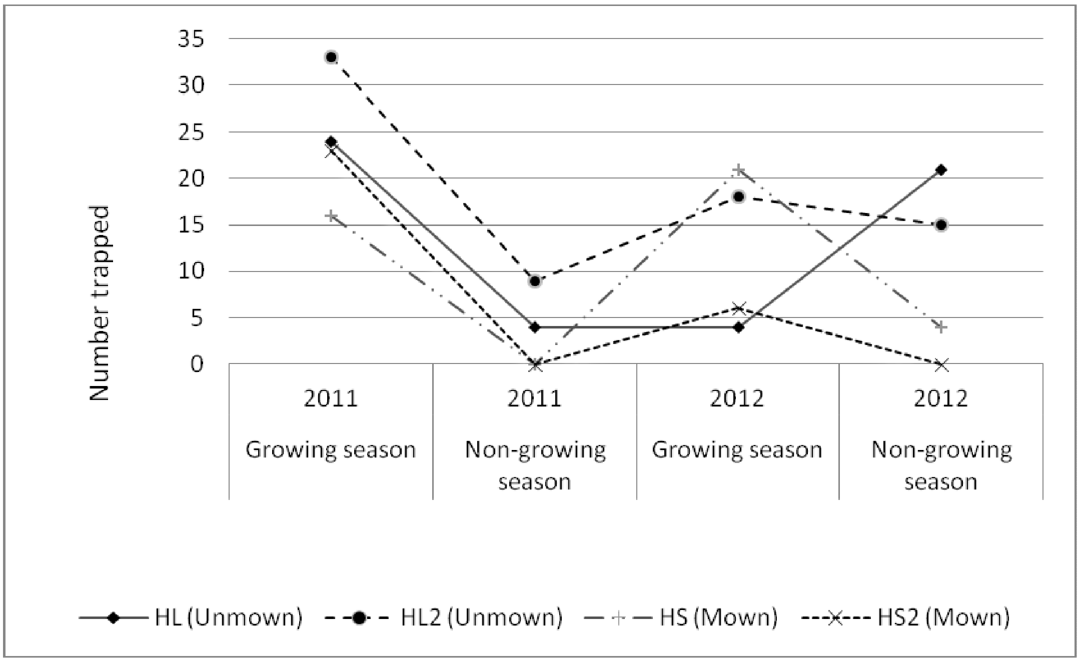


Figure 4.6: The number of *Mastomys coucha* individuals trapped on standard transects at two mown and two unmown habitats at Hosea Kutako International Airport.

When considering species richness, the pattern where richness decrease from the end of the growing season to the end of the following non-growing season, could be found at HF, HS1, HS2, EA, EG and ES (Figure 4.7). At HL, HL2 and EL such clear pattern could be found for one growing season – non-growing season only. Only at one site, and then during one season only, were the species richness higher at the end of the non-growing season than at the end of the growing season.

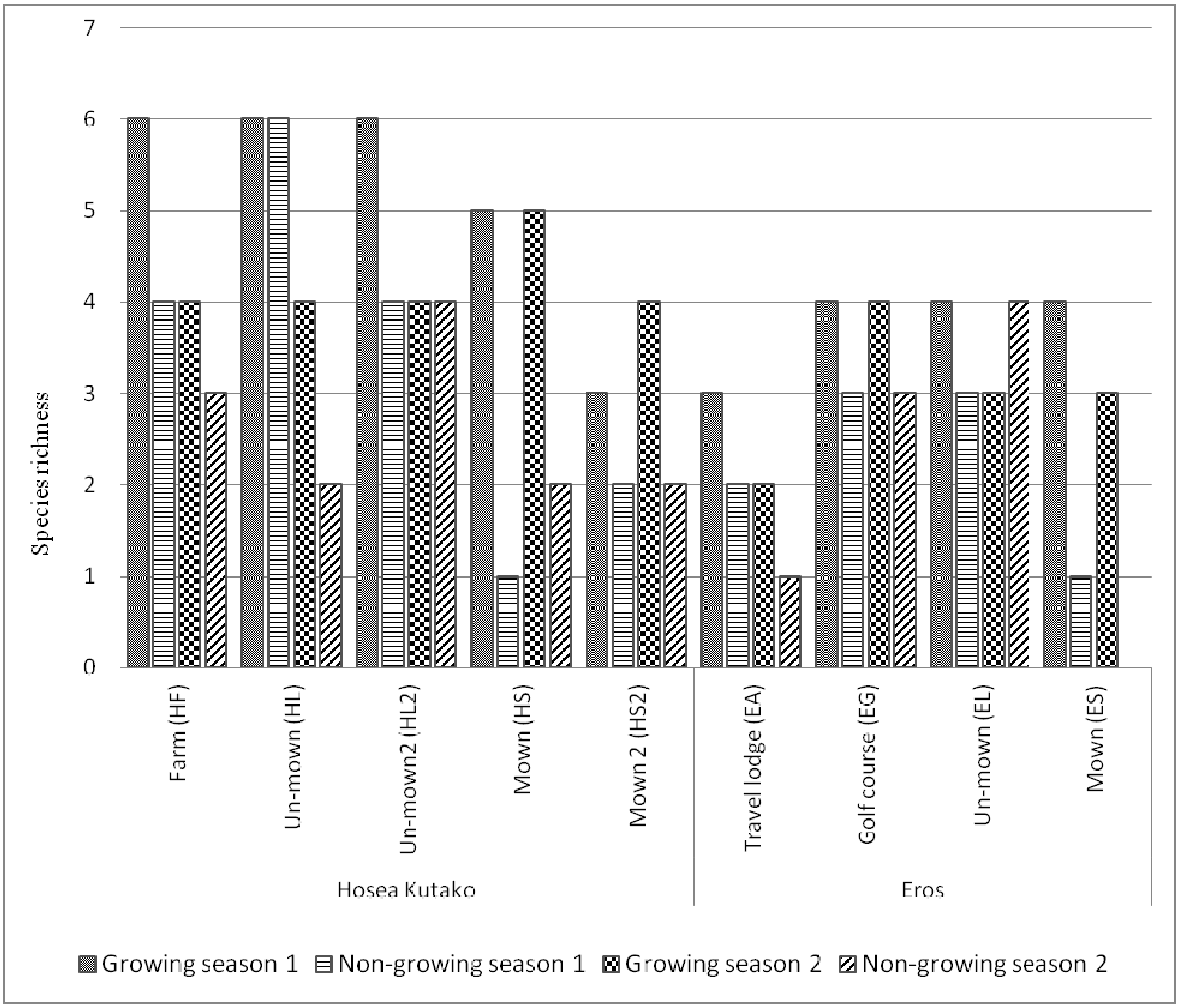


Figure 4.7: Small mammal species richness per transect and season on the nine standard 495m line transects.

Species richness was significantly higher at Hosea Kutako than at Eros in the first growing season ($Z = 3.67$, $p<0.01$) and the first non-growing season ($Z = 3.06$, $p<0.01$). In both seasons of the second year the difference was not significant.

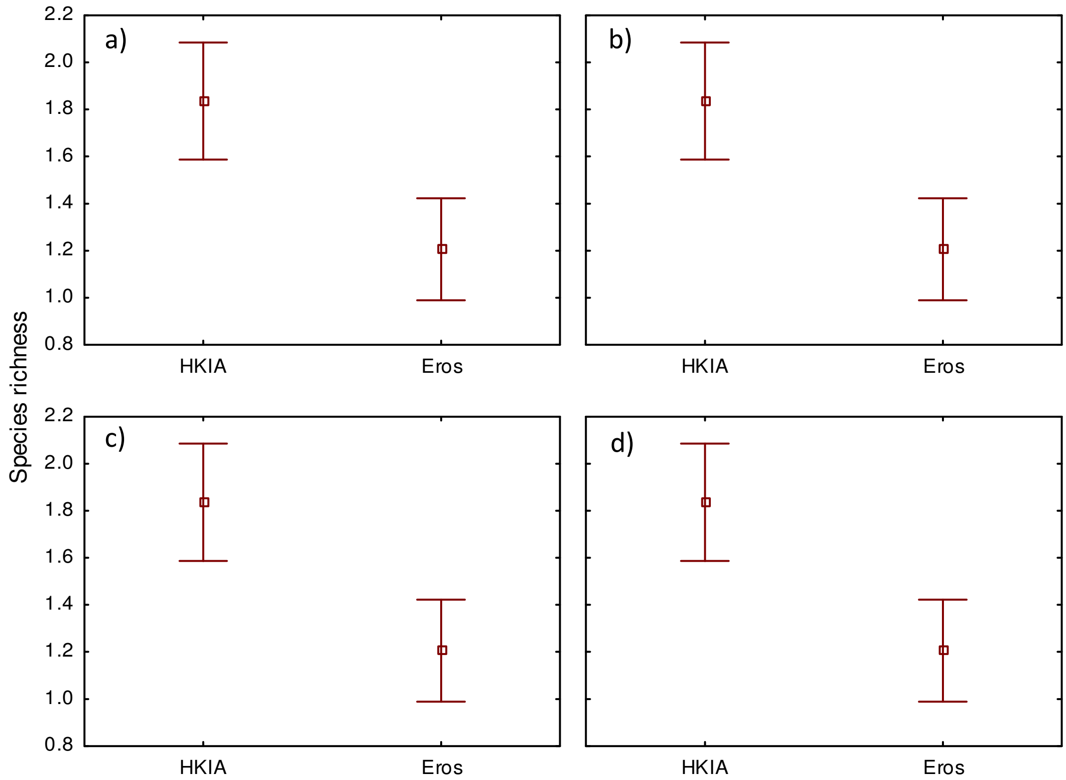


Figure 4.8: Mean small mammal species richness in: a) First growing season, GS1; b) First non-growing season, NG1; c) Second growing season, GS2; d) Second non-growing season, NG2. Whiskers indicate 95% confidence limits.

When broken down per transect for both growing seasons (Figure 4.9a) and both non-growing seasons (Figure 4.9b), the only significant difference in species richness was at Eros where the travel lodge EA showed significantly lower species richness that the golf course EG ($Z = 2.18$, $P<0.05$). At the end of the non-growing season species richness was significantly higher in the unmown transects than in the mown transects at Hosea Kutako (HL vs HS: $Z = 3.06$, $p<0.01$; HL vs HS2: $Z = 2.82$, $p<0.01$; HL2 vs HS: $Z = 3.18$, $p<0.05$; HL2 vs HS2: $Z = 2.71$, $p<0.01$) and at Eros between EL and ES ($Z = 2.93$, $p<0.01$).

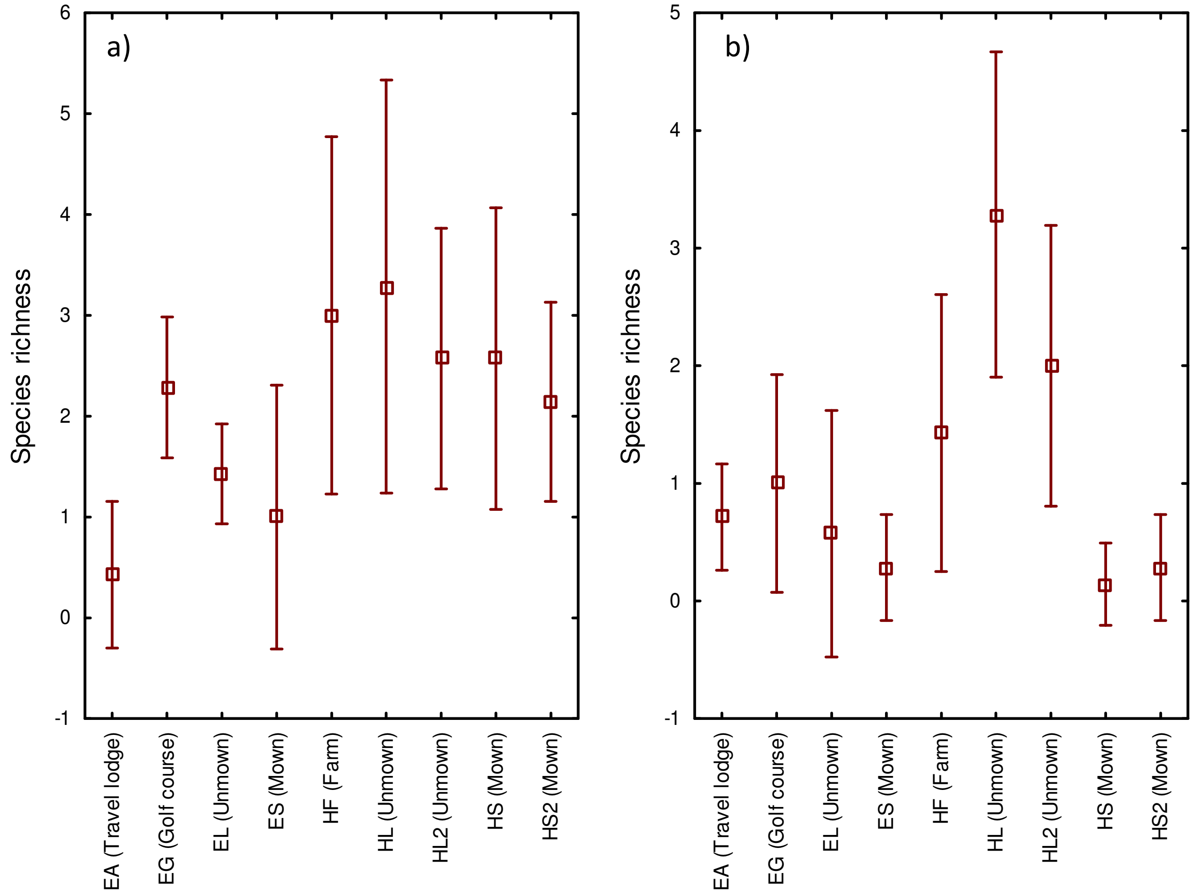


Figure 4.9: Mean (with 95% confidence) small mammal species richness on nine transects at Eros and Hosea Kutako airports at the ends of both (a) growing and (b) non-growing seasons.

4.3.3 Diversity

Shannon diversity was the highest during the first growing season per transect (1.22 – 1.91, mean: 1.43), and dropped during the first non-growing season (0 – 1.75, mean: 0.99) (Figure 4.10). It was marginally higher in the second growing season (0.42 – 1.57 mean: 1.06) and then dropped again, to its lowest value, in the second non-growing season (0 – 1.65, mean: 0.83). Big differences were observed between transects and, within transects, between seasons (Figure 4.11). At Hosea Kutako diversity was highest at the farm transect HF (1.26 – 1.91, mean: 1.62) and lowest in the mown transect HS (0 – 1.28, mean: 0.86); at Eros diversity was highest in the un-mown transect EL (1.22 – 1.65, mean: 1.41) and lowest at the mown transect ES (0 – 1.42, mean: 0.60). When compared within seasons, however, the following fairly common pattern appeared: at seven of the nine transects diversity dropped from the end of one growing season to the end of the next non-growing season. The decline was significant between GS1 and GS2 ($Z = 2.55$, $p<0.05$), and NG2 ($Z = 2.31$, $p<0.05$).

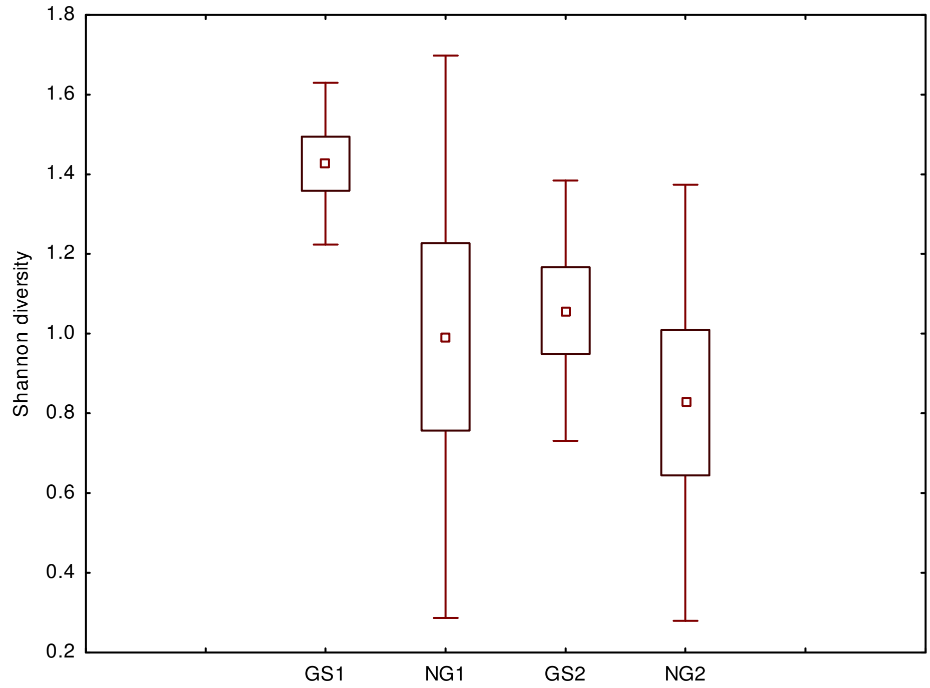


Figure 4.10: Mean small mammal Shannon diversity at the end of two growing and two non-growing seasons on nine transects at Hosea Kutako and Eros airports (Boxes = standard error, whiskers = standard deviation).

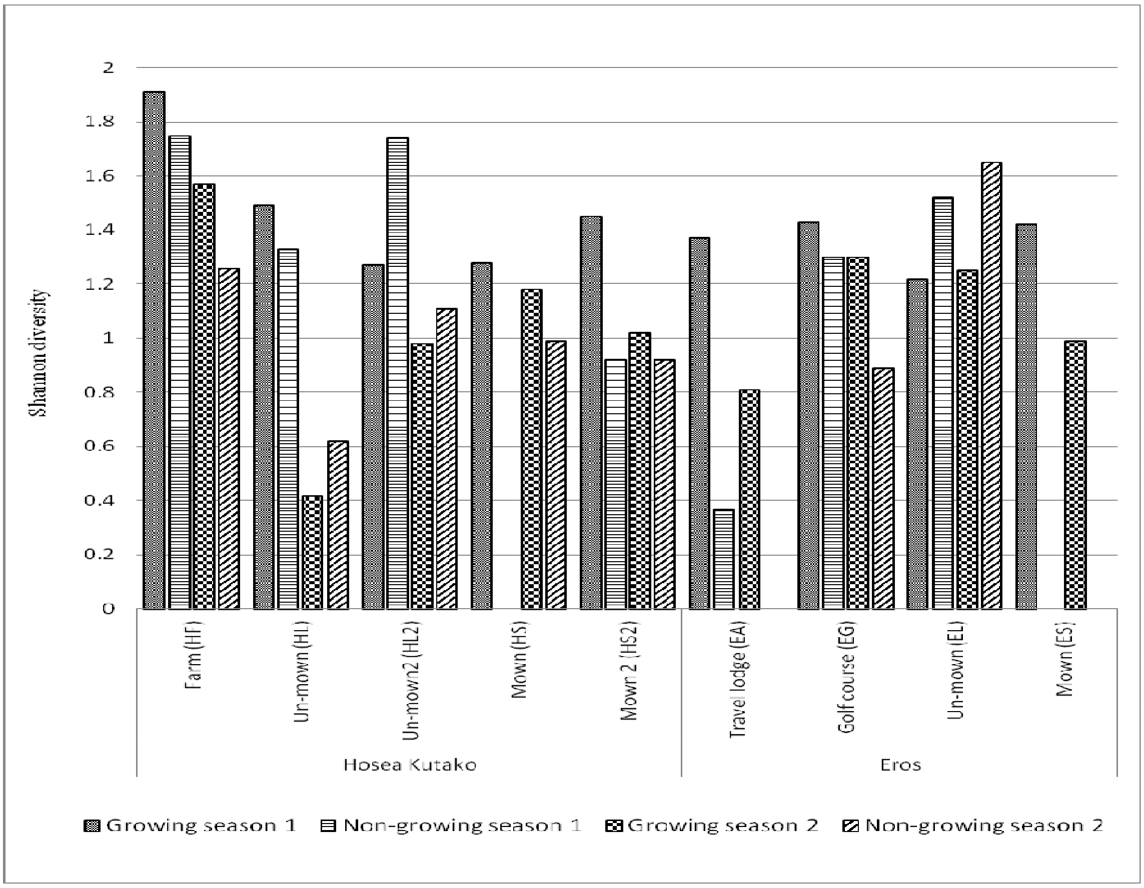


Figure 4.11: Shannon diversity of small mammals trapped at the two airports' nine transects over four seasons.

4.4 Discussion

4.4.1 Small mammal abundance

With very little information on small mammal trapping events at airports, it was difficult to contextualise the densities found during this study. Results of only one other small mammal survey at airports could be found in literature globally (Baker & Brooks 1981) while Seamans *et al.* (2007) studied small mammals in simulated airport vegetation regimes. Only Seamans *et al.* (2007) expressed small mammal density in trap success per 100 trap nights and, in that case, it was considerably lower than what was found during this study. This elevates the importance of small mammals at the Namibian airports studied, and confirms a conclusion of Mendelsohn *et al.* (2002) that Namibia's abundant wildlife is a unique aspect of the country.

The dominant species at both study sites (*R. pumilio*) was also found to be the only diurnal species present. With the majority of flights at both airports being during daylight hours (Hauptfleisch *et al.* 2013) it is considered an important attractant to bird species encountered at the airport. As the second most sighted avian species at Hosea Kutako (see Chapter 3), Black-shouldered Kite (*Elanus caeruleus*) preys predominantly on this species of small mammal (Tarboton 1978, Mendelsohn & Jaksic 1989). In addition, it has been found to make up a major proportion of prey for other common raptors such as African Marsh Harrier (*Circus ranivorus*)(Simmons *et al.* 1991), Barn Owl (*Tyto alba*)(Torok 1999, Avenant 2005). Of the other eight raptor species recorded at Hosea Kutako and Eros on numerous occasions, Yellow-billed Kite (*Milvus aegyptius*) (Dean 2005), Rock Kestrel (*Falco tinnuculus*)(Jenkins 2005), Greater Kestrel (*Falco rupicoloides*) (Jenkins 2005) Southern Pale-chanting Goshawk (*Melierax canorus*)(Allan 2005), Secretarybird (*Sagittarius serpentarius*) (Dean & Simmons 2005) are diurnal small mammal predators.

This study, at least for small mammals, confirmed what Price *et al.* (2010) described: that subtropical savannas are highly seasonal systems in flux, where water availability, soil nutrients, vegetation composition, fire, grazing regimes and topography play varying roles. The higher numbers, diversity and species richness of small mammals caught at the end of the growing season corresponds with the findings of Coetzee (1965), Swanepoel (1980), Bronner *et al.* (1988) and Avenant (2011) who, in the central South African grasslands, found the highest trap success and species richness in late-autumn (the end of the growing season), followed by a population reduction throughout winter and recovery thereafter (the reproductive peak is during the latter part of the rainy season and stops at the beginning of the dry season). This conforms to the findings of Coetzee (1965), Swanepoel (1980), Bronner *et al.* (1988) and others (e.g. Delany 1975, Taylor & Green 1976, Neal 1977) throughout Africa. These cycles could be coupled to the reproductive cycles of the dominant species trapped during this study, where scrotal males and reproductive active females are commonly observed between *c*. August to May, and young only present in traps from September to late-May / early-June (pers. obs., Avenant 2011). During winter the old and young individuals presumably dies off first, and drastic declines in populations have been reported (see Coetzee 1965, Neal 1977, Bronner *et al.* 1988, Avenant 2011). During July, the coldest month of the year (Mendelsohn *et al.* 2002) minimum temperatures are on average between 2 and 4^{o}C, confirming Andrews & O'Brien (2000) and Muck & Zeller (2006)'s comments that thermal seasonality may have an important influence on small mammal numbers. However, the current results shows that this seasonal pattern is not necessarily as simple and constant in central Namibia: in the final (2012) non-growing season an unexpected increase in small mammal numbers (particularly *R. pumilio* and *M. coucha*) was found at the unmown transects at both airports. A possible reason for this could be the above average rainfall event of 2011, when annual rainfall of 1221.8 mm was noted (weather.namsearch.com); 3.4 times the mean annual of 362.8 mm (Windhoek City – MOWT, 2012). Andrews & O'Brien (2000) and Yarnell *et al.* (2007) found that rainfall had a positive influence on small mammal population numbers, with species specific lag periods. More and late rain may extend the growing period, and the more food available may lengthen the small mammal reproductive season and decrease mortality during the dry winter months. Similarly, good early rains may lead to an early start of the reproductive season (Linn 1991). Wirminghaus & Perrin (1993) found that body fat and water levels, as affected by food quality, controlled breeding of small mammals, particularly r-selected species (such as *R. pumilio* and *M. coucha*). This may indirectly imply that predator species (e.g. raptor) occurrences at the airports, and hence bird collisions with aircraft, would be highest at the end of high rainfall seasons, and may also extend later into the dry season. It remains, however, important to note that healthy small mammal populations can exist at airports throughout the year (as also confirmed by Witmer 2011).

Another likely reason for the high numbers of small mammals in the second non-growing season during the present study may be the airport mowing regimen. Areas in the vicinity of runways and aircraft manoeuvring sites are mown annually, at the end of the growing season (personal observation 2010-2013). Not all grassland at either airport was mown, leaving patches of unmown grassland often adjacent to mown areas. Upon mowing at the end of the 2012 growing season, approximately eight weeks before the current small mammal survey, small mammals may have merely moved into adjacent unmown areas resulting in increased densities in these areas. Studies on small mammals elsewhere (e.g. on *Microtus spp.* in North America; Edge *et al.* 1995) found that, although mowing reduce their abundance, populations recover quickly thereafter. The dominant species at the two Windhoek airports, *R. pumilio*, for example has been found to move its home-range readily in relation to its requirements (Schradin & Pillay 2004, Schradin & Pillay 2006). Mown grass can provide nesting material and corridors for travel between unmown areas (Witmer 2011, Garratt *et al.* 2012). In the present study area the movement of small mammals to undisturbed "hotspots" of increased small mammal densities, when compared to neighbouring areas, can therefore not be excluded. Such "raptor restaurants" may increase the AWC risk. Baker & Brooks (1981) and Schmidt *et al.* (2013) warn that prey abundance should be considered in parallel to prey availability, as a high abundance of small mammals in dense grassland will be less vulnerable to predators than in sparse vegetation. This is considered less of a factor in the semi arid conditions of Hosea Kutako and Eros where grass density even in above average rainfall years is low when compared to the mesic and temperate environments where the studies by Baker & Brooks (1981) and Schmidt *et al.* (2013). Unpublished data on grass standing biomass at Hosea Kutako and Eros found grass standing biomass to vary between 56.2 and 458 kg / ha.

In light of the above, the effectiveness of grass mowing as a control measure for the risk of AWCs at airports (ICAO 1991) has, understandably, been found to have varied success and does not guarantee reduced risk (Blackwell *et al.* 2013, DeVault *et al.* 2013). Barras *et al.* (2000) and Dekker & Van der Zee (1996) report that no difference in the densities of birds in mown versus unmown areas have been proven. Where tall grass was found to interfere with feeding and ground movement of birds, it also provides nesting sites and food diversity for other species (Barras & Seamans, 2002). Mowing, or other means of reducing grass cover, has been found to reduce small mammal cover and food at airports (Blackwell *et al.* 2013) and decrease populations in general (Birney *et al.* 1976, Edge *et al.* 1995, Peles & Barrett 1996, Washburn & Seamans 2007, Garratt *et al.* 2012, Moorman *et al.* 2013). In the present study the significantly lower abundance of small mammals in mown compared to unmown transects at both airports, particularly in the non-growing seasons, indicates the effectiveness of mowing to reduce small mammal presence. The consequence of this is a likelihood for reduced raptor presence, with the dominant *R. pumilio* being an important prey component of Black-shouldered Kite (Tarboton 1978, Pickford *et al.* 1989, Hockey *et al.* 2005) and Southern Pale Chanting Goshawk (Malan 1998, Hockey *et al.* 2005) - which are regularly seen at Hosea Kutako and Eros airports (Chapter 3). Seamans *et al.* (2007) found a similar reduction in both small mammal and raptor species following mowing in late summer / early winter.

4.4.2 Richness and diversity

The mean total species richness across the five transects at Hosea Kutako (7 ± 1.7) and the four transects at Eros (4.5 ± 1.29) is high when compared to southern African studies in similarly semi arid areas by Avenant (2011) in the Kalahari (Sandveld and Koranaberg) (mean = 3.8), Nel (1978) in the Fynbos biome (mean = 3.6) and by Kerley (1992) in the Karoo (mean = 3.8); it is also high in comparison to a similar study at Toronto International Airport where a total of only four species were found (Baker & Brooks 1981). The results support the finding of Kelt *et al.* (1996) that arid areas produce high alpha small mammal diversity, coupled to a diverse vegetation community structure and broad resource spectrum (Abramsky 1978, Els & Kerley 1996). Avenant (2011) found species richness between 1 and 7 in a variety of grassland sites. He also observed that species richness in small mammal communities increased with succession until a state of climax, and then decreased to an expected point of equilibrium. Avenant (2005, 2011) then hypothesized that species richness will fluctuate around this point until disturbance such as caused by fire, drought or overgrazing, after which it may drop further before increasing again with succession. As such the well-known natural fire regime, that has shaped plant communities in the South African Grassland Biome, correlates also with small mammal community structure where specific species enter and leave a habitat during different stages of succession, causing species richness and diversity to increase with ecological integrity. Generalist species, such as *Mastomys coucha*, dominate at more disturbed areas, and specialist species such as *Dendromus melanotis* (expected in central Namibia; Monadjem 2013) increase in composition closer to climax conditions. Indicator species may also enter and exit the small mammal community at specific stages coupled to ecological value or integrity.

This dictates that species richness is highest in an ecosystem with regular light to moderate disturbance. The highest species richness in the unmown transects at Hosea Kutako supports this observation, as some disturbance through occasional fires and human disturbance do take place in these areas. If Tilman's curve (Tilman 1982, Tilman *et al.* 1996) is applied where species richness increases with ecosystem productivity, transects at Hosea Kutako would indicate that unmown areas within the airport have highest ecosystem productivity, with lowest productivity in the neighbouring game ranch. This will also correspond with Muck & Zeller (2006), in north central Namibia, who found that species richness of small mammals correlates positively with vegetation cover, and is supported by the findings of the vegetation component of this thesis (Chapter 5).

Although species richness and mean diversity in the current study were high in comparison to the South African grasslands (Avenant 2011), it was comparable to that of transects in cattle and wildlife farming areas of north-central Namibia (Muck & Zeller 2006). A number of indicators, however, point towards all transects being in disturbed conditions. Avenant (1996, 2000, 2011, Avenant & Cavallini 2007, Avenant *et al.* 2008) proposed the use of *Mastomys coucha* as an indicator of disturbed habitat. Similar to *M. natalensis*, this species was found to dominate in areas of low ecosystem integrity following natural habitat destruction caused by fire and human destruction (Meester *et al.* 1979, Bronner *et al.* 1988) and after long, extended dry periods (Monath *et al.*1974; Taylor & Green 1976, Linn 1991); their numbers later decreasing as other more specialized rodents (e.g. *Rhabdomys pumilio*) increase. In the current study this species was one of the three most numerous on all transects.

4.4.3 Impact of land use on small mammals

Land use around airports has been found to conflict with airport operations and safety (Blackwell *et al.* 2013). In the current study significant differences in small mammal community structure was found between different land use types in and outside the Hosea Kutako airport property. Inside the airport property densities, species richness and diversity were lower on mown (HS and HS2) than unmown transects (HL and HL2), indicating a higher level of disturbance. Outside, in the neighbouring game and cattle ranch, the significantly lower small mammal abundance was most probably caused by overgrazing [evident from a low ecological index value and high percentage (75.6%) of pioneer Increaser IIc grass species; see Chapter 5]. This corresponds with observations by Saetnan & Skarpe (2006), Hoffman & Zeller (2005) and Muck & Zeller (2006) in similar habitat types within Namibia, with *inter alia* Monadjem (1999) and Caro (2001) elsewhere in Africa, and with Moser & Witmer (2000) in North America.

At Eros the anthropogenically altered (urban) environment showed reduced small mammal numbers in general and confirmed the finding of Lizee *et al.* (2011) that mostly generalist species of wildlife inhabit urban areas. The artificially enhanced productivity of the ecosystem at the golf course (through fertilizer application and irrigation) houses higher small mammal numbers than the neighbouring airport, and possibly acts as a source population for the airport small mammals. It is also important to note that significantly more small mammal individuals and species were caught at the airport with rural surrounds (Hosea Kutako) than the airport in the urban setting (Eros).

Higher numbers of small mammals inside Hosea Kutako airport could further be affected by the lack of mammalian predators (such as Black-backed jackal and African wildcat) which cannot breach the wildlife control perimeter fence. This effectively makes the airport a refuge from most non-volant predators.

This study takes cognisance of the snapshot level of the small mammal survey (= during only two autumns and two springs). Naturally, more accurate conclusions can be drawn from longer term data (as recommended by Baker & Brooks 1981). The Wildlife and Aircraft Research Namibia (WARN) project (initiated as a mitigation measure in this study) is conducting longer term small mammal surveys to strengthen conclusions drawn at this stage. A factor which according to Devault *et al.* (2013) needs to be considered is the decreased accessibility of small mammals to raptors in long grass.

4.5 Conclusions and recommendations

Small mammal abundance was higher at the rural airport (Hosea Kutako) compared to the urban-situated Eros, they are a more important attractant for risk bird species, and need to be considered as part of the wildlife hazard management, especially at rural airports. At Hosea Kutako, high concentrations of small mammals (especially the diurnal *R. pumilio*) when compared to outside the airport fence suggest the airport is a sanctuary against grazing, fire and non-volant predation. At both airports late summer mowing reduced small mammal abundance and diversity through the non-growing season, but without additional early growing season mowing the effectiveness of mowing was greatly reduced through the growing season. Patchy mowing (where some areas of grassland around runways are mown and others not) was found to increase small mammal densities in the unmown areas (moving from mown areas), resulting in localised hotpots of exceptionally high small mammal abundance to which raptors may be drawn to hunt. Furthermore surrounding land use had an effect on small mammal abundance and diversity.

Small mammal abundance and consequently their predatory raptor species could be reduced at the airports by more frequent mowing (once in early summer and once in late summer at least) as well as complete (not patchy) mowing of all grassland areas on the airport properties. The sanctuary effect has been mitigated at golf courses and crop fields through installation of owl nest boxes and raptor perches. In this particular case such a measure is likely to be counter-productive.

CHAPTER 5: COMPARISON OF ECOSYSTEM FACTORS IN DIFFERENT LAND-USES IN AND AROUND TWO NAMIBIAN AIRPORTS WITH SPECIFIC REFERENCE TO VEGETATION, ARTHROPODS AND SMALL MAMMALS

Abstract

Linkages between ecosystem components such as vegetation structure and rangeland condition and arthropod and small mammal abundance and diversity were explored at Namibia's two main airports; an approach seldom adopted when considering the risk of collisions between aircraft and wildlife. The study found a significantly higher species richness, ecological productivity and ecological integrity at transects in and around Hosea Kutako airport (in rural surrounds) compared to Eros (in urban surrounds). The different land use surrounding the airports did, however, not result in a significant difference in overall diversity, productivity, species richness or ecological integrity inside the airport properties. Here, significant differences in small mammal abundance were found in mown and unmown areas. Differences in rangeland condition and productivity outside the airport properties depended on land use, which may have a considerable impact on aircraft wildlife collision risk.

Key words: arthropod, ecological index, ecosystem, Namibian airports, primary productivity, rangeland, risk, small mammal

5.1. Introduction

The association between ecosystem components vegetation structure and condition, insect abundance and diversity, and small mammal abundance and diversity were investigated within and around Hosea Kutako International and Eros (national) airports. The objective was to determine the attractiveness of various land uses around the airports (game and cattle farming, urban, and recreational) as well as mowing regimes within the airport property to address aircraft-wildlife collision (AWC) risk. This tactic has seldom been used (Soldatini *et al.* 2010). The current study is also the first ecological investigation into any aspect of AWCs in Namibia, and one of few in Africa (Hauptfleisch *et al.* 2013). It aims to understand the relationship between ecosystem components and their effect on the risk of AWCs occurring at Namibia's two largest airports, Hosea Kutako and Eros. As such it investigates resource availability and diversity for the identified damage-causing wildlife which, according to Siemann *et al.* (1998), should also indicate the abundance and diversity of consumers of those resources (including birds). Airports are described as peculiar habitats (Soldatini *et al.* 2010) and provide niches and ecosystem services such as primary food supply (grass / vegetation, insects, small mammals and carrion), water, shelter and nesting sites. The monitoring of ecosystem components that provide these services should consequently be useful to airport wildlife management.

Small mammal (including rodents, shrews and elephant shrews) sampling, for example, has been argued to be a relatively quick and inexpensive tool for determining ecosystem health and functioning in the southern African Grassland Biome (Avenant 2003, 2011) and can indicate varying environmental contexts and responses (De Graaff 1974, Ferreira & Avenant 2003). These taxa are valuable prey and predator species, but also dispersers of seeds, benefactors of soil nutrients and aeration, and habitat modifiers (see Weltzin *et al.* 1997 Avenant 2000, Witmer, 2011): in short, small mammals are an integral part of virtually all southern African terrestrial ecosystems, and understanding their community changes in response to natural and human induced changes is valuable in the search for an understanding of the underlying causes of AWC risk (Chapter 3). It has been suggested that, although time consuming, the inclusion of taxa such as vegetation and invertebrates in management studies could broaden this understanding, and where these results support that of a specific indicator for more rapid, attainable assessments, motivate for its continued use (e.g. Kuyler 2000, Kaiser 2006, Avenant & Schulze In prep).

Rangeland condition, a factor known to affect small mammal numbers and species (Eccard *et al.* 2000), was also assessed as an indicator of ecosystem function and primary productivity. With grazing being the predominant land use in savanna ecosystems throughout history (Hudak 1999), and an evolutionary driver of savanna grasslands (Kelly & Walker 1976), it is important to consider rangelands in any ecological investigation within this biome. They are indicative of and respond to a number of biophysical factors, such as biomass productivity, herbivory, vegetation, soil and moisture (Gibson *et al.* 1990, Bothma 1995, Snyman 1998, Fridley 2002, Landsberg & Crowley 2004, Lynam & Stafford-Smith 2004, Ash *et al.* 2004), in a complex way. Rangeland condition has been reported to be a major driver of vegetation composition (Milton & Hoffman 2010), production (Roberts 1970) and water-use efficiency (Snyman 1999). Plant primary production (a grazing component measured in this study) was also found to correlate positively with mammal biomass (e.g. Coe *et al.* 1976) and influence the composition of small mammal communities (Grant *et al.* 1982, Wang *et al.* 1999, Avenant 2000).

Diversity of vegetation and plant structure was, in turn, found to affect arthropod richness and diversity (Brose 2003, Kaiser *et al.* 2009, Buschke & Seaman 2011). Arthropods not only provide food for some birds, reptiles and mammals, but may also compete with them for food (Christensen & Whitham 1993). They account for the majority of faunal species and biomass in most ecosystems (Groombridge 1992 in Simmons *et al.* 1998, Dennis 2003) and their diversity tends to be reflected in higher trophic levels (Siemann *et al.* 1998). Chen *et al.* (2008) found a correlation between the number of birds and the number of insects in an ecosystem, while Jonas *et al.* (2002) found a significant positive correlation between plant diversity and richness, and macro-invertebrate species diversity and richness. At airports insects provide ecosystem services and food for birds and other wildlife (Bernhardt *et al.* 2010), were found to be attracted to the heat of runways and taxiways (Pennell & Rolston 2007), and use airport grasslands as refugia (Kutchbach-Brohl *et al.* 2010). Reductions in invertebrate numbers at airports is expected to reduce risk of AWCs (Buckley & McCarthy 1994, Bernhardt *et al.* 2010, Steele & Renner 2010, Washburn *et al.* 2011), and the possible influence of arthropods on AWCs can therefore not be ignored. This study investigates the diversity, richness and productivity of vegetation, arthropods and small mammals within different land use and management types within and around both airports.

5.1.1 Study area

Namibia is a largely arid country with unpredictable rainfall (Mendelsohn *et al.* 2002). Despite this it hosts a large diversity of living organisms; at least 292 mammal species, 644 bird species, 269 reptile species and 8064 insect species (Griffin 1998, Robertson *et al.* 1998, GRN In prep.).

Both airports are situated in the "Highland Shrubland" Tree and Shrub Savanna vegetation type of the savanna biome (Mendelsohn *et al.* 2002) which is characterised by low unpredictable rainfall (350-400 mm) (Mendelsohn *et al.* 2002). Dominant woody species include a number of *Acacia* species (e.g. *Acacia mellifera, Acacia hebeclada, Acacia hereroensis*) while climax grass species are dominated by *Anthephora pubescens*, *Brachiaria nigropedata*, and *Heteropogon contortus* (Joubert *et al.* 2008). This biome also carries the majority of Namibia's large mammal species.

Eros and Hosea Kutako International Airports are Namibia's largest and busiest airports. Hosea Kutako (22°28'S; 17°28'E) is Namibia's primary international airport. Situated in a rural setting, surrounded by commercial cattle and game farms approximately 40 km east of the capital city, Windhoek, the airport is the largest of Namibia's nine parastatal airports. Eros Aerodrome (22°36'S; 17°04'E) is primarily a local destination airport. It is situated in the capital city of Windhoek, and carries the highest flight volumes in Namibia (+/- 32 000 flights per year) (NAC pers.comm.). It is surrounded on three sides by suburban and business properties, and by the Windhoek Golf course on the other.

5.2. Material and methods

5.2.1 Vegetation surveys

A step point survey (Evans and Love 1957) was conducted in March/April 2011 (at the end of the growing season) on single line transects laid out in representative areas of similar environmental characteristics (soil type, topography), but different land use or vegetation management (see Chapter 4, Figure 1). At Hosea Kutako these were i) two areas within the airport where grass was not disturbed (labelled HL and HL2), ii) two areas where grass was mown annually (HS and HS2), and iii) one area in the neighbouring game and cattle ranch (HF). At Eros they were i) an area within the airport where grass was not disturbed (EL), ii) an area within the airport where grass was mown annually (ES), iii) a neighbouring golf course (EG) "rough", and iv) the neighbouring Arebbusch urban travel lodge (EA). Linear transects were preferred to grids as space utilization at airports are relative to runways, causing airport properties to be largely linear with long narrow ecotones. As the arthropod and small mammal surveys were done on the same transects (and at the same time), this arrangement was further important as larger areas are covered with the same number of small mammal traps (Pearson & Ruggiero 2003), increasing the opportunity to trap more small mammal species (as these are not homogenously distributed over an area – Avenant 2003, Avenant 2011).

The step point method is considered both rapid and accurate, and is commonly used in rangeland and forage quality determinations (Tainton 1999, Kaiser *et al.* 2009, Avenant *et al.* 2008). A mark on the observer's boot was used as a strike point, and the nearest grass plant (= the overwhelmingly dominant plant type at both locations) was identified at 250 points on each transect (Tainton 1999 and Zimmermann *et al.* 2001 found 200 points to be adequate). If no plant was found within 300mm of the strike point, it was marked as bare ground. The Ecological Index Method (Vorster 1982), as adapted by Bothma (1995, 2002) and Tainton (1999), was applied to the survey data. This method classifies and assigns relative index scores to grass species according to their ecological status (≈ response to grazing) (Trollope 1990, Bothma 1995, Tainton 1999). The ecological status groups recognised here, are i) Decreaser (mostly palatable perennial sub-climax to climax grass species which dominate in lightly grazed, generally healthy ecosystems; score = 10); ii) Increaser I (species which dominate in under-grazed ecosystems[2]; score = 7); iii) Increaser IIa (species which dominate in lightly overgrazed ecosystems; score = 4); iv) Increaser IIb (species which dominate in moderately overgrazed ecosystems; score = 4); v) Increaser IIc (mostly annual grass species which dominate in heavily overgrazed and disturbed ecosystems; score = 1); and vi) Invasive species (score = 1). Bare ground points were awarded a score of 0. As the classification of specific species may vary in different ecoregions, characteristics of grass species from Gibbs Russell *et al.* (1990), van Rooyen *et al.* (1991), van Oudtshoorn (1994), Klassen and Craven (2003) and Muller (2007) were used as reference to classify grass species in this study.

[2] In southern African rangelands under-grazing causes deterioration in ecosystem condition due to moribund effects and an increase in unpalatable grass species (Savory 1999).

Zimmermann *et al.* (2001) suggested including woody species in the assessment of rangeland condition in arid savannas, but as woody species were removed at both airports, it was not appropriate for this study.

5.2.2 Arthropod surveys

Arthropods (phylum Arthropoda – classes Arachnida and Insecta) were sampled using standard sweep netting (McGavin 1997) along the same transects as used in the vegetation and small mammal sampling (following Kaiser 2006, Buschke 2010). Five repetitions of 100 sweeps were taken on consecutive days during two consecutive months at the end of the growing season. Arthropods within each transect were sorted according to order (according to Scholtz & Holm 1985, Picker *et al.* 2002) and functional feeding group (FFG; according to Kaiser *et al.* 2009 and Buschke & Seaman 2011). Such classification has been proposed for rapid assessment of ecosystem function, diversity and richness in the grassland of South Africa (Seaman & Louw 1999). FFGs within different arthropod orders were assigned intolerance scores (weighting based on their expected occurrence in a healthy ecosystem; see Seaman & Louw 1999, Kaiser *et al.* 2009, Buschke 2010). Population density of each FFG was noted. Total SAGraSS (adding the intolerance scores of each taxa present) and FFG taxa richness scores were calculated for each transect.

5.2.3 Small mammal surveys

Small mammal mark-recapture surveys were conducted in order to determine the abundance and diversity of rodents and shrews both within and immediately around the two airports. One hundred ventilated stainless steel box traps (7.6x7.6x25.4 cm) were spaced 5 m apart on single line transects in each of nine different habitats (following Avenant 1996, 2000, Avenant & Cavallini 2007 and Seamans *et al.* 2007) during March 2011 (= the height of the growing season). The traps were baited with a mixture of peanut butter, rolled oats, sunflower oil and a meaty extract, Bovril® (for insectivores). Each trap was checked for successful trappings and re-baited at dawn and dusk for four consecutive days, in order to consistently sample diurnal and nocturnal small mammal species (following Muck & Zeller 2006, in similar habitat in Namibia, and Avenant 1996, 2000, 2011 in Free State grasslands). Captured specimens were identified, sexed and marked with fur pattern clippings to ensure identification of retrapped individuals. Mortalities were donated to the collection of the National Museum of Namibia.

The term "trap night" was used to describe one trap which was set for a 24 h-period (Rowe-Rowe & Meester 1982). Three measures of abundance were used, viz. trap success, species richness (or variety), and diversity. Trap success (or percentage success) is the number of small mammals captured per 100 trap nights (with 100 traps per transect, this equals the number of individuals caught per 24h-period on each transect). Species richness is the number of species collected, and diversity was calculated using the Shannon information index (Magurran 2004).

5.2.4 Ecosystem parameters

An indicator was selected for each ecological parameter, in order to allow comparison of vegetation, arthropod and small mammal data collected. Indicators selected were as follows:

- Vegetation (indicators dependent on species composition and not on biomass)
    - Diversity: Shannon information index - a commonly used index to describe ecological diversity (Spellerberg & Fedor 2003);
    - Productivity: Ecological index score - although the ecological index score is used for determination of rangeland condition (Vorster 1982, Bothma 1995, Tainton 1999, van Rooyen 2002), a clear positive relationship between rangeland condition and pasture productivity exists (Trollope 1990, Snyman and Fouche 1993, Snyman 1999, Tainton 1999);
    - Richness: The number of Poaceae species;
    - Ecosystem condition: Abundance percentage of Increaser IIc Poaceae species (classified as mostly annual pioneer species known to dominate in heavily disturbed or overgrazed rangeland). An increase in Increaser IIc species indicates a decrease in ecosystem condition (Trollope 1990, Tainton, 1999);
    - Evenness: A measure of how evenly abundance of species is distributed among all species (Magurran 2004).
- Arthropoda
    - Diversity: Shannon information index per order;
    - Productivity: Dry biomass per transect;

  - Richness: Total number of orders;
  - Ecosystem condition: SAGraSS score (Seaman & Louw 1999, Kaiser *et al.* 2009; Buschke & Seaman, 2011).
- Small mammals
  - Diversity: Shannon information index;
  - Productivity: Trap success, as an indication of abundance (= the number of individuals trapped per 100 trap nights);
  - Richness: The number of all rodent, shrew and elephant shrew species trapped.

5.2.5 Statistical analyses

Normality of data was determined with Shapiro-Wilk's W test. Vegetation variables were compared to each other using Pearson Product Moment Correlation. Differences in arthropod variables between the two airports was determined through the use of the Mann-Whitney U Test, comparison of land uses around each airport through Kruskal Wallis Analysis of Variance, and relationships between arthropod variables using Pearson Product Moment Correlation. Small mammal trap success and species richness was compared per trap event using Wilcoxon matched pairs test. The Pearson Product Moment Correlation Coefficient and Cluster Analysis (Single Euclidean Distance) was used to correlate selected ecosystem parameters, transects (land use) and airports (Hosea Kutako, Eros). All statistical analyses were completed using the computer program Statistica ® for Windows version 10. The 95% confidence level ($p<0.05$) was regarded as statistically significant for all tests.

5.3. Results

5.3.1 Vegetation

Twenty two (22) grass species were found on transects at Hosea Kutako, and 19 at Eros (Table 1). Species richness within the airport was 13 and 19 at the two mown grass transects (HS and HS2) and 16 and 14 within the unmown transects (HL and HL2). The neighbouring game and cattle farm (HF) had the lowest species richness (10 grass species) and a poor ecological index score (< 36% of the lowest value inside the airport property - HS); on both the mown and unmown transects inside the airport property the pasture quality can be described as good (see explanation below Table 1). The evenness of grass species was, however, highest at the game and cattle farm (0.78); transects within the airport varied in evenness only minimally (0.60 to 0.72). Shannon diversity of grasses were similar at all transects inside and outside the airport property.

A mean of 55.28% (± 2.08%) of individual grasses identified on transects within the Hosea Kutako airport property (HL, HL2, HS, HS2) were Decreaser species. In comparison, the cattle and game ranch transect (HF) had only 6.80% Decreaser grass species. Conversely, Increaser IIc grass species (mostly annual pioneer species) accounted for a mean of 37.30% (± 4.00%) of grasses within the airport (HL, HL2, HS, HS2), and 75.60% in the cattle and game ranch (HF).

Table 5.1: Comparison of grass species composition (indicated as percentage frequency) and pasture condition at nine transects (= various land uses) in and surrounding Hosea Kutako and Eros airports, Windhoek, Namibia. A, annual species; P, perennial species.

		Hosea Kutako					**Eros**			
Ecological status	**Species**	**Farm (HF)**	**Un-mown (HL)**	**Un-mown2 (HL2)**	**Mown (HS)**	**Mown 2 (HS2)**	**Travel lodge (EA)**	**Golf course (EG)**	**Un-mown (EL)**	**Mown (ES)**
Decreaser	*Anthephora pubescens(P)*	0	8	0.8	2	0.8	0	0	0	0
	Cenchrus ciliaris (P)	0	0.8	0	0	0.8	17.2	24.8	10.8	32
	Cynodon dactylon (P)	0	0	0	0	0	4.8	0	0.8	0
	Eragrostis nindensis (P)	0	0.8	0	0	0.4	0	0	0	0
	Fingerhuthia africana (P)	0	0	0	0	0	0	0	0	1.2
	Heteropogon contortus (P)	0	1.2	1.2	18.4	0.4	0	0	0	1.6
	Panicum coloratum (P)	0	0	0	0	0.4	24	0	0	0
	Pennisetum clandestinum(P)	0	0	0	0	0	0	1.2	0	0

		Hosea Kutako						Eros		
Ecological status	**Species**	**Farm (HF)**	**Un-mown (HL)**	**Un-mown2 (HL2)**	**Mown (HS)**	**Mown 2 (HS2)**	**Travel lodge (EA)**	**Golf course (EG)**	**Un-mown (EL)**	**Mown (ES)**
	Schmidtia pappophoroides (P)	6.8	39.2	48	35.2	51.2	1.6	7.6	2.4	0.8
	Stipagrostis uniplumis (P)	0	5.6	2	1.2	1.6	0	9.6	4.8	0
Increaser 1	*Aristida meridionalis(P)*	1.2	0	0	0	0	0	0	0	0
	Paspalum scrobilatum (P)	0	0	0	0	0	2.4	0	0	0
Increaser 2a	*Eragrostis rotifer(P)*	0.8	0	0	0	2	0	0	3.6	0
	Eragrostis superba (P)	0	1.6	0.8	5.2	0.8	3.2	0	0.8	0.8
Increaser 2b	*Eragrostis echinochloidea (P)*	0	0	0	0	0.4	0	7.6	0	10.8
	Eragrostis rigidior(P)	15.6	8	4	1.2	6.4	0	0	0.4	0.8
Increaser 2C	*Aristida adscensionis (A)*	0	2.4	1.2	1.2	2	0	0	0	0
	Aristida congesta (A)	10	0	0	0	0	0	0	0	0
	Chloris virgata (A)	4.8	0.4	0.4	0.8	0.4	0	4.4	11.6	0.8
	Enneapogon cenchroides(A)	0	0	1.2	0	3.6	0	0	0	0
	Eragrostis porosa (A)	2	2	0.8	0.8	0.4	0.4	0	6.4	0.4
	Eragrostis trichophora	21.2	1.6	0.4	1.2	2	3.6	31.2	11.2	14.8
	Melinis repens(P)	2	20	22.8	28.8	14	6	0	11.6	0.8
	Microchloa caffra(P)	0	0.4	0	1.2	0	0	4.8	4.8	0.8

		Hosea Kutako					Eros			
Ecological status	**Species**	**Farm (HF)**	**Un-mown (HL)**	**Un-mown2 (HL2)**	**Mown (HS)**	**Mown 2 (HS2)**	**Travel lodge (EA)**	**Golf course (EG)**	**Un-mown (EL)**	**Mown (ES)**
	Pogonarthria fleckii (A)	35.6	4.8	3.2	2.4	4.8	0	0	0	0
	Urochloa brachyura (A)	0	3.2	13.2	0	7.6	20	8.4	30.8	35.2
Ecological Index score[3]		214	621	598	697	630	578	515	278	466
Percentage Decreasers		6.80	55.20	53.06	59.92	55.65	43.60	43.60	18.00	35.89
Percentage Increaser IIc		75.60	36.80	42.86	38.40	34.68	32.00	48.80	76.40	52.42
Species richness		10	16	14	13	19	11	9	13	12
Shannon diversity		2.59	2.86	2.30	2.50	2.60	1.97	2.72	3.06	2.29
Evenness		0.78	0.72	0.60	0.66	0.61	0.82	0.86	0.83	0.64

At Eros Airport (urban) the Ecological Index score on transects within the airport was lower than the transects on the outside. Here the unmown transect within the airport had a poor score, of 278 out of 1000. On the mown transect the score of 466 indicated pasture in low-average condition. The Golf Course transect (rough, unkept area adjacent to fairway) showed a score of 515 and the Travel Lodge a score of 578, both indicating rangeland in high-average condition. Decreaser grasses accounted for 18.80% of the unmown (EL) area of the airport, and Increaser IIc grasses (indicative of disturbance) 76.40%. The remaining transects (EA, EG and ES) showed a balance of Increaser and Decreaser species. Species richness was highest on the transects inside the airport fence, and Shannon diversity was highest on unmown transect (also inside the fence). Evenness was lowest on the unmown transect of the airport (0.64) and ranged between 0.82 and 0.86 on the other three transects.

[3] An ecological index score of 0 to 399 is roughly categorised as poor quality pasture (grazing), 400 to 600 as average, and 601 to 1000 as good quality pasture (Bothma, 1995).

The Ecological Index score correlated significantly with the relative contribution of (1) Decreasers ($r = 0.99$, $p < 0.01$) and inversely with (2) relative contribution of Increaser IIc's ($r = -0.95$, $p < 0.01$), but not with species richness or diversity (all transects at both airports included). Grass species richness correlated inversely with evenness ($r = -0.66$, $p < 0.05$), but no significant correlation was found with Shannon diversity or the relative contribution of Decreaser or Increaser IIc grasses. In addition to the negative correlation with species richness, evenness did not correlate to diversity, Ecological Index score or the relative contribution of Decreasers or Increaser IIc's.

5.3.2 Arthropods

All 12 arthropod orders were found at both airports (Table 2). Although more individuals were sampled on the Eros transects (mean - 8230.50 ± 5034.52 vs 2505 ± 595.70), both the mean biomass (19.12 g ± 8.57 g vs 10.46 g ± 3.25 g) and diversity (2.48 ± 0.16 vs 1.73 ± 0.54) were highest at Hosea Kutako. Insecta contributed the most individuals at all transects (both sites), with Arachnida (all from the Araneae order) contributing between 1.48% and 6.57% of the total number of individuals collected. Of the class Insecta, Psocoptera dominated at the Travel Lodge transect (EA)(61.24%). Hymenoptera dominated most other transects at Eros (30.2% to 68.31% of individuals collected), while at Hosea Kutako bugs (Hemiptera – 12.96% to 52.81% of individuals collected), Orthoptera (3.3% to 17.71%), Hymenoptera (9.35% to 41.13%) and Coleoptera (7.03% to 28.84%) were collected in high numbers.

Table 5.2: Percentage contribution of arthropod orders on nine different transects at Hosea Kutako and Eros airports. The number of individuals collected are in parentheses.

	Hosea Kutako					Eros			
Orders	**Farm (HF)**	**Un-mown (HL)**	**Un-mown2 (HL2)**	**Mown (HS)**	**Mown 2 (HS2)**	**Travel lodge (EA)**	**Golf course (EG)**	**Un-mown (EL)**	**Mown (ES)**
Class - Arachnida									
Araneae	2.49 (74)	3.09 (93)	2.39 (37)	2.7 (71)	4.98 (118)	1.48 (215)	6.57 (151)	2.35 (208)	1.66 (121)
Class - Insecta									
Coleoptera	7.03 (209)	10.86 (327)	28.84 (447)	27.48 (722)	26 (616)	11.67 (1694)	16.71 (384)	3.66 (323)	3.63 (264)
Diptera	9.22 (274)	7.34 (221)	11.55 (179)	5.79 (152)	4.09 (97)	1.95 (283)	16.88 (388)	7.1 (627)	3.52 (256)
Hemiptera	52.81 (1570)	12.96 (390)	22.90 (355)	29.88 (785)	34.7 (822)	3.95 (574)	13.36 (307)	11.52 (1018)	19.39 (1410)
Hymenoptera	9.35 (278)	41.13 (1238)	10.06 (156)	15.57 (409)	15.75 (373)	18.11 (2629)	30.2 (694)	62.3 (5504)	68.31 (4966)
Lepidoptera	0.94 (28)	0.83 (25)	2.06 (32)	0.27 (7)	0.59 (14)	0.1 (15)	0.88 (20)	0.12 (11)	0.03 (2)
Mantodea	0.23 (7)	0.07 (2)	0.26 (4)	0.15 (4)	0.08 (2)	0.2 (29)	0.17 (4)	0.01 (1)	0.04 (3)
Neuroptera	0.07 (2)	0.03 (1)	0.06 (1)	0.04 (1)	0.04 (1)	0.01 (1)	0 (0)	0 (0)	0 (0)
Orthoptera	3.3 (98)	17.71 (533)	17.55 (272)	12.07 (317)	7.43 (176)	0.32 (47)	1.61 (37)	1.14 (101)	0.92 (67)
Phasmatodea	0.13 (4)	0.03 (1)	0.13 (2)	0.11 (3)	0.76 (18)	0 (0)	0.09 (2)	0 (0)	0 (0)
Psocoptera	0.03 (1)	3.72 (112)	0.32 (5)	3.01 (79)	0.3 (7)	61.24 (8892)	10.40 (239)	10.32 (912)	0.92 (67)
Thysanoptera	14.4 (428)	2.23 (67)	3.87 (60)	2.93 (77)	5.28 (125)	0.97 (141)	3.13 (72)	1.46 (129)	1.57 (114)
Number of individuals sampled	2973	3010	1550	2627	2369	14250	2298	8834	7270

	Hosea Kutako					Eros			
Orders	**Farm (HF)**	**Un-mown (HL)**	**Un-mown2 (HL2)**	**Mown (HS)**	**Mown 2 (HS2)**	**Travel lodge (EA)**	**Golf course (EG)**	**Un-mown (EL)**	**Mown (ES)**
Biomass (g dry mass)	8.49	31.86	21.22	18.66	15.37	9.01	6.72	12.02	14.1
SAGraSS score (mean)	25.25	28.7	25.65	23.5	24.35	33.75	28.4	28.2	21.5
Order richness (mean)	6.4	7.1	5.95	6.35	6.5	8.16	6.9	7.45	6.3
Shannon diversity (orders)	2.2	2.5	2.6	2.6	2.5	1.7	2.5	1.4	1.3

Arthropod order richness ($U_{1,360}$ = 12689.5, $p < 0.001$) (Figure 2a) and abundance (individuals of all orders per 100 sweeps) ($U_{1,360}$ = 5876, $p < 0.001$) (Figure 2b) were both higher at the Eros transects than at the Hosea Kutako transects. As an indicator of productivity, arthropod biomass was significantly higher at Hosea Kutako ($U_{1,73}$ = 451, $p < 0.05$) (Figure 2c). No difference in SAGraSS score could, however, be found between the two airports (Figure 2d).

When comparing transects (=different land use areas) at each airport, order richness did not vary significantly at either of them (Figure 3a). At the Eros study site arthropod abundance (Figure 3b) was significantly higher at the Travel Lodge, EA, compared to the golf course ($H_{8,360}$ = 117.39, $p < 0.001$). The golf course, again, showed significantly lower arthropod abundance than the two transects on the airport property ($H_{1,360}$ = 117.39, $p < 0.001$) in both instances). No difference could be detected between any of the Hosea Kutako transects.

When comparing ecosystem condition (≈ SAGraSS scores) between transects at the Eros study site, EA (Travel Lodge) only showed a significantly higher SAGraSS score than ES (mown grass transect within Eros airport property) ($H_{8,180}$ = 25.07, $p < 0.001$) (Figure 3c). No significant differences were found in ecosystem condition between transects on or surrounding Hosea Kutako. Arthropod biomass also did not differ significantly between any of the transects at either airport, although HF (neighbouring farm) produced consistently lower biomass than HL1 (unmown transect on the airport property) (Figure 3d). Biomass was significantly higher on the airport property transects at Hosea Kutako ($U_{1,40}$ = 56, $p < 0.05$) and Eros ($U_{1,32}$ = 53, $p < 0.05$) than on the transects outside the airport. No difference between mown and unmown "on airport" transects were found for arthropod abundance, order richness biomass or ecosystem condition ($p<0.05$).

A significant positive correlation was found between arthropod abundance and order richness when comparing all transects / land uses ($r = 0.80$, $p<0.05$). No significant relationship existed between arthropod order richness and biomass of collected individuals, abundance and biomass, or SaGraSS score and biomass, or SaGraSS score and abundance of arthropods.

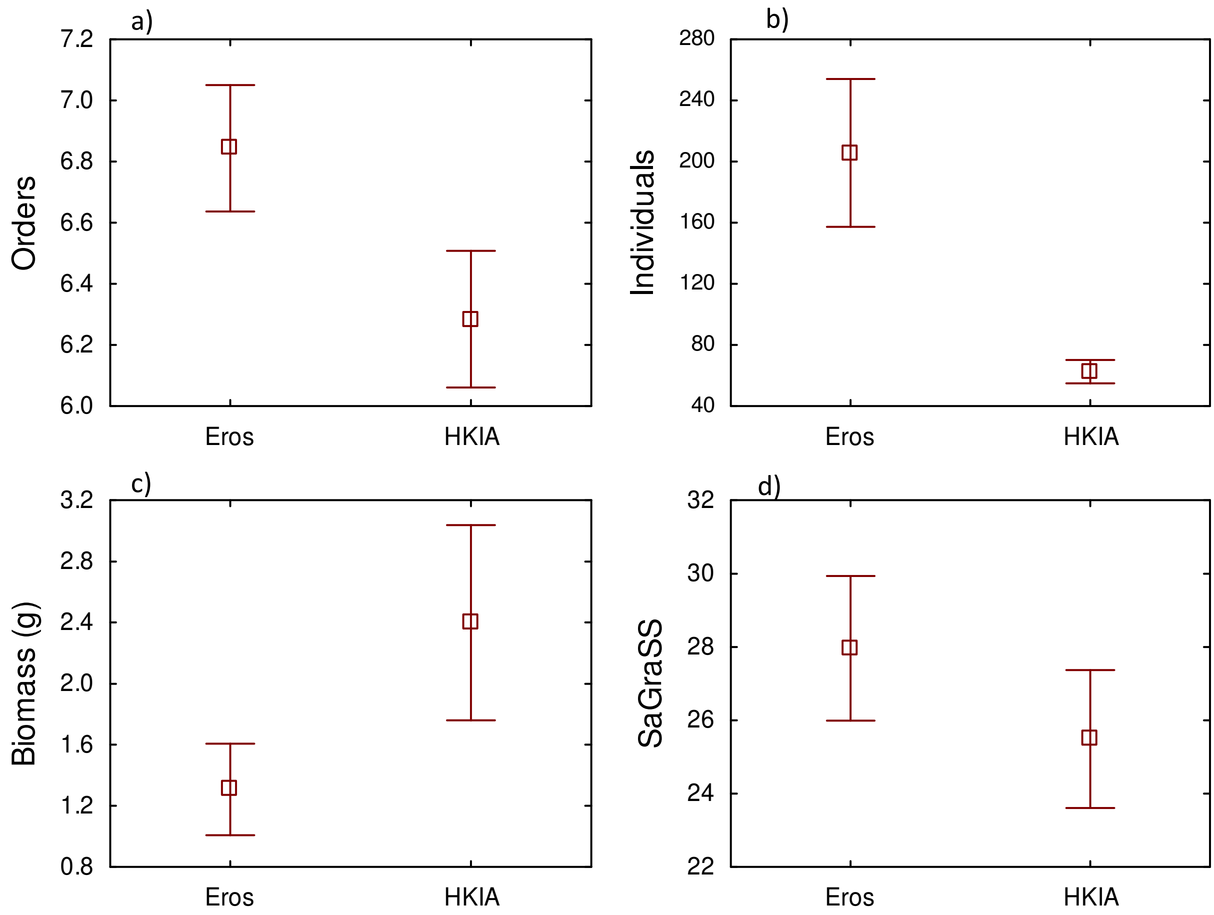


Figure 5.1: Combined mean (± 95% confidence interval) arthropod (a) order richness per 100 sweeps, (b) number of individuals per 100 sweeps, (c) biomass per 100 sweeps and (d) SAGraSS score for all transects at Hosea Kutako and Eros airports, respectively.

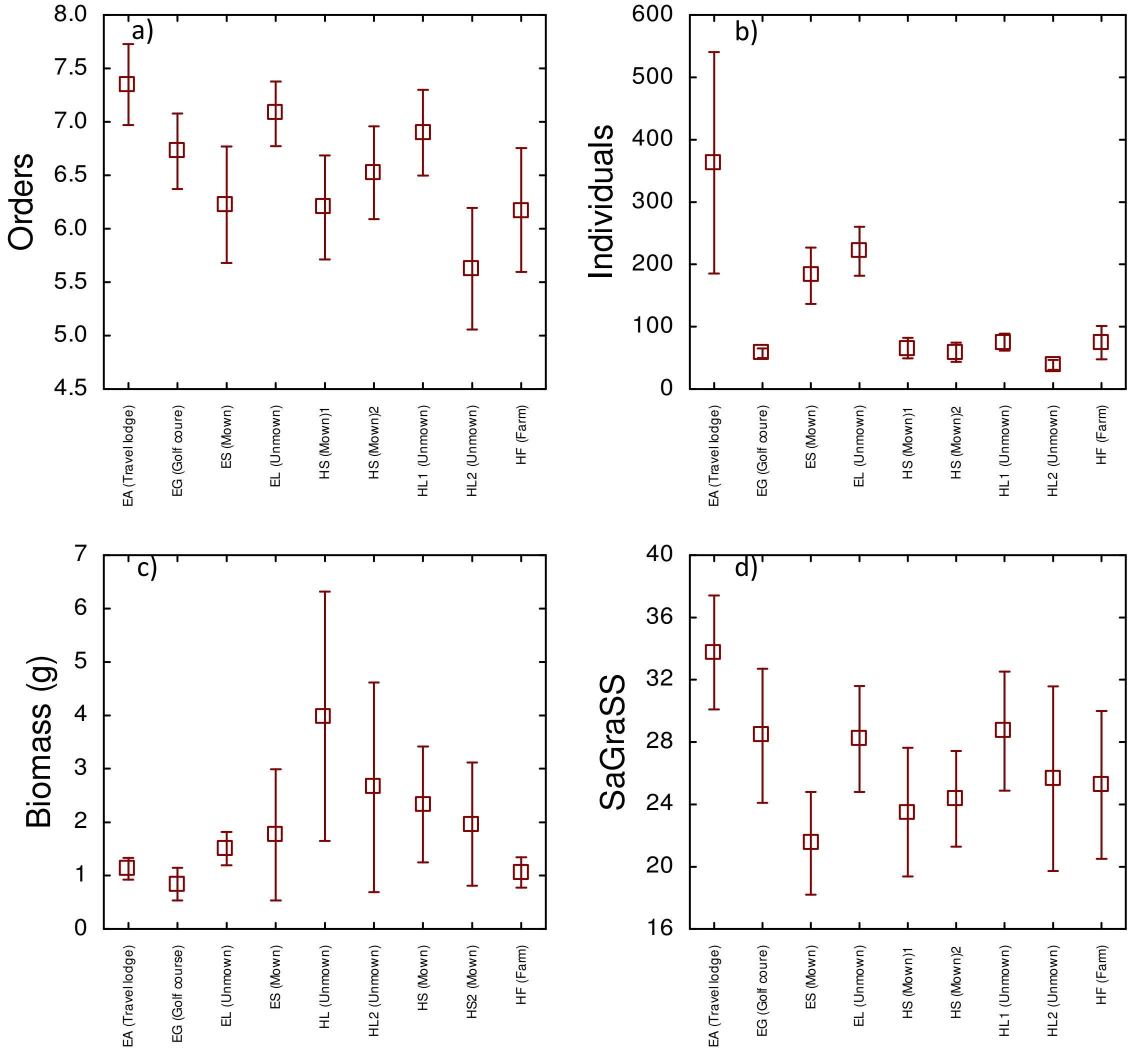


Figure 5.2: Mean (± 95% confidence interval) arthropod (a) order richness per 100 sweeps, (b) number of individuals per 100 sweeps, (c) biomass per 100 sweeps and (d) SAGraSS score on five and four transects at Hosea Kutako and Eros airports, respectively.

5.3.3 Small mammals

Six species of the order Rodentia were trapped, two species of the order Eulipotyphla and one species of the order Macroscelidea . Diurnal *Rhabdomys pumilio* and nocturnal *Mastomys coucha* was the dominant diurnal small mammal species trapped at Hosea Kutako and Eros, respectively (Table 3); *Elephantulus intufi* was the dominant insect eating small mammal at both airports.

Table 5.3: Percentage contribution of small mammal species trapped on different transects (≈ different land uses) in and surrounding Hosea Kutako and Eros airports. The actual numbers trapped are given in brackets.

	Hosea Kutako						Eros		
Species	**Farm (HF)**	**Un-mown (HL)**	**Un-mown2 (HL2)**	**Mown (HS)**	**Mown 2 (HS2)**	**Travel lodge (EA)**	**Golf course (EG)**	**Un-mown (EL)**	**Mown (ES)**
Order - Rodentia									
Desmodillus auricularis	0 (0)	0 (0)	1.26 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	8.33 (1)
Mastomys coucha	30.51(18)	13.95(24)	20.75 (33)	18.82(16)	31.94(23)	60 (3)	60.24(50)	40 (16)	66.67(8)
Mus indutus	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5 (2)	8.33 (1)
Rhabdomys pumilio	45.76(27)	68.6(118)	69.81(111)	70.59(60)	51.39 37)	20 (1)	27.71(23)	55 (22)	16.67(2)
Saccostomus campestris	3.39 (2)	6.4 (11)	0.63 (1)	7.06 (6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Gerbilliscus leucogaster	5.08 (3)	8.14 (14)	6.92 (11)	0 (0)	16.67(12)	0 (0)	8.43 (7)	0 (0)	0 (0)
Order - Eulipotyphla									
Crocidura sp1	1.69 (1)	0.58 (1)	0.63 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Crocidura sp2	0 (0)	0 (0)	0 (0)	1.18 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Order - Macroscelidea									
Elephantulus intufi	13.56 (8)	2.33 (4)	0 (0)	2.35 (2)	0 (0)	0 (0)	3.61 (3)	0 (0)	0 (0)
Species richness	6	6	6	5	3	2	4	3	4
Shannon diversity (species)	1.91	1.49	1.27	1.36	1.45	0.72	1.43	1.23	1.42
Trap success	0.7	2.1	1.9	1.22	0.83	0.05	0.9	0.42	0.12

Significantly more small mammals were trapped ($U_{1,63} = 137.5$, $p < 0.001$) (Figure 5.2a) and species richness found ($U_{1,63} = 249.5$, $p < 0.001$) (Figure 5.2b) at Hosea Kutako than at Eros when results from all transects were included in the analyses. Within the airport properties, higher trap success was also found at unmown transects compared to mown transects ($H_{2,63} = 13.83$, $p < 0.05$).

When comparing transects within each airport, mean daily trap success at Hosea Kutako was highest in the two unmown transects (HL = 24.57 ± 9.22; HL2 = 22.71 ± 3.50), followed by the two mown transects (HS = 12.14 ± 4.22; HS2 = 10.29 ± 5.02)(Figure 5.3c). The game and cattle farm (HF) showed the lowest trap success at the Hosea Kutako study site (HF = 8.43 ± 4.24)(Figure 4.4a). This was significantly lower than HL ($Z = 2.37$, $p<0.05$), HL2 ($Z = 2.37$, $p<0.05$) and HS ($Z = 2.20$, $p<0.05$). Further significant differences were observed between HL and HS ($Z = 2.20$, $p<0.05$), HL and HS2 ($Z = 2.37$, $p<0.05$), HL2 and HS ($Z = 2.37$, $p<0.05$), HL2 and HS2 ($Z = 2.37$, $p<0.05$). At Eros, trap success was highest on the golf course (EG = 11.86 ± 7.17) and lowest at the Travel Lodge (EA = 0.71 ± 1.50)(Figure 5.3c). There were significant differences between EA and EG ($Z = 2.37$, $p <0.05$) as well as EA and EL ($Z = 2.37$, $p <0.05$). A further significant difference was found between EG and ES ($Z = 2.37$, $p <0.05$).Within airports, species richness did not differ significantly between transects (Figure 5.3d).

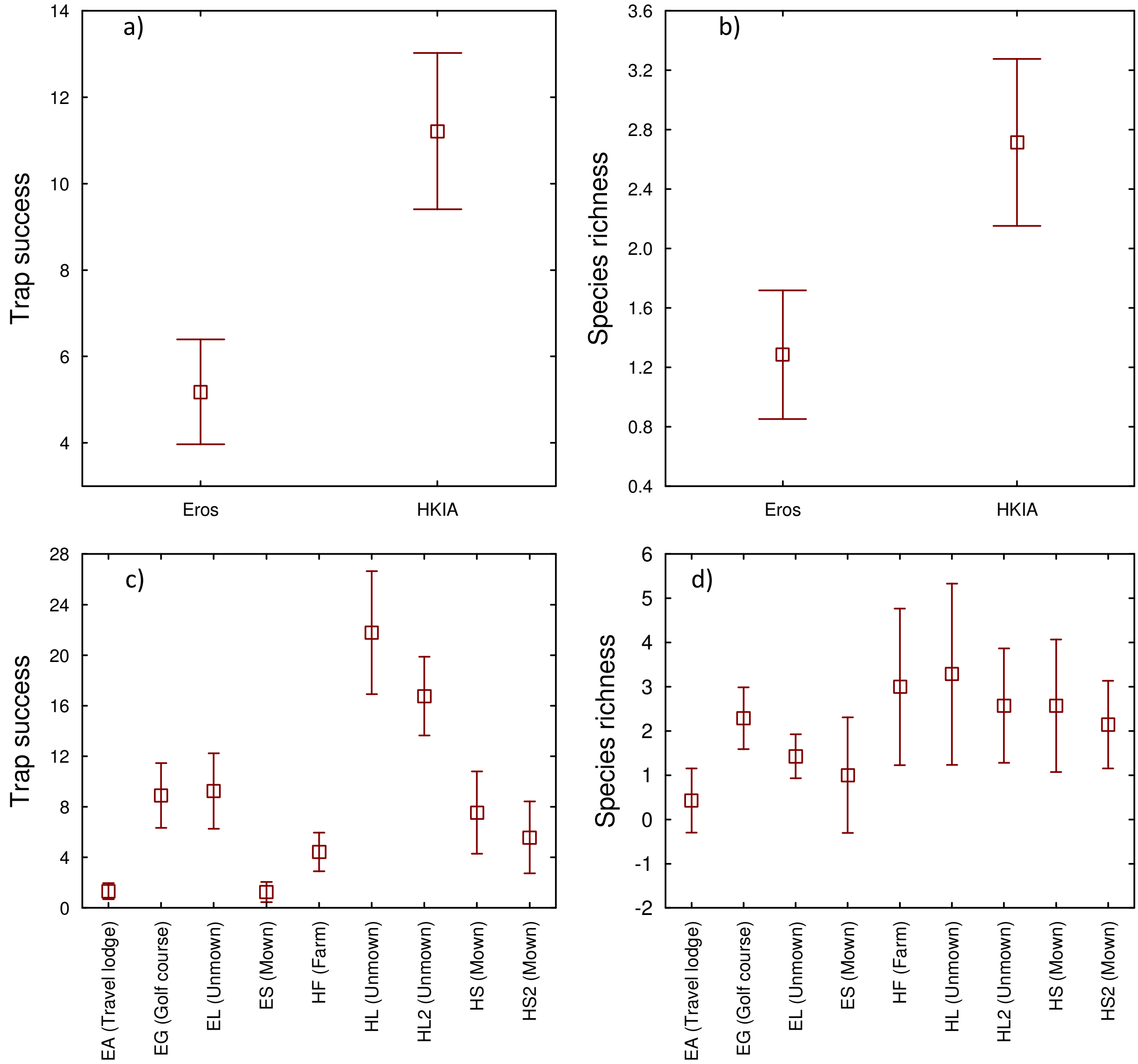


Figure 5.3: The mean (indicated with 95% confidence intervals) a) small mammal trap success per airport, b) species richness per airport, c) trap success per transect, and d) species richness per transect.

Overall, a positive correlation was found between species richness and trap success ($r=0.71$, $p < 0.05$)(Figure 5.4).

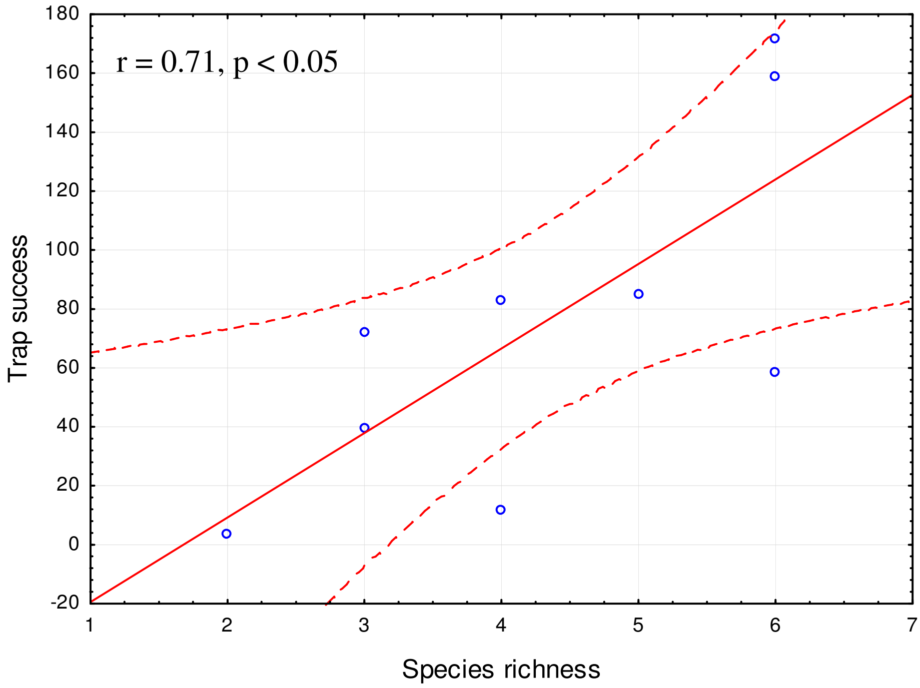


Figure 5.4: Scatterplot correlating small mammal species richness with trap success considering all transects at Hosea Kutako and Eros.

When considering the abundance of the totally dominant diurnal (*R. pumilio*; Figure 5.5a) at Hosea Kutako, significantly higher numbers were captured at the unmown transect HL compared to the mown transects HS ($Z = 2.03$, $p < 0.05$) and HS2 (($Z = 2.37$, $p < 0.05$), and the neighbouring farm (HF) ($Z = 2.37$, $p < 0.05$). The second unmown transect (HL2) also produced significantly higher numbers of *R. pumilio* than on HS ($Z = 2.20$, $p < 0.05$), HS2 ($Z = 2.37$, $p < 0.05$) and HF ($Z = 2.37$, $p < 0.05$). At Eros the Travel Lodge (EA) had significantly lower numbers compared to the on airport unmown transect EL (Figure 5.5a).

The dominant nocturnal species (*M. coucha*; Figure 5.5b) species present at all transects was not found to be significantly different in abundance between any of the five transects at Hosea Kutako, or any of the four transects at Eros.

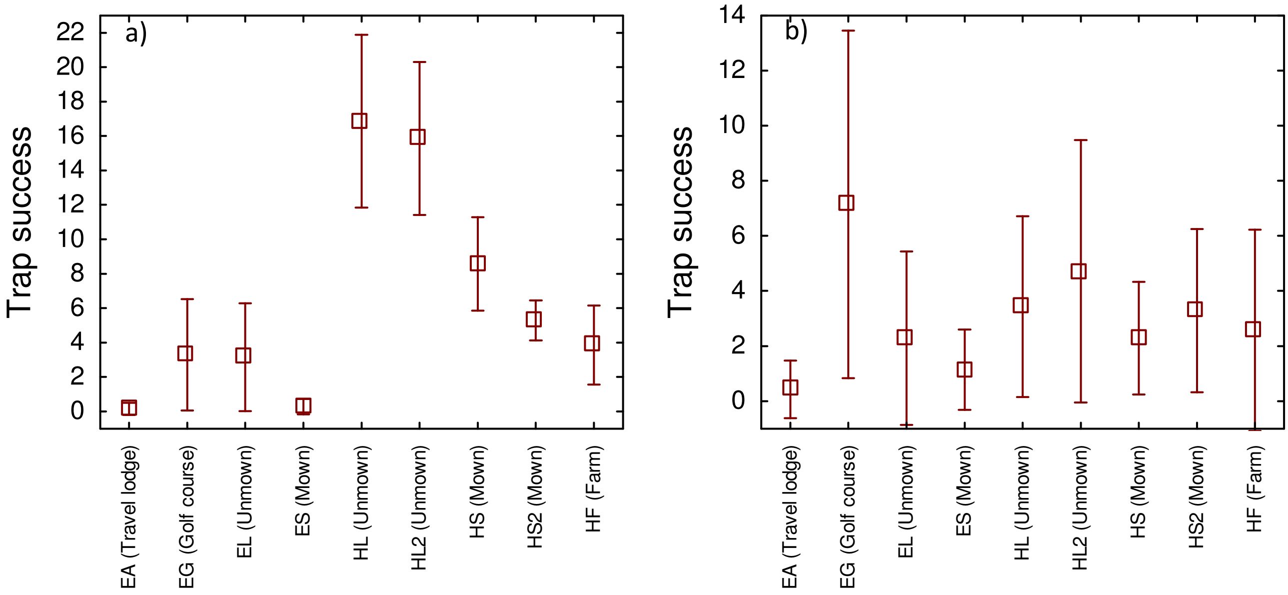


Figure 5.5: Mean daily trap success of a) *R. pumilio* and b) *M. coucha* per transect (Whiskers = 95% confidence limit).

5.3.4 Relationship between, grasses, insects and small mammals

The only vegetation (= grass) variable which significantly correlated with another ecosystem variables was the relative abundance of Increaser IIc (pioneer grass species) with trap success of the small mammal species *E. intufi* ($r=0.89$, $p < 0.01$), while a moderately positive correlation (not significant) was found between Ecological Index score and small mammal trap success ($r = 0.44$, $p > 0.05$).

Arthropod biomass correlated significantly with small mammal trap success ($r = 0.80$, $p < 0.05$) while the arthropod order Coleoptera showed an inverse correlation with the relative abundance of Increaser IIC grasses.

5.3.5 Overall relationship between all nine transects at the two airports

When all ecological parameters discussed above are clustered (Figure 5.6) all Hosea Kutako transects are more closely related to each other than to the Eros transects, except for EG. The mown transects (HS and HS2) are more closely related to each other than the unmown transects (HL and HL2). HF (the cattle and game ranch) is furthest (in Euclidean distance) from the other Hosea Kutako transects. The Eros transects EL and ES are more closely related to each other than to the other two transects (both outside the airport property). Here, only EG (golf course) is more closely related to the Hosea Kutako transects, while EA is most unlike the other Eros transects.

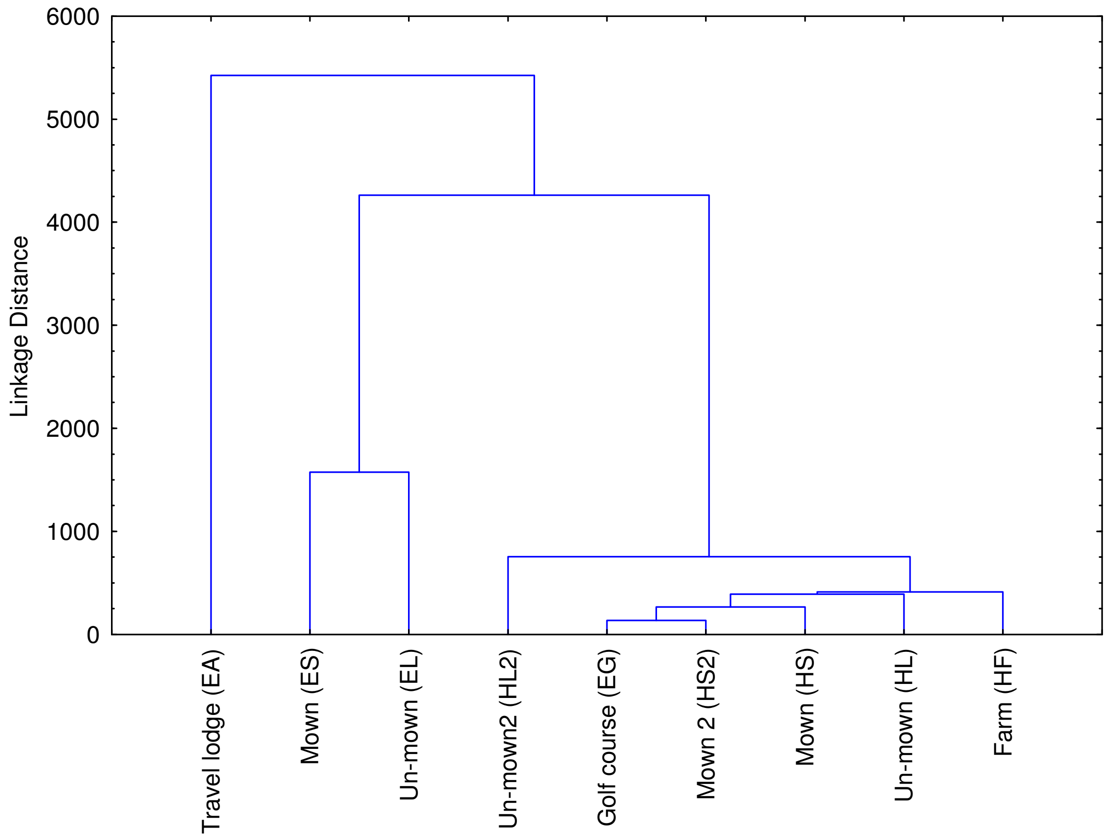


Figure 5.6: Cluster analysis (single Euclidean distance) of all ecological parameters for the four transects at Eros and five transects at Hosea Kutako.

5.4 Discussion

Vegetation, arthropod and small mammal variables have been investigated here to address the issues of ecosystem integrity and productivity at Hosea Kutako and Eros airport habitats and their immediate surrounds. The study transects were chosen in such a way to gauge the different habitats' potential to lure and or keep a high density of damage-causing animals in differently managed areas. Plants (for example soil cover, ecological value, pioneer to climax species ratio – see Vorster 1982) have traditionally been used as indicators of ecosystem integrity. Many other groups of organisms, however, also hold potential as indicators of ecosystem function and integrity (see Avenant 2011), and a variety of variables referring to vegetation, arthropods and small mammals (dealt with in this thesis) have been indicated to correlate with rangeland and or ecological condition.

EI score have been positively related to both rangeland condition (Vorster 1982, Bothma 1995, Tainton 1999) and pasture productivity (Trollope 1990, Snyman and Fouche 1993, Snyman 1999, Tainton 1999), and therefore give some indication of the relative number and or biomass of herbivorous fauna that the specific area can accommodate; a higher contribution of Decreaser species and lower contribution of Increaser IIc grass species have been related to a higher ecosystem integrity or condition (= less disturbed habitat) (Trollope 1990, Tainton, 1999). Also, Tilman's hump-shaped curve model (Tilman 1982) predicts an increase in the number of species with advancing successional stage after disturbance, up to the point of ecological climax, followed by a secondary decline in post-climax contexts (see also Rosenzweig 1995). These relationships, between ecosystem condition and specifically plant species richness, evenness and diversity, have not been well studied in southern African biomes.

Arthropod assemblages have been found to be closely linked to primary producers (see Buschke *et al.* 2011). Of all the Arthropod variables investigated in this study, however, only the SAGraSS score have been positively correlated with EI score before (Kaiser 2006). For small mammals, a number of variables have been linked to EI scores and primary productivity (e.g. Wang *et al.* 1999, 2001; Avenant 2005, 2011). These include both species richness and diversity that decline with habitat degradation and a decrease in primary productivity, generalist species *Mastomys coucha* and diurnal *Rhabdomys pumilio* that dominates community numbers at low ecological integrity; the number of specialist species that increases towards ecological climax; and specific species that act as indicators during the successional process.

In this study few of the indicator variables mentioned above correlated with each other: only the EI score correlated with the relative contributions of Decreaser and Increaser IIc species (positive and negative, respectively), percentage contribution of the order Coleoptera had a negative correlation with the relative abundance of Increaser IIC grasses, and arthropod biomass correlated positively with small mammal abundance (trap success). This lack of correlations can be ascribed to (a) the indices and associations of the investigated variables having not been tested in the Savanna biome before, and or (b) the habitats (= transects) studied here giving a false impression of relatively high integrity. In the latter case it will then be assumed that the mowing regime has a positive effect on grass species only, while the impact of other disturbances (such as noise, light tremors and the comparatively depauperate diversity and density of terrestrial predators) on higher taxa are not measured and considered properly. The ecological integrity may, therefore, be much lower than indicated by the vegetation variables EI score and the relative contribution of Decreasers and Increaser IIc species (see also Kaiser 2006). Both the SAGraSS score (arthropods) and the small mammal data are in support of this. When compared to Kaiser *et al.* 2009 (currently the only published SAGraSS scores available; work done in the South African Grassland biome) even the highest SAGraSS score obtained at the Namibian airport study sites relates to that of the grassland in an early stage of succession (only *c*. one year after fire). Interestingly, EI values also agrees to that of Kaiser *et al.* 2009 attained at the same plots, less than two years after fire. In the Kaiser *et al.* (2009) study SAGraSS and EI scores reached considerably higher mean values of 59.14 and 803, respectively. Although none of the small mammal trap success, species richness and Shannon diversity scores was low in the present study (see also Chapter 4 and Avenant 2011), the absence of specialist species, low contribution of insectivores and the total dominance of *Mastomys coucha* (nocturnal) and *Rhabdomys pumilio* (diurnal) indicated that the study habitats were in relatively low ecological integrity condition.

From a managerial point of view, recording the productivity measurements EI score, relative contributions of Decreaser and Increaser IIc species, arthropod biomass and small mammal trap success was most important in the current study. While primary productivity measurements were highest on the mown areas at both airports, arthropod biomass and small mammal trap success was highest in the unmown areas. The last observation was mostly due to differences observed in diurnal *R. pumilio* populations indicating that the unmown areas is a major source of food for terrestrial and avian predators, and therefore a higher direct and indirect risk for AWCs; especially for diurnal predators, which is of importance for airports such as Hosea Kutako and Eros where most flights take place during the day. Also important was the facts that all of these measures indicated that productivity was higher inside the airport properties than on the specific farm (Hosea Kutako study site), and higher at rural Hosea Kutako than urban Eros. This is discussed in more detail, below.

5.4.1 Difference observed between an airport in a rural environment (Hosea Kutako) and an urban environment (Eros)

This study found a significantly higher small mammal abundance and species richness in and around rural Hosea Kutako airport, compared to urban Eros. Although arthropod abundance and order richness was higher at Eros, biomass was significantly higher at Hosea Kutako. The arthropod samples at Hosea Kutako was characterized by relatively low numbers of large arthropods (e.g. order Orthoptera), a known food source of common avian insectivores; Eros samples were dominated by smaller insects (e.g. of the order Psocoptera). Grassland condition (EI score) and grass (Poaceae) species richness was also higher at Hosea Kutako, confirming the link between plant and mammal species richness described by Coe *et al.* (1976), Grant *et al.* (1982) and Andrews & O'Brien (2000). Increased grassland condition has been found to be directly related to higher productivity in other southern African studies (Trollope 1990, Snyman & Fouche 1993, Snyman 1999, Tainton 1999). The higher productivity indicators of all three ecosystem parameters (grass, small mammal and arthropod) indicate a generally more productive ecosystem, and therefore one which would provide resources for hazardous wildlife (Siemann *et al.* 1998). An avifaunal study at the airports (Chapter 3) confirms more frequent bird sightings at Hosea Kutako, and Chapter 2 found more mammal collision incidents at Hosea Kutako, supporting Siemann *et al.* (1998)'s findings.

5.4.2 Impact of land use on ecosystem parameters

This study found a significantly higher small mammal abundance and species richness in and around rural Hosea Kutako airport, compared to urban Eros. Although arthropod abundance and order richness was higher at Eros, biomass was significantly higher at Hosea Kutako. The arthropod samples at Hosea Kutako was characterized by relatively low numbers of large arthropods (e.g. order Orthoptera), a known food source of common avian insectivores; Eros samples was dominated by smaller insects (e.g. of the order Psocoptera). Grassland condition (EI score) and grass (Poaceae) species richness was also higher at Hosea Kutako, confirming the link between plant and mammal species richness described by Coe *et al.* (1976), Grant *et al.* (1982) and Andrews & O'Brien (2000). Increased grassland condition has been found to be directly related to higher productivity in other southern African studies (Trollope 1990, Snyman & Fouche 1993, Snyman 1999, Tainton 1999). The higher productivity indicators of all three ecosystem parameters (grass, small mammal and arthropod) indicate a generally more productive ecosystem, and therefore one which would provide resources for hazardous wildlife (Siemann *et al.* 1998). An avifaunal study at the airports (Chapter 3) confirms more frequent bird sightings at Hosea Kutako, and Chapter 2 found more mammal collision incidents at Hosea Kutako, supporting Siemann *et al.* (1998)'s findings.

When considered in totality, "on airport" transects at Hosea Kutako showed significantly higher small mammal abundance than the "off airport" transect. This suggests that the fenced off airport provides sanctuary to small mammals from predators such as black-backed jackal (*Canis mesomelas*) and African wild cat (*Felis silvestris lybica*), creating a possible double-edged sword effect of fencing as a bird strike prevention mechanism. Fencing also created a sanctuary for grass species at Hosea Kutako, where overgrazing was evident in the cattle and game farm adjacent to the airport. Dennis (2003) and Vohland *et al.* (2005) found that insect diversity and abundance was lower on ecologically degraded stock farms compared to farms with healthy rangeland in other semi-arid habitats in southern Africa. Results of this study found the surrounding land use at Hosea Kutako to be heavily grazed by cattle and wildlife, and the pasture on the airport property to be in substantial better condition than on the cattle and game ranch. Over 50% of all grasses identified on transects within the airport property were Decreaser grass species, while the cattle and game ranch transect had only 6.80% Decreaser species. Conversely, Increaser IIc grass species made up between 34.68% and 42.86% of grass species within the airport, and 75.60% on the cattle and game ranch. Species richness within the airport was 13 and 19 at the two mown grass transects (HS and HS2) and 14 and 16 within the unmown transects (HL2 and HL); the neighbouring game and cattle farm (HF) had only 10 (= the lowest species richness observed). As a measure of ecosystem stability (Oldeland *et al.* 2010), this indicates that the on-airport transects are within more stable ecosystems than the cattle and game farm. Shannon diversity of grasses were similar at all transects inside and outside the airport property. This study corresponds with observations by Hoffman & Zeller (2005) and Muck & Zeller (2006) in similar habitat types within Namibia where small mammal abundance was lower in degraded rangeland. This effect compounds the sanctuary effect mentioned earlier.

At Eros, the anthropogenically altered (urban) environment held lower small mammal numbers and diversity in general, confirming the finding of Lizee *et al.* (2011) that mostly generalist species of wildlife inhabit urban areas. The artificially enhanced productivity of the ecosystem at the golf course (through fertilizer application and irrigation) houses higher small mammal numbers than the neighbouring airport, and possibly acts as a source population for the airport small mammals. The lower arthropod abundance and diversity is thought to reflect the effect of pest control measures at the golf course (as discussed with K. Short, golf course manager. pers. comm.). As the airport is in an urban environment, grazing pressure outside the airport is not present, and differences in rangeland condition on opposite sides of the fence are not substantial.

5.4.3 Impact of grass mowing

The effectiveness of grass height management as a control measure for the risk of AWCs at airports is debatable. Barras *et al.* (2000) and Dekker & van der Zee (1996) report that no difference in the densities of birds in mown versus unmown areas have been scientifically proven. Tall grass was found to interfere with feeding and ground movement of birds, but provides nesting sites and food diversity for birds (Barras & Seamans 2002; confirmed in this study). The present study found a significant difference between small mammal abundance on mown and unmown transects. Reduced cover likely made this prey species more vulnerable to predators such as Black-shouldered Kite (Tarboton 1978, Pickford *et al.* 1989, Hockey *et al.* 2005) and Southern Pale Chanting Goshawk (Malan 1998, Hockey *et al.* 2005) which were regularly seen at the airport during this study (see Chapter 3). No difference in arthropod abundance or diversity was found between mown and unmown habitats.

Contrary to the positive AWC effect of reducing diurnal small mammal numbers, the mowing of grass was found to increase pasture condition. At both Kutako and Eros mown areas had higher EI scores, higher presence of Decreasers, and lower presence of Increaser IIc species, supposedly indicating most healthy ecosystems on mown plots. Other studies have found that regular mowing can increase species richness as well as general ecological functioning in grasslands (Maron & Jefferies 2001, Stammel *et al.* 2003, Frances & Kirkpatrick 2005), stimulates the generation of larger storage organs in grasses (Klimes & Klimesová 2002) and results in an increase of perennial species (Collins *et al.* 1998, Maron & Jefferies 2001), all factors resulting in increased grazing productivity. Kok & Kok (2002b) found nearly double the abundance of ground living insects in mown grass compared to long grass at an airport in

South Africa. The mowing of some areas at both airports and not others may also increase productivity as the structural vegetation diversity that this "mosaic mowing" effect creates increases vegetation niches for more species of insects (Chambers & Samways 1998, Kutchbach-Brohl *et al.* 2010) and mammals (Seamans *et al.* 2007). This habitat structure diversity was found by Garden *et al.* (2007) to be more influential to small mammal and reptile species composition than plant community composition. Price *et al.* (2010) also found that a high interspersion of grasses, trees and bare ground across a landscape resulted in a higher diversity of small mammals as well as reptiles. As a consequence it could be expected that this would be correlated to bird species diversity, as was confirmed by Hudson & Bouwman (2007) in a study within a broad habitat type similar to the present study.

The claim that higher ecological integrity at mown plots could, however, not be confirmed by the arthropod variables, nor by the small mammal data. Importantly, small mammal trap success (≈ abundance) was consistently higher on the unmown transects than on the mown. This difference was mainly due to the differences observed for diurnal *R. pumilio*, which was significantly more abundant on the unmown transects. Similarly, arthropod biomass and SAGraSS score was almost consistently higher on the unmown plots, but at Hosea Kutako only. These observations are bound to have a major impact on diurnal raptor/insect-eating bird species in the study area.

Lack of consensus regarding the effect of mowing of grass and other habitat manipulation methods at airports around the world points to reactions of ecosystems and their components being highly site specific (conclusion supported by Deacon & Rochard 2000, Dekker 2000 and DeVault *et al.* 2009 & 2013). To gain a more robust understanding of the impact of mowing, Seamans *et al.* (2007) Dekker (2000) and Froneman (2000) suggested the investigation also of vegetation species composition, density and biomass (in addition to grass height).

The only transect at Hosea Kutako with a poor EI score (214) is within the neighbouring game and cattle ranch. The ranch surrounds the airport to the east, north and south (see Chapter 4, Figure 1). The score, mostly caused by a high percentage of Increaser IIC grass species, indicates an area of high overgrazing over an extended period. This causes unpalatable species to outcompete and replace palatable grass species (Hudak 1999). Conversely, the combination of zero grazing (by fencing off the airport property) and mowing of grass within the airport property has created a reservoir of good quality grazing with a high percentage of Decreaser grass species (palatable, mostly perennial), and placed additional confinement pressure on grazers on neighbouring properties. This process artificially mimics the ideal grazing situation where above ground grass parts are "mown" after grass plants have become dormant, leaving to vigorous grass growth (particularly of palatable perennial species) at the onset of summer rains (Savory 1999). This is likely to attract grazing wildlife to the airport, especially during late summer / autumn when grazing pressure will force herbivores from the surrounding areas to seek grazing on the airport property. The fenced off airport property places additional pressure on surrounding grazing, as found in grazing areas elsewhere in southern Africa (Boone & Hobbs 2004) where fencing of "parcels" reduced total grazing capacity. McMurtry (2006) mitigated a similar situation at Kansas City International Airport by introducing cattle to unused airport property; this reduced herbivore pressure and provided income.

Conflicting findings, however, also exist on grazing exclusion's effect on ecosystems. Oba *et al.* (2000) found grazing exclusion to reduce plant cover over time, with moderate grazing resulting in higher grazing productivity than grazing exclusion. Studies by Oba *et al.* (2000) and Hejcmanova *et al.* (2009) found increases in perennial grasses with grazing exclusion. Areas under grazing exclusion are known to have less compact soils (Du Toit *et al.* 2009) reducing plant cover and production (Dunne *et al.* 2011), as well as small mammal numbers (Garden *et al.* 2007). In the present study the overgrazed neighbouring ranch is therefore likely to have more compacted soils than the airport, making the airport habitat more attractive for raptor prey species (small mammals). Low species richness on the ranch, compared to the airport property, also contradicts the results of Materechera & Modiakgotla (2006) who found increased herbaceous (especially grass) species diversity, spread by herbivore manure.

The fact that no significant correlation between grass species richness and EI score was found, indicates that a pasture in good condition does not necessarily have a high species richness. Plant species richness remains, however, an important consideration at airports as it was found by Andrews & O'Brien (2000) to account for over 75% of variability in mammal richness. Hejcmanova *et al.* (2009) found species richness of plants to be highest in ecosystems which are in a transitional state of recovery. This corresponds with the finding on only one transect in this study (HS2) where grass is mown annually, and therefore constantly in a transitional state (sub-climax).

At Hosea Kutako there was a strong positive correlation in grass species composition and relative abundance between all transects within the airport property (r varied between 0.81 and 0.97, df = 26, $p<0.05$). There was, however, no correlation between transects within the surrounding game and cattle farm (HF) and any of the on airport transects (r varied between 0.04 and 0.16, $p>0.05$). As there is no difference in pedology, geology or topography between these transects, this result suggests that grazing has a major influence on grass species composition and diversity. The palatable grass species *Schmidtia pappophoroides* dominated all on-airport transects (between 35.2% and 48% of all grass cover). This is a valuable perennial grazing species (van Oudtshoorn 1994, Skarpe 2000, Van Rooyen 2001, Verlinden & Kruger 2007), and is known to increase in areas with low grazing intensity (Skarpe 2000, Zimmermann et al. 2001, Smet & Ward 2005), indicates pasture in good condition (Verlinden & Kruger 2007) and indicates a climax state rangeland (Kelly & Walker 1976, Joubert *et al.* 2008). Its stoloniferous characteristics make it fast spreading and soil anchoring. It is a common dominant species in semi-arid rangelands of southern Africa (Smet & Ward 2005). A relatively high occurrence of *Melinis repens* subsp. *repens* was also found. This species has low grazing value (van Oudtshoorn 1994), and its preference for disturbed areas explains its presence (along roads, aprons, etc.) at the airport. The species was found to increase in under grazed sites in northern Namibia (Klintenberg & Verlinden 2008), again explaining how the on-airport sites (with grazing exclusion) would show high numbers of this species. The cattle and game ranch transect HF was dominated by *Pogonarthia fleckii*. This annual species has low grazing value (Muller 2007), but is grazed (Wesuls & Lang 2010). It has been found to increase in degraded (Joubert *et al.* 2008) or overgrazed pasture (Nangula & Oba 2004, Klintenberg & Verlinden 2008) within semi arid southern Africa, supporting the result of the EI score determined for this transect.

As with Hosea Kutako, a strong positive correlation (r = 0.76, $p<0.05$) between the two on airport transects EL and ES was found at Eros Airport, while only a weak positive correlation existed (r varies between 0.31 and 0.63) between any of the other transects. Eros' on airport transects EL and ES are dominated by the annual *Urochloa brachyura* (30.8% and 35.2% contributions, respectively). This species is less preferred and dominant in overgrazed / disturbed areas (Strohbach, 2000) while Verlinden & Kruger (2007) rated it as a species indicating a pasture in medium condition. Two other grass species, *Cenchrus ciliaris* and *Eragrostis trichophora,* also occur in high numbers. *C. ciliaris* is a very palatable perennial species which generally decreases in grazed areas (van Oudtshoorn 1994). In contrast, the perennial *E. trichophora* produces little biomass (Strobach 2000) and is known to increase with grazing pressure (van Oudtshoorn 1994, Verlinden & Kruger 2007); it is one of few perennial species known to do so in Namibia.

As a wildlife control and fire risk reduction measure both airports mow the grass once a year around the runways and taxiways to 200mm as per International Civil Aviation Organisation (ICAO) recommendation (ICAO 1991). Research has found conflicting results on the effectiveness of grass mowing to reduce AWC hazards (Hesse *et al.* 2010). An extensive study of 12 153 bird observations found no difference in avian use of mown and unmown areas on an airport (Seamans *et al.* 2007). Although it is found that mowing reduces the abundance of small mammals, it improves grazing condition (both statements supported by this study). The two transects in mown areas at Hosea Kutako had the highest EI score indicating better rangeland condition and pasture productivity. At Eros the mown transect also had a higher EI score than the unmown transect. Similarly, roadside verges (where grass is mown and not grazed) are known to be a valuable habitat for insects and other small organisms (Raemakers *et al.* 2001). It has also been shown that unmown or ungrazed tall grass ecosystems house less grasshopper (Orthoptera) species and individuals than areas with short grass. Importantly, timing of mowing affects ecosystem condition and dynamics. At Hosea Kutako and Eros the study sites are mown at the end of summer, and this produces slower ecosystem recovery than mowing at the end of winter (Chambers & Samways 1998). Mowing more frequently produces a uniform grass sward with less diverse vegetation species and structure than areas mown only once a year. It also increases risk during and immediately after mowing when insectivores are attracted to insects being flushed (Soldatini *et al.* 2010). Reduction of habitat diversity, and not vegetation height, was found by Hesse *et al.* (2010) to be the most successful habitat manipulation method to reduce wildlife hazards at airports.

5.4.4 Impact of removal of woody vegetation

At both airports all shrubs and trees have been removed, leaving only grassland habitat. With both airports being within the “Highland Shrubland” Tree and Shrub Savanna vegetation type (Mendelsohn *et al.* 2002) surrounding ecosystems contain an estimated 40 percent shrub cover and 10 percent tree cover. Savannas are defined as tropical grasslands containing woody species (Shorrocks 2007). Tree and shrub removal has been found to reduce nesting, shelter, predator cover and perch sites for birds and small mammals (Barras & Seamans 2002, Washburn & Seamans 2004); this has also been shown within 10km of Hosea Kutako where a study found increased bush cover resulting in increased nesting sites for birds (Cunningham & Joubert 2011).

In contrast, increased woody species density reduces space, sunlight and moisture availability for other organisms (Mbatha & Ward 2006), including palatable grass species such as *S. pappophoroides* (Smit & Swart 1994). This species dominates at Hosea Kutako, but is largely absent at the off-airport transect HF where no shrub removal took place. As such, rangeland productivity is reduced at the farm (transect HF); also confirmed by Richter *et al.* 2001 in the South African savanna. Blaum *et al.* (2006) found *R. pumilio* abundance to be hump-shaped in relation to shrub cover largely because of increased resource abundance in shrub free areas and reduced predator cover and nesting sites in similar habitat type (Kalahari), a pattern found to be repeated with bird populations (Sirami *et al.* 2009), reptiles (Blaum *et al.* 2008) and carnivores (Blaum *et al.* 2007). In general species richness in the Kalahari biome decreases with increased shrub cover, and increased shrub cover results in a decrease in small mammal abundance (Blaum *et al*. 2006). Samways *et al.* (1996) found shrub thickets to have lower bird diversity as a result of impeded flight, and lower grass production, and conversely open grassland higher biodiversity. Up to 77% of variability in the species richness of arboreal, frugivorous and insectivorous mammal species has been found to be explained by woody plant species richness (Andrews & O' Brien 2000, Whittington-Jones *et al.* 2008). Sirami *et al.* (2009) believes that shrub encroachment, a common problem in southern African savannas and known to occur in the vicinity of Hosea Kutako airport (Joubert *et al.* 2008), significantly influences bird population distribution and abundance in the savanna biome. This is likely to influence bird occurrences around airports in savannas. At a local scale, it strengthens the notion that airports (largely free of woody species) can be considered islands of attractive habitat within degraded (e.g. bush encroached, overgrazed or urbanised) landscapes.

5.6 Conclusions

As suggested by Soldatini *et al.* (2010) an understanding of vegetation, small mammals and arthropods made an important contribution to understand wildlife hazards at the two study airports. It indicates the relative higher ecosystem productivity of a rurally situated airport compared to an urban airport, an important consideration when planning airport locations. Airport pastures provide refugia for small mammals. Mowing as an ecosystem tool for reducing AWCs did not have a significant effect on diversity in general, but arthropod biomass and small mammal abundance was reduced, resulting in a lower attraction risk for birds of prey.

This study also pointed out the dearth of information related to ecological integrity measurement in the Namibian Savanna. Here, no studies have been done on the indicator variables coupled to taxa such as arthropod and small mammal communities, and how these relate to vegetation variables such as Ecological Index (EI) score and relative abundances of Decreasers and Increaser IIc species.

While interpretation of the latter already proved useful when studying the relative densities of damage-causing species that different areas on the airport properties and surrounding areas can lure and or "house", the shortage of information regarding arthropod and small mammal integrity indicator variables indicated that, currently, we can only learn from their relative biomass in differently managed and used land areas.

As small mammal abundance is related to primary productivity, but also a number of habitat variables, the relationship between vegetation and small mammal variables on airports is not as straight forward as in more natural areas. Small mammal numbers were, therefore, the most useful small mammal indicator studied. Studying small mammals also proved to be the most practical, affordable and realistic approach of the three factors studied; where both vegetation and arthropod sampling are time consuming, heavily dependent on the availability of specialists in these fields, and limited to specific periods of the year, assistants can be trained to sample small mammal populations and communities on fixed transects using standard methods. Where time, funding and the availability of expertise is not an issue, it remains most valuable to study airport ecosystems at more levels, including more taxa. The value of the latter approach is expected to become increasingly clear as the ecosystems, ecosystem variables and their relations are better understood.

THEME 3: UNDERSTANDING THE INFLUENCE OF ECOSYSTEM PARAMETERS AND OTHER FACTORS ON THE EFFECT OF AIRCRAFT WILDLIFE COLLISIONS USING SYSTEMS MODELLING

CHAPTER 6: A SYSTEMS MODEL TO PREDICT THE EFFECTS OF MANAGEMENT ACTIONS ON THE RISK OF AIRCRAFT WILDLIFE COLLISIONS

Abstract

Aircraft-wildlife collisions (AWCs) are an increasing global concern as a result of greater flight volumes and increasing risk bird populations. Linear and spatial models currently used by the aviation industry to identify and rank the risk of AWCs have been described as inadequate in considering the complexity and interlinked causality of AWCs. This contribution proposes a conceptual systems model to illustrate the dynamics of aircraft-wildlife collisions, considering the inter-connectedness of various ecological and anthropogenic causes of the problem. It is subjected to a sensitivity analysis of preventative and control wildlife reduction programs at Namibia's Eros airport. The systems model appropriately described the complexity of the AWC problem at Eros Airport, for one species only. It also illustrated that many influencing factors are highly site specific. The sensitivity analysis found that AWC control measures that reduce the ecological carrying capacity of an airport are more effective than lethal control measures in reducing the risk of AWCs. Also, a combination of lethal control and habitat management resulted only in a lower risk of AWCs in the short term; in the long term the risk was found to increase. Application of this model to other airports and for other species will require careful study of species reaction to aircraft and lethal control and will not necessarily produce a similar result.

Key words: Aircraft wildlife collisions, airport risk mitigation, bird strike, systems model

6.1 Introduction

The International Civil Aviation Organization (ICAO) recognizes collisions between aircraft and wildlife (birds in particular) as a priority safety risk (Buurma and den Haag 2004, IBSC 2006, Messmer 2009, Keirn *et al.* 2010). Greater flight volumes and increases in wildlife populations (attributed to more successful conservation efforts) are also leading to an increased risk of such collisions (Froneman 2000, Robinson 2000, Cleary *et al.* 2006, Dolbeer 2011).

Modelling, a process described by Costanza *et al.* (1993) as analogous mapping, is today widely used in ecology and conservation biology (Kettenring *et al.* 2006). It is also used to identify and rate the risk of aircraft-wildlife collisions (AWCs) in some countries. In Greece, Anagnostopoulos (2003) ranked the risk of birds to aircraft using an aviation safety ranking volume (ASRV); i.e. using the mean density of bird species (g / m^3) as an index of their risk of causing significant damage to aircraft. The United States Bird Avoidance Model (US BAM) (Lovell and Dolbeer 1999, Beermann and Bobo 2001, Brown and Herricks 2002) uses Geographic Information Systems (GIS) data in conjunction with observations of sixty key species to predict the risk of bird strikes for US aircraft. It considers available GIS information concerning climatic, environmental and historical (previous bird strike) factors, as well as observations of bird populations and migration patterns to produce risk maps which inform pilots of risk “hotspots” to avoid in flight. The BAM is also applied in the Netherlands (Shamoun-Baranes *et al.* 2005, Shamoun-Baranes *et al.* 2008), Switzerland and Germany (Ruhe 2005). Current developments in the use of avian radar are expected to strengthen the accuracy of these models (Sowden & Eschenfelder 2009). Furthermore, modelling is extensively used in Aeronautical Engineering to predict the forces and possible structural damage bird strikes cause (Huertas-Ortecho 2006).

DeVault *et al.* (2009) and Nja *et al.* (2012) describe AWCs and their causes as a complex problem, and state that it is impossible to take all influencing factors into account when predicting the risk of AWCs. Criticism of current models and risk assessments for AWCs includes the simplification of a complex problem. Ruhe (2005) suggested that current models be combined in order to provide modelling on a global scale, but this is difficult as the models are distinctly different. A panel discussion at the 2012 International Bird Strike Committee Meeting identified current risk assessment and modelling to be mostly linear (logical), and a need for alternative methods was identified. Systems modelling as proposed in this study is one solution which can combine and link data in 3 or even 4 dimensions (Bivand 2002), thereby addressing the shortcomings of current models.

Systems thinking (or systems dynamics, and modelling) attempts to address problems which are complex (Sterman 2001, Barlas 2007, Senge *et al.* 1994). Senge (2006) defines systems thinking as a discipline of seeing wholes, while Costanza *et al.* (1993) describe it as a tool to understand the interrelationships and interconnectedness of exchanges in energy, information and matter (natural or anthropogenic). It provides a framework for identifying interconnectedness in elements of a system (natural, man-made or hybrid) often not identified in other analytical methodologies, and simulates the dynamics of the system over a set time (Herendeen 1998, Coyle 2000). Subtle causality between factors affecting AWCs occur over time and these can be simulated using systems dynamics. The complexity of the AWC problem makes it an ideal situation to apply the systems thinking methodology. Costanza *et al.* (1993) first identified its value in understanding the link between ecology and economics. Coughenour (2004), Lynam and Stafford-Smith (2004), Tongway and Hindley (2004) and Ash *et al.* (2004) found it useful when modelling the complexities of ecosystem and landscape function, rangeland management and plant-animal dynamics. Value in using this method lies not only in the ability to quantify the dynamics of the problem (or system), but in the methodology of unpacking and describing a system in detail (Coyle 2000) in order to understand it better (Den Exter 2004). It also enables the modeller to focus on specific aspects of the model and simulate their influence on the greater system. By fully layering the model, the complexity can be effectively modelled without making the model less understandable to non-modellers (e.g. airline and airport managers and operators).

This chapter proposes, as far as could be determined, the first conceptual systems thinking model for the issue of collisions between aircraft and wildlife as a partial solution for problems with current AWC models as identified by Ruhe (2005) and Nja *et al.* (2012). The model (Figure 6.1) does not represent all influences and interrelationships relevant to the problem and only considers one risk species, Crowned Lapwing *Vanellus coronatus*, the main culprit of AWCs at the study airport. The model can however be expanded and refined as and when a greater understanding of the system is developed.

6.1.1 Study area

Eros Aerodrome (22°36'S; 17°04'E) is a local destination airport within the municipal area of Namibia's capital city, Windhoek. This airport carries the highest flight volumes (+/- 32 000 flights per year) in Namibia (N. Pule, Namibia Airports Company, unpublished data) and experiences an AWC collision rate of 11 per 10 000 aircraft movements, or one collision every 31 days (Hauptfleisch *et al.* 2013). Crowned Lapwing were responsible for 68.9% of all records between 2006 and 2010 at this airport; the other main species involved with AWCs here are Helmeted Guinea Fowl *Numida meleagris* (8.1%), Feral Pigeon *Columba livia* (2.1%), Yellow-billed Kite *Milvus aegyptius* (2.1%) and unidentified birds (9.5%). Most aircraft using the airport are propeller driven.

The airport is surrounded on three sides by suburban and business properties, and by the Windhoek Golf course on the other. It is situated in the "Highland Shrubland" Tree and Shrub Savanna vegetation type (Mendelsohn *et al.* 2002).

6.2 Methodology

6.2.1 Systems modelling

Systems modelling was used to illustrate the linkages between various factors affecting the risk of AWCs (Figure 6.1) relying on the discipline of systems thinking and systems dynamics (Fisher 2011, Senge 2006). A system can be defined as a collection of parts which interact to cause something to function or, in this case, to cause a problem (Fisher 2011, Senge *et al.* 1994, Barlas 2007, Sterman 2001). Systems thinking is the mental process of identifying the interconnectedness which gives such a system its unique character (Senge 2006). It quantifies the structures and interactions as well as underlying actions through the use of stock-flow diagrams. Stocks are defined as entities or states of being which are affected by flows (actions). Flows either increase or decrease the value of stocks which they flow into or out of (Herendeen 1998, Senge 2006). Theoretical experienced and inexperienced populations of the collision culprit species *V. coronatus* were modelled as stocks. The "inexperienced bird populations" stock increases in value (number of birds) through hatchings (births) and in migration from surrounding properties. The stock value decreases through population losses such as mortalities and out migration. The learning ability of resident birds becoming habituated to aircraft noise and movement, developing aircraft avoidance skills (Kelly *et al.* 2001) that results in a lower risk of collisions between experienced bird populations and aircraft, is reflected in the model as the stock of experienced bird populations. Such learning behaviour was witnessed at both Eros and Hosea Kutako airports during structured avifaunal observations in the Windhoek area [940 observations of *V. coronatus* reaction to aircraft, (Chapter 3)].

Aircraft movements (stock) are influenced by the number of aircraft entering and leaving the airport manoeuvring area. This encompasses aircraft in final approach, landing, taxi, apron movements, take-off and initial climb and are generally within the 13km radius of influence of an airport (IBSC 2006). The risk of AWCs (stock) in the model was expressed as the likelihood of manoeuvring aircraft and birds to converge. The risk is reduced by influences on the ability of aircraft and wildlife to be separated at the airport through wildlife control mechanisms such as culling, scaring or habitat alteration.

The model building methodology applied is described in the following four steps:

1. Defining the problem of AWCs at two Namibian airports (Eros Aerodrome, but also Hosea Kutako International) and identifying some of the root causes and linkages of the problem (Den Exter 2004).
2. Developing a hypothesis that explains the dynamics of the AWC system, taking into account global research and theories regarding the problem.
3. Building a model of stocks and flows, as well as connections between them, using estimated parameters and observed behavioural relationships (Figure 6.1). Each parameter was quantified and time based simulations of the functioning of the system graphed using the Stella ® modelling tool (Richmond 2004).
4. Testing the behaviour of the model through constant manipulation of its parameters in order to achieve results observed in reality (as in Zacharias 2004).

Testing and validation of the model required stakeholder input from the aviation community as well as the IBSC (at the 30th conference in Stavanger, Norway, 2012), a critical step in the systems approach (Western 2004) and also used in other forms of ecological modelling (MacMillan & Marshall 2006).

6.2.2 Determination of parameter values and multiplier factors used in the initial model simulation

Initial (t 0) values used in the model were determined as follows:

1. Flight volumes –the number of aircraft within the airport zone of influence was calculated (final approach, landing, taxi, takeoff and apron manoeuvring) from flight schedules for Eros airport, held by NAC.
2. The initial experienced bird population (birds that have become habituated to aircraft movements and avoid collisions) was determined through conducting daily bird surveys at Eros airport: we used the population data of Crowned Lapwing *V. coronatus* (Chapter 3).
3. The population loss factor applied to the model (= natural mortalities and predation) and reproductive rate of inexperienced and experienced *V. coronatus*, are described in the review of the species by Turpie & Ryan (2005) in Hockey *et al.* (2005).
4. Bird carrying capacity was estimated as a factor of the productivity of the ecosystem based on a study of the ecosystem parameters insect abundance and diversity, small mammal abundance and diversity, rangeland condition, and observations of *V. coronatus* behaviour (Chapter 3 and Chapter 5).
5. The inexperienced and experienced bird avoidance factor was based on observations of *V. coronatus* behaviour at the study site (Chapter 3), and their reaction to manoeuvring aircraft (see Kelly *et al.* 2000, 2001).
6. The control factor was based on an estimate of the effort that airport management placed into reducing birds at airports through culling and harassment (2008-2012 personal observations).
7. The habitat manipulation management factor was based on preventative management actions which are focused on reducing the carrying capacity of the airport for birds (such as vegetation augmentation, reduction of prey species, etc.). The influences of surrounding land use and rainfall are generalized in the "carrying capacity" converter, and should be developed as part of an expanded model.

6.2.3 Sensitivity analysis

Starfield and Bleloch (1986) describe sensitivity analysis as a systematic testing of changes in parameters and the effect of these changes on the output of the model. As this systems model is non-linear there are, in addition to individual parameters that can be changed, countless combinations of parameters that can be set. Baseline parameter values were adjusted to test their effect on the overall AWC problem as modelled (Table 6.1). For this, the objectives of the model and experience of four years' of observations at Eros airport were used to concentrate on changing parameters (or combinations) which are likely to be fruitful (Starfield and Bleloch 1986). The sensitivity tests were applied as informative experiments to assist in predicting the behaviour of the system under such changes (Lynam & Stafford-Smith 2004).

6.3 Results

6.3.1 The systems model

The systems model framework (Figure 6.1), illustrates how the different aspects impacting on AWCs at the study site are incorporated. Figure 6.2 illustrates changes in experienced and inexperienced *V. coronatus* populations when the initial experienced bird population is set at 80 individuals, and the carrying capacity at 300. Initially (as the carrying capacity is not yet reached) inexperienced birds (see line 2 in Figure 6.2) increased in number, and then "learned" to become experienced birds, resulting in a reduction in their numbers. Inexperienced bird populations never reduced to zero as mortalities and migration constantly occurred. The experienced bird population (line 1 in Figure 6.2) increased in number as inexperienced birds "learned". Figure 6.3 represents the effect of the dynamics of the experienced and inexperienced populations illustrated in Figure 6.2 on risk of AWCs (collisions per 10 000 aircraft movements) over a theoretical 12 month period. Initially (as a result of the high number of inexperienced birds) the risk was found to increase, and then decrease (to slightly above 4 collisions per 10 000 aircraft movements) as inexperienced birds learned aircraft avoidance and habituation.

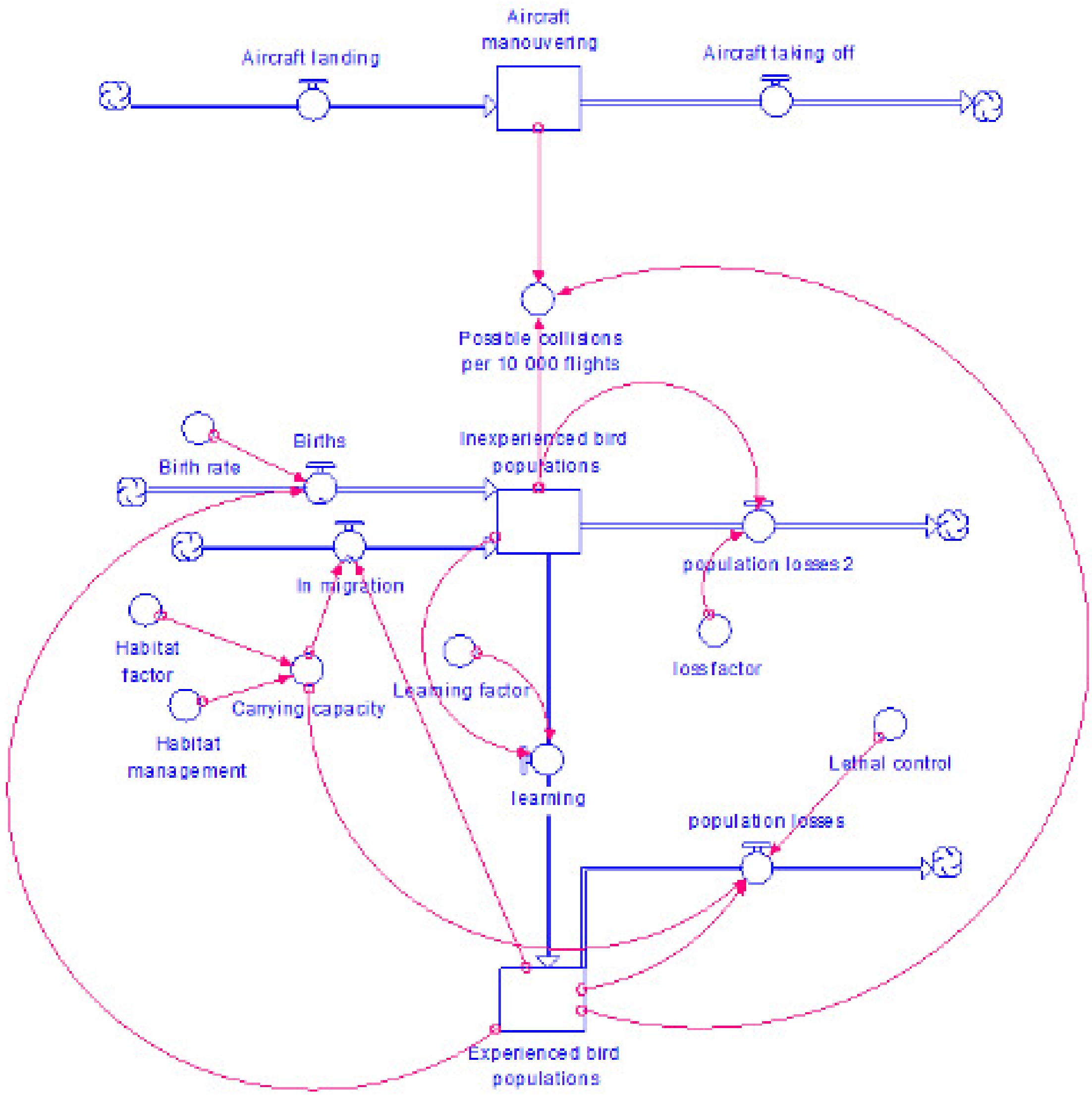


Figure 6.1: Systems thinking model diagram of AWCs using the modelling tool Stella ® (Richmond 2004).

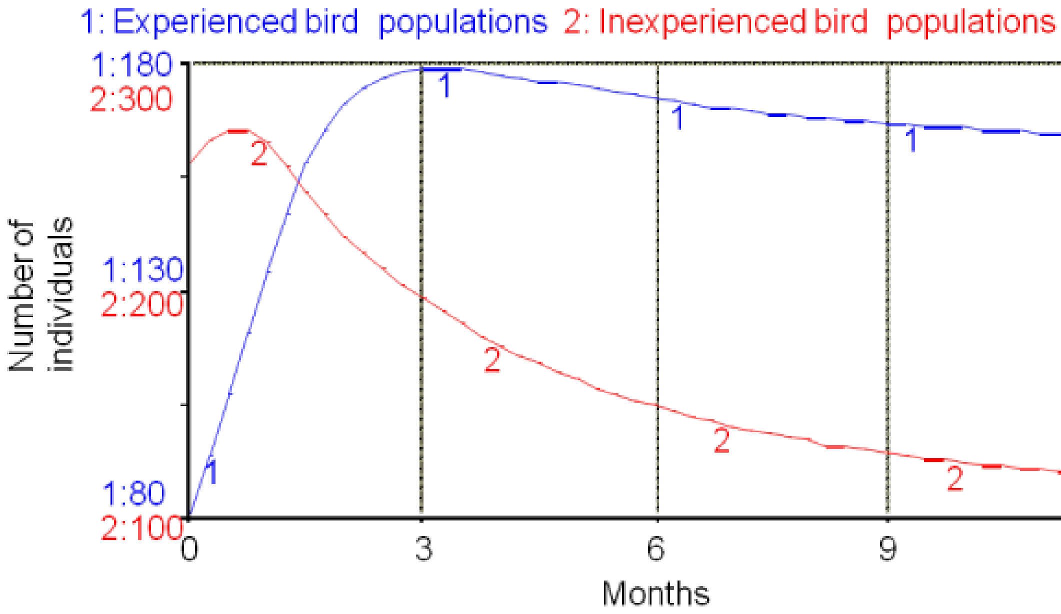


Figure 6.2: Predicted changes in experienced and inexperienced *V. coronatus* populations at Eros airport over 12 months (initial experienced bird population = 80 individuals)

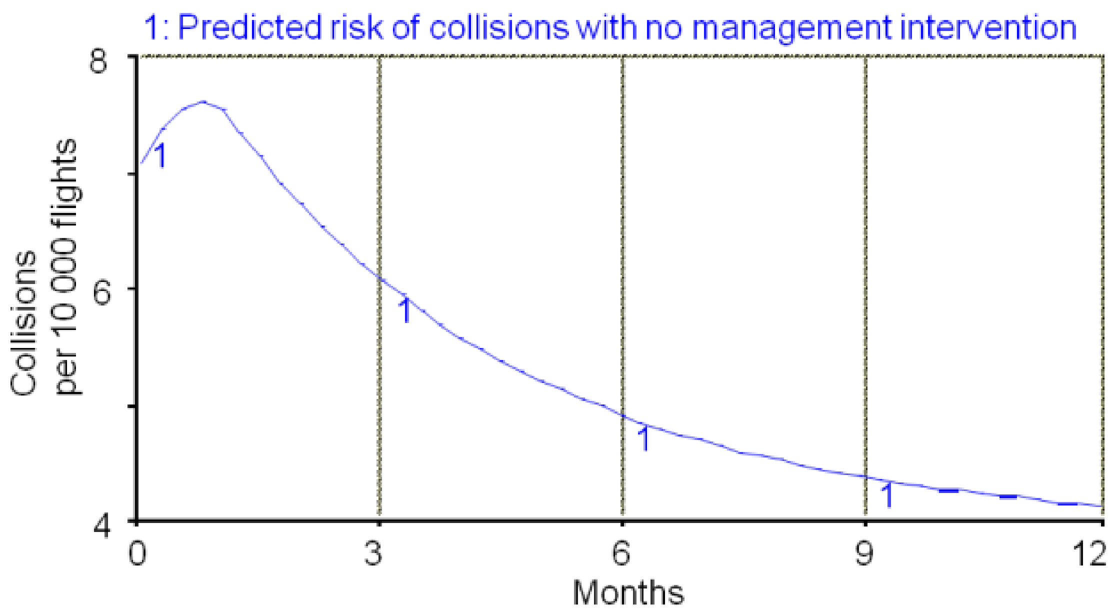


Figure 6.3: Predicted changes in the risk of AWCs at Eros airport as a result of the population changes illustrated in Figure 6.2.

6.3.2 Sensitivity analysis

Table 6.1 summarizes the results of sensitivity analyses for five model parameters; the baseline risk (line 1 in Figures 6.4 to 6.7) represents the effect of the dynamics of the experienced and inexperienced birds on risk of AWCs (collisions per 10 000 aircraft movements) over a 12 month period with changes to the following parameters:

1. Percentage wildlife management effort spent on lethal control of birds at the airport (Figure 6.4).
2. Percentage wildlife management effort spent on habitat manipulation measures (Figure 6.5).
3. A combination of lethal control and habitat management (Figure 6. 6).
4. Birth rate of risk bird species (as a possible result of e.g. changes in seasonal rainfall) (Figure 6.7).
5. Rate of learning of inexperienced birds to become experienced, in order to lower the risk of them colliding with aircraft (Table 6.1).

Table 6.1: Sensitivity analysis for five parameters using the systems model (table format modified from Fischer (2011).

Parameter tested	Original value (%)	Test value (%)	Description of test effect	Effect on the risk of AWCs (Sensitivity)
Lethal control management effort	0	60	A lethal control effort of 60% resulted in a similar initial increase in risk of AWCs (Figure 6.3a, line 2) as per the baseline (= where no wildlife management took place, line 1), but resulted in a slower reduction of risk thereafter. The risk further settled out at fractionally below 6 collisions per 10 000 aircraft movements, higher than the baseline.	Increased risk (Highly sensitive)
Habitat manipulation management effort	0	60	Figure 6.3b represents a proportionally lower risk of AWCs by reducing the total carrying capacity of the airport for birds.	Decreased risk (Moderately sensitive)
Combination of lethal control and habitat manipulation	0:0 (Lethal control : habitat manipulation)	40:60 (Lethal control :habitat manipulation)	Figure 6.4 illustrates that initially the risk of AWCs roughly follows the risk when only habitat manipulation is conducted; when approaching month 3, the risk of the combined management effort is lower than when only habitat manipulation is conducted; the risk stabilizes at a higher	Initially decreased risk but long term (5^+ months) increased risk (Moderately sensitive)

Parameter tested	Original value (%)	Test value (%)	Description of test effect	Effect on the risk of AWCs (Sensitivity)
			rate than for both the baseline and the habitat manipulation only scenarios.	
Birth rate increase (fraction of population)	0.2	0.45	Figure 6.5 illustrates a higher risk over the baseline scenario, with a consistent increased risk after month 3.	High increase in short and long term risk (Highly sensitive)
Learning factor of inexperienced birds (to avoid AWCs)	0.2	0.45	The birds' increased ability to learn aircraft avoidance and habitation leads to a faster reduction in risk, and a lower stable state risk as a result of the ability of birds to learn faster when replacing out-migrating or dying birds (not illustrated).	Decreased risk (Highly sensitive)

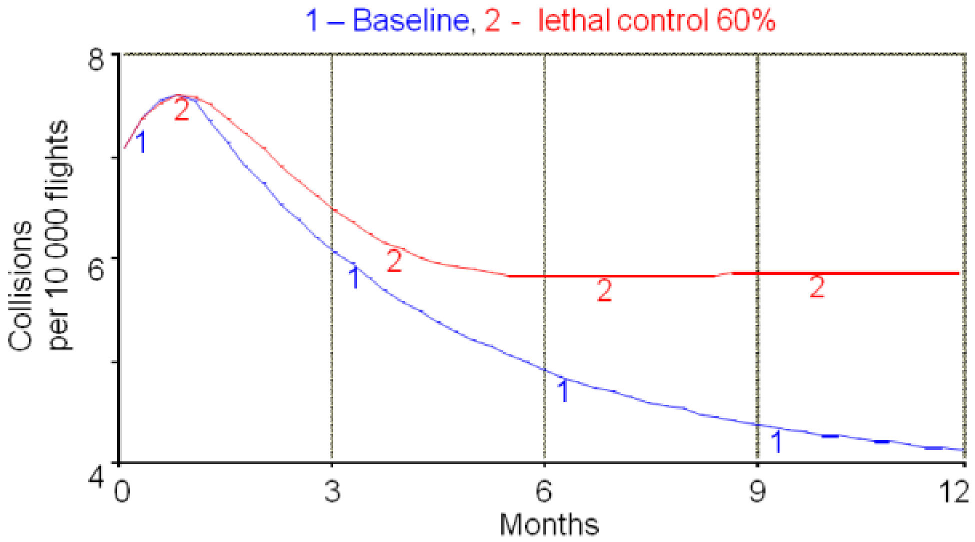


Figure 6.4: Predicted effect of lethal control effort of 60% on the risk of AWCs (line 2).

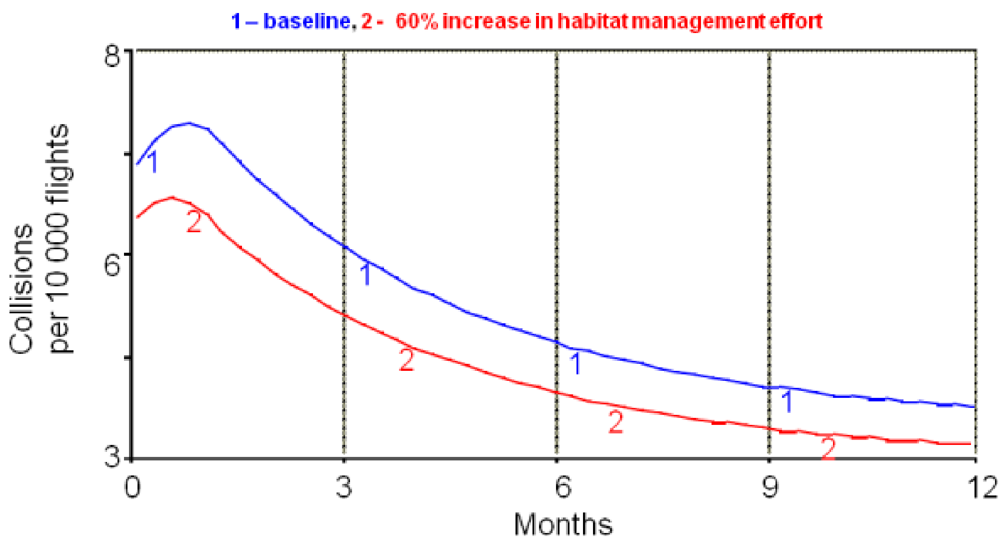


Figure 6.5: Predicted risk of AWCs with an increase in habitat management effort (from 0% to 60%; line 2).

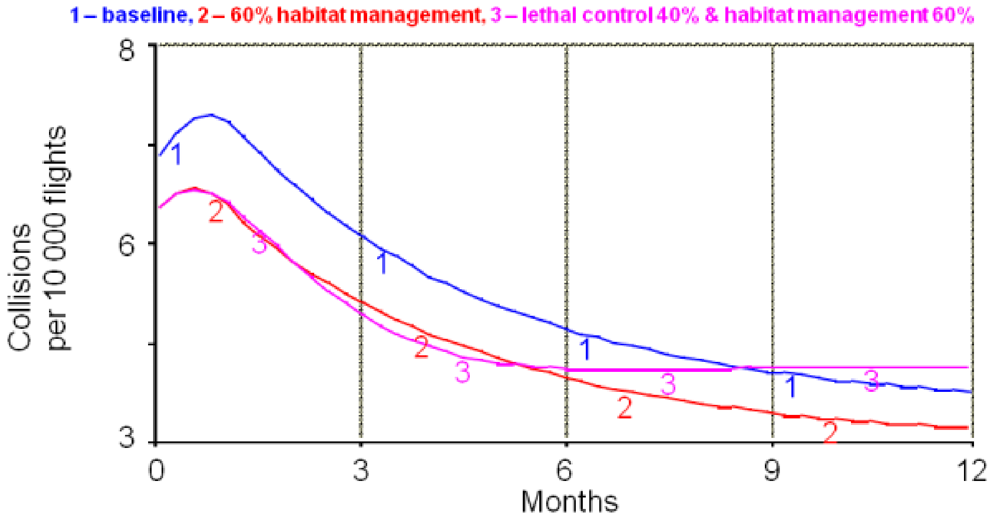


Figure 6.6: Predicted risk of AWCs over time with a lethal control effort of 40% combined with a habitat management effort of 60% (line 3), as compared to a habitat management effort of 60% only (line 2).

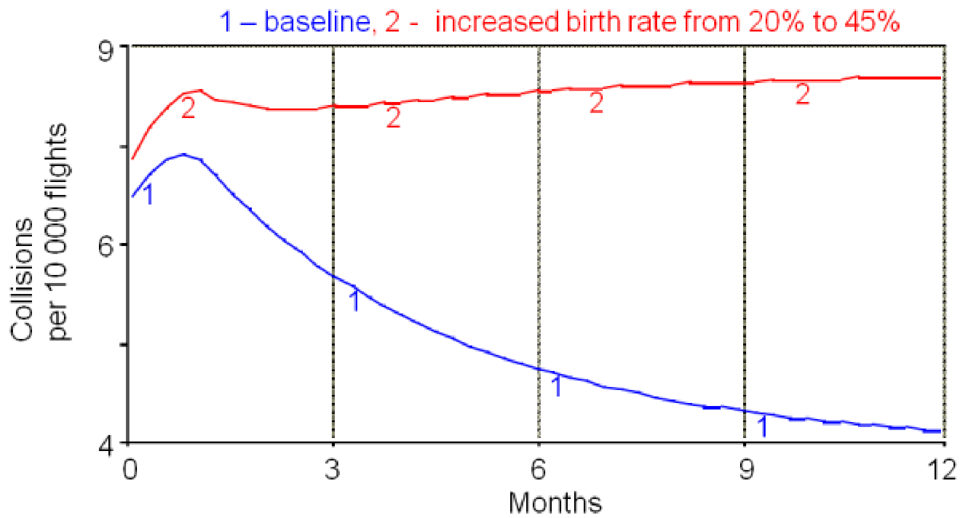


Figure 6.7: Predicted risk of AWCs over time with increased birth rate of V. coronatus (annual population increase from 20% to 45%; line 2).

6.4 Discussion

Collisions with all birds at Eros airport over the period 2006-2010 were 11 per 10 000 aircraft movements, of which 68.9% were with Crowned Lapwing (Chapter 2, Hauptfleisch *et al.* 2013). This made the model predictions of risk of collisions (Figure 6.1) a conservatively realistic representation of possible collisions risks with this species.

The model construction process facilitated understanding of the complexity of factors which affect the risk of collisions between aircraft and wildlife. The organic, non linear characteristic of systems modelling allowed for linkages between factors to be illustrated and tested on a temporal scale. It further illustrated the effect of habitat management and control measures on the risk, more specifically, the importance of reducing the carrying capacity of airports for resident bird populations as opposed to lethal population reduction mechanisms which merely increase the numbers of inexperienced birds. At Eros Airport it provided a guiding mechanism for the managers when deciding to allocate resources to wildlife control or habitat management. It also identified and clearly illustrated where uncertainties in the understanding of AWCs exist, and could focus research to address such uncertainties.

The sensitivity analysis as described in Table 6.1 and Figure 6.4 to 6.7 found that lethal control alone is not always a solution to reducing wildlife numbers (De Wet 2002). Lethal control resulted in a disturbance to the population of experienced resident birds at the airport. Inexperienced birds then in-migrated to occupy the vacant niches left by controlled birds, resulting in no net reduction in the bird population as observed by Belant *et al.* (2000) and Bosch *et al.* (2000). These inexperienced individuals were assumed to have a higher likelihood of colliding with aircraft as they are more “flighty” and less experienced in aircraft avoidance or had not learned appropriate avoidance behaviour (Kelly *et al.* 2001). When no wildlife management was applied in the model, AWC risk was lower than with lethal control, identifying lethal control as a possible counterproductive measure when used for resident bird populations. Less birds present (= lower birth rates) also decreased the risk of collisions. Dolbeer *et al.* (1993) found that for non-resident birds flying over airports, lethal control was successful in reducing AWCs while Dolbeer & Franklin (2013) found successes in Canada Geese, semi resident birds at best.

Understandably applying habitat manipulation management to decrease the carrying capacity resulted in a consistently lower risk of AWCs. When, however, combined with lethal control, an initial greater reduction in AWC risk was observed in the short term only; in the long term (beyond 5 months), however, a higher risk is predicted. The model, further, indicated how faster evasive learning rates decrease the risk of AWCs.

The factors affecting AWC risk vary globally. This is compounded by findings that all wildlife species react differently to aircraft (Lensink *et al.* 2000). A generic model would therefore not be highly accurate. As more local research is, however, conducted (e.g. on the "learning" process of inexperienced birds), the parameters of the model can be adjusted for site specific results. These results should be tested in conditions where the effect on AWC control methods can be monitored – the next important step in the modelling process (Lynam & Stafford-Smith 2004).

6.5 Conclusion

The systems modelling process suggests it is possible to model the complexity of AWCs. It also highlighted that no factors influencing the risk of AWCs, or the extent of their influence, are expected to be the same at any two airports. Individual airports, therefore, need to identify and use their particular understanding in conducting simulations of risk using the systems model. In the current study the modelling process informed recommendations to increase habitat management effort, and reduce the reliance on culling for the management of the AWC problem at Eros airport. The model should be expanded, and become more informative as more data becomes available.

THEME 4: MANAGEMENT INTERVENTIONS TO MINIMISE THE RISK OF AIRCRAFT WILDLIFE COLLISIONS WITH INSHIGHTS FROM THEMES 1, 2 AND 3

CHAPTER 7: TOOLKIT FOR THE REDUCTION AND MANAGEMENT OF WILDLIFE AT SOUTHERN AFRICAN AIRPORTS AND AIRFIELDS

7.1 Introduction

The obligation placed on airport staff to control wildlife hazards in the vicinity of airports (ICAO 1991) is often difficult to fulfil, especially at smaller airports or in countries with inadequate resources and capacity. In addition to this, research into wildlife habitat, species and habits at airports has predominantly originated in Europe and North America, and hence mitigation measures are most effective in these conditions, and less effective elsewhere.

This toolkit was designed to guide airports in southern Africa to minimise risk of aircraft-wildlife collisions. It is based on the understanding of ecosystems in the vicinity of the two airports on which this study was based and on other studies in sub-Saharan Africa (Bitebekezi 2007, Byron & Downs 2002, Froneman 2000, 2001, 2005, 2006, Froneman & van Rooyen 2003, Kok & Kok 2002a, 2002b, Kok 2006, Leshem & Froneman 2003, Mundy undated, Nasirwa 2001, Oduntan *et al.* 2010, Owino *et al.* 2004, Yohannes *et al.* 2000). It also considers the recommended practices of ICAO (ICAO 1991), the World Birdstrike Association (IBSC 2006), and global best practice (e.g. Blackwell *et al.* 2012).

7.2 Toolkit contents

- Use of the toolkit;
- The responsibility for managing wildlife and reducing bird strikes;
- Airport planning;
- Training and capacity building;
- Wildlife management planning;
- Preventative wildlife management;
- Responsive wildlife management;
- Extraordinary event management;
- Wildlife identification;

- Monitoring / auditing wildlife reduction programmes.

7.3 Use of the toolkit

This toolkit is designed for use by managers and operators of airports and aerodromes in southern Africa. It also applies to aircraft pilots and managers of airlines concerned with the safety hazard posed by aircraft-wildlife collisions. It contains no technical jargon and does not require biological or scientific background to use. It can be used in full, or sections can be selected to supplement existing programmes. Observations during this study and literature have informed that airport personnel who are assigned the responsibility of managing the problem of aircraft-wildlife collisions in southern Africa are often unqualified to do so (see Chapter 8), as they have no biological or wildlife management background. Therefore this toolkit provides basic information for use by airport staff. As far as possible access to a computer is not necessary in order to implement the toolkit. It is further intended to empower airports and their stakeholders to approach the problem from a pro-active ecosystem based perspective.

7.4 The responsibility for managing wildlife hazards and preventing bird strikes

Aerodrome operation is globally regulated under the Chicago Convention on International Civil Aviation of 1944. The following southern African countries are signatories to the convention (www.ICAO.int):

- Angola
- Botswana
- Democratic Republic of Congo
- Lesotho
- Madagascar
- Malawi
- Mauritius
- Mozambique
- Namibia
- South Africa

- Swaziland
- Zambia
- Zimbabwe.

Volume 1 (Aerodrome design and operations) of the convention places a responsibility on aerodromes to manage wildlife hazards at airports and in the immediate vicinity. Provisions related to this are specified in the Airports Services Manual (Doc 9137 (3) Bird control and reduction) (ICAO 1991). The document prescribes that airports approach wildlife management comprehensively, identifying and systematically reducing wildlife hazards through a wildlife management plan or programme. In addition to this, the International Bird Strike Committee (IBSC), now known as the World Birdstrike Association (WBA) produced a set of nine standards for wildlife hazard management at airports (IBSC 2006). These standards, in addition to ICAO (1991), were used as a basis for this toolkit.

It is clear from ICAO (1991) that aerodromes are responsible for managing the wildlife hazards in a systematic and comprehensive manner. If this responsibility is ignored or shirked, aerodromes are often held liable for damage or injury caused by aircraft-wildlife collisions. Examples of this are explained by Matijaca (2001) and Battistoni (2009).

<u>The flip side</u>

In addition to the obligation of aerodromes to reduce wildlife hazards, they have the added responsibility to ensure that any activity causes minimal harm to the environment (Blackwell *et al.* 2009, Blackwell *et al.* 2013). This is implicit in the following international conventions:

- United Nations Convention on Biological Diversity;
- United Nations Convention to Combat Desertification;
- The Brundtland Report and Agenda 21; and
- Ramsar Convention on Wetlands of International Importance, especially as Waterfowl Habitat.

In response to the above, each country in southern Africa have developed comprehensive legislation and regulations regarding the protection of the environment and wildlife (SAIEA

2003). Wildlife management methods need to take cognisance of these, and ensure that lethal management of wildlife populations around airports, as well as use of chemical or physical measures to alter airport habitats do not contravene these laws (see Wittman *et al.*1998).

7.5 Airport planning

In hindsight, a number of airports would have been situated in alternate locations, had wildlife hazards been considered during their planning. In addition, the planning and zonation of land use surrounding airports could assist in reducing wildlife hazards to aircraft (Harrison 1976, van der Meide & Pieterse 2013).

All southern African countries have a legislative requirement for developments which could affect the environment to conduct an Environmental Impact Assessment (EIA) (SAIEA 2003). Airports in most cases fall into this category of development. Airport planners or developers should ensure that the terms of reference for airport EIAs contain a requirement for the possible wildlife hazard for the airport site and alternative sites to be assessed. Aspects that need consideration include:

- Airport neighbouring land use;
- Local and regional wildlife conservation initiatives;
- Airport waste management;
- Water supply and storage;
- Landscaping / horticulture;
- Bird migration routes;
- Infrastructure design (suitability as roots and nesting sites).

This is also applicable when airports plan new infrastructure or activities. An example of this is an assessment of the impact that the addition of photo-voltaic cells for electricity generation at airports may affect AWC risk in the USA (DeVault *et al.* 2014).

7.6 Training and capacity building

Building capacity among key individuals in the aviation industry is an important intervention in addressing the root causes of wildlife hazards at airports. Below are suggested programmes for training courses for which a full set of training PowerPoint slides have been developed. The courses were piloted in Namibia during September 2011, and are based on the requirements of ICAO (1991) and the guidelines of IBSC (2006). Hazard identification and risk assessment methodologies are based on Allan *et al.* (2003), Anagnostopoulos (2003), WSP-Walmsley (2003) and Hauptfleisch (2009).

Two day course: The Control and Reduction of Wildlife to Minimise the Risk of Aircraft-wildlife Collisions at southern African Airports

Course objectives:

The objectives of the course are to **e**quip airport personnel with the skills and knowledge to:

- *Understand airports and their neighbours as ecosystems;*
- *Understand what attracts wildlife to airports;*
- *Understand what ICAO, international and local law are concerning AWCs;*
- *Practically identify hazards relating the Aircraft Wildlife Collisions;*
- *Practically assess and rate risks relating to Aircraft Wildlife Collisions;*
- *Identify and apply preventative measures to reduce the risk of AWCs;*
- *Identify and apply control measures to reduce the risk of AWCs;*
- *Apply methods to identify mammals and birds;*
- *Effectively report and record Aircraft Wildlife Collisions.*

Methods of facilitating learning:

- Group exercises;
- Group discussion;
- Interactive input;
- Case learning (learning by doing).

Course Programme

Day One	
	Registration
Session 1	Welcome and introductions Purpose and objectives of the course Course outline
Session 2	Airports as ecosystems **Session outcome:** **Understanding the concepts of ecosystems (biotic and abiotic)** **Understanding the airport "ecosystem"** **Understanding why airports and surroundings attract wildlife** What is an ecosystem? Explaining the concept, introducing the idea of ecosystems and their services to us. The airport as an ecosystem How do neighbouring activities affect the airport ecosystem? Parts of the ecosystem that attract wildlife / birds
Session 3	What does the law say? **Session outcomes:** **Understanding of the international / national laws, policies and guidelines regarding Aircraft Wildlife Collisions** ICAO and the IBSC National laws relating to AWCs National laws relating to wildlife A wildlife management plan / programme (ICAO recommendation)
Session 4	Step 1 in managing wildlife – Identifying hazards Continue the interactive discussion as started in session 3 above. Also keep the groups as in session 3. **Session outcomes:** **Practically understanding how to identify hazards which lead to**

	risks of AWCs at an airport **Understanding where hazard identification fits into an airport Wildlife Management Plan / Programme** Hazards relating to AWCs in theory Practical identification of hazards (group exercise).
Session 4	Group feedback on hazards identified
Session 5	Risk assessment **Session outcomes:** **Understanding how to conduct a risk assessment relating to AWC hazards;** **Understanding where hazard identification fits into an airport Wildlife Management Plan / Programme;** **Practice relating to assessing and rating risks.** Theory on conducting a risk assessment Group work using identified hazards – conducting a risk assessment.
Session 6	Recap day 1: The airport as an ecosystem Why and how are wildlife attracted to airports? What is a wildlife management programme? Hazards Risk assessment
Day Two	
Session 7	Recap of day one
Session 8	How to identify wildlife **Session outcomes:** **Understanding the need to identify wildlife** **Basic identification skills regarding mammals and birds at airports in Namibia.** Mammals of our country

	Birds of our country
Session 9	Practical bird and mammal identification **Session outcomes:** **Study birds and mammals, learn behaviour and identification** **Become familiar with mammal and bird identification based on reference books**
Session 10	Recording and reporting AWCs **Session outcomes:** **Understanding the need for recording and reporting AWCs** **The system of recording and reporting AWCs.** What you don't measure you can't manage Demonstration of analysis of 2006-2010 NAC AWC reports.
Session 11	Managing the problem (reducing the risks) **Session outcomes:** **Understanding the two types of measures to prevent AWCs** **Understanding various methods of preventative management actions** **Understanding various methods of control measures** Preventative management actions Control measures.
Session 12	Recap of Day 2
Close, course evaluation and certificates	

Pilots, Airline Representatives and Air Traffic Controllers (ATC)

<u>The Responsibility of Airport Users to Minimise the Risk of Aircraft-Wildlife Collisions</u>

<u>(A course for pilots, airline representatives and Air Traffic Controllers)</u>

Course objectives:

The objectives of the course are to **e**quip pilots, airline representatives and Air Traffic Controllers (ATCs) with the knowledge to:

- *Understand the severity and risk that birds and wildlife pose to flight safety;*
- *Understand what ICAO, international and local law are concerning AWCs;*
- *Practically identify hazards relating the Aircraft Wildlife Collisions;*
- *Apply methods to identify mammals and birds;*
- *Effectively report and record Aircraft Wildlife Collisions and near miss incidents*

Methods of facilitating learning:

- Group exercises;
- Group discussion;
- Interactive input;
- Case learning (learning by doing).

Course Programme

Day One	
	Registration
Session 1	Welcome and introductions Purpose and objectives of the course Course outline
Session 2	How serious is the Aircraft-Wildlife Collision Problem in southern Africa? **Session outcome:** **Understanding the severity of AWCs in southern Africa** **Understanding the need for all stakeholders in playing a role in preventing collisions** **Understanding what the responsibility of airports are in minimising the problem** AWC statistics for the past 5 years Case studies of actual AWCs This is the airport's problem, right?
Session 3	What does the law say? **Session outcomes:** **Understanding of the international / national laws, policies and guidelines regarding Aircraft Wildlife Collisions** ICAO and the IBSC National laws relating to AWCs National laws relating to wildlife A wildlife management plan / programme (ICAO recommendation)
Session 4	Helping airports minimise the problem – Identifying hazards **Session outcomes:** **Practically understanding how to identify hazards which lead to risks of AWCs at an airport**

	Understanding where hazard identification fits into an airport Wildlife Management Plan / Programme Hazards relating to AWCs in theory Practical identification of hazards (group exercise).
Session 4	Group feedback on hazards identified
Session 5	Recording and reporting AWCs **Session outcomes:** **Understanding the need for recording and reporting AWCs** **The system of recording and reporting AWCs.** Who reports what to whom? Need to accurately record and report AWC information. What you don't measure you can't manage Near miss incident reporting Demonstration of analysis of 2006-2010 NAC AWC reports.
Session 6	Practical bird and mammal identification **Session outcomes:** **Study birds and mammals, learn behaviour and identification** **Become familiar with mammal and bird identification based on reference books**
Close, course evaluation and certificates	

7.7 Wildlife management planning

The ICAO airport services manual (Doc 9137 (3)) (ICAO 1991) requires every airport to have a wildlife control and reduction programme. The programme should identify and manage wildlife (birds in particular) which pose a potential risk to aircraft. It can in effect be seen as a conventional Wildlife Management Plan in reverse, where habitat and other environmental conditions are made as unsuitable as possible for wildlife.

The functioning of a wildlife control and reduction programme is illustrated in Figure 7.1 below:

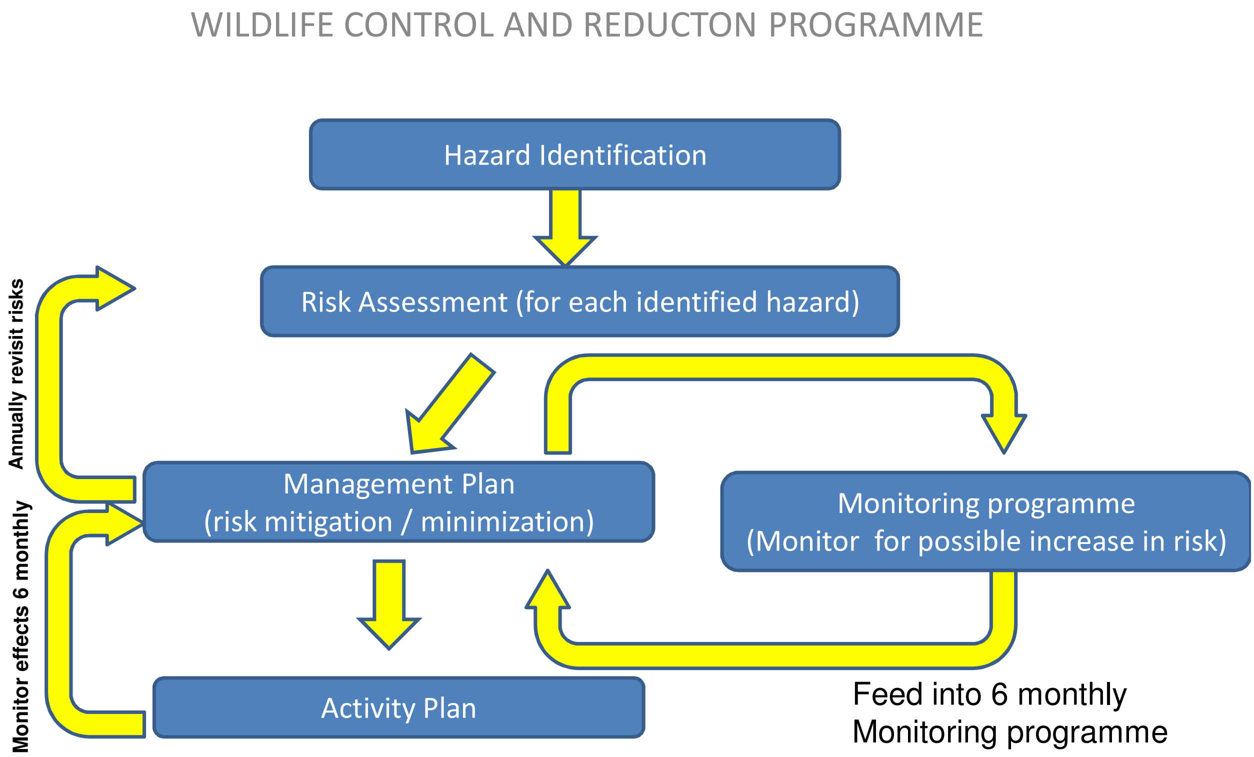


Figure 7.1: Flow diagram of an adaptive wildlife control and reduction plan

The Wildlife control and reduction programme for each airport will therefore have the following steps:

7.8 Hazard identification

Hazard identification should be undertaken annually (at least), and should include:

- A site inspection by a wildlife expert;
- A multi-sectoral stakeholder workshop to identify hazards and design mitigation measures;
- Analysis of past year's near miss and collision incidences; and
- Analysis of past year's wildlife occurrence monitoring.

A multi-sectoral workshop as mentioned above is critical in identifying and managing wildlife risks at and in the vicinity of airports. Stakeholders from the vicinity of the airport that should attend may include: airport staff, airport management, airline operators, pilots, civil aviation authorities, conservation organisations, bird clubs, academic institutions, ecological research bodies and airport neighbours (particularly farmers and municipalities).
An example of a workshop agenda is provided below:

Agenda for Stakeholder Workshop to Identify and Address Wildlife / Bird Hazards to Aircraft at Hosea Kutako and Eros Airports

Opening and welcome	09h00
Rationale for the workshop	09h15
The current risk of collisions and actions currently being taken	09h45
Open discussion in response to presentations	10h15
Identification of wildlife hazards at airports	10h30
Group brainstorm sessions – designing mitigations for identified hazards	11h00
Designing an action plan for implementation of identified mitigation measures	12h15
Next steps and closure	13h00

The outcome of the workshop should be an action plan. Table 7.1 below is an example of such an action plan, developed as part of this study at a meeting of the Wildlife Hazard Management Committee of NAC on 9 June 2011:

Table 7.1: Action plan for hazards identified at the Wildlife Hazard Management Committee meeting of NAC on 9 June 2011.

Action Plan:

Hazard	Action to be taken	By whom	By when
Birds in general (Vultures, seasonal bird occurrences, guinea fowl, lapwings)			
General actions			
	Research – take stock of what occurs there – during the day and at night	Birds & Aircraft Research Namibia (BARN-P) MET Vultures Namibia	ASAP
1 Vultures:			
Carcasses:	Neighbours to remove carcasses	Landowners	Immediately
Poaching	ASAP Poachers to be apprehended	NamPol	ASAP
Feral dogs	Dogs to be caught and impounded	SPCA	ASAP
Disease			
Vulture restaurants	This committee to identify suitable locations for vulture restaurants in the area	NAC, Vultures Namibia	ASAP
Nesting	Map nesting locations – research on where the birds are feeding	MET & Bird clubs	ASAP

Hazard	Action to be taken	By whom	By when
Nampower powerlines as perches for vultures	Network with Nampower / NNF partnership	NAC – Nampower/NNF	ASAP
Flying vultures	Have an early warning system – get warnings to pilots (use Air Traffic Control – give them binoculars)	ATC & NAC	ASAP
2 Birds in General: **Guinea Fowl** **Seasonal bird occurrences**			
Food sources that attract birds	Research on insects, small mammals as food sources Impact of light (attracting insects to the apron)	BARN-P to coordinate	Continuously
Ignorance (public and responsible institutions)	Awareness campaign (general public and decision makers in the industry) Press releases Information pamphlet Open communication between NAC and neighbours BARN-P newsletters DCA to be brought on board as soon as		Immediately

Hazard	Action to be taken	By whom	By when
	possible		
3 <u>Lack of communication and coordination</u>			
Directorate of Civil Aviation (DCA)	Lobby DCA to take a leading role, enforce reporting of bird strikes, oversight, funds	NAC / DCA	Continuously
Ministry of Environment and Tourism (MET) and Namibia Tourism Board (NTB)	Provide expertise, participate in NAC wildlife committee meetings	MET/NTB	Annually
Ministry of Works & Transport	Provide support and get involved – fund activities	MOWT	Continuously
Aviation charter operators	Increase awareness of wildlife hazards, report effectively to NAC	IOA	Continuously
Tertiary Institutions	Conduct research & avail students	Polytechnic, UNAM	Continuously
Namibia Airports Company	Funding / competent staff to deal with the problem on airports / provide a "Birdstrike Centre" / facilitate the wildlife management partnership	NAC (HKIA & EROS and HQ)	Continuously
National Museum of Namibia	Provide expertise	Museum mammals section	Continuously
Farm owners	Report issues,	Airport neighbours	Continuously

Hazard	Action to be taken	By whom	By when
(neighbours of airports)	provide expertise		
Bird clubs	Provide support and expertise	NAC to approach bird clubs	Continuously
Reporting	DCA to enforce the reporting of all birdstrike incidents and near misses NAC to provide birdstrike reports on a quarterly basis Operators to ensure reports are sent to NAC	NAC and operators to lobby DCA	Continuously
4. <u>Habitat management</u>			
Habitats within airports are suitable for wildlife	Research on different habitats	MOWT / BARN-P	Immediately
	Cutting of grass (research)	BARN-P / NAC	Continuously
	Infrastructure to be designed to be bird “unfriendly”	MOWT / NAC	Immediately
	Look for green solutions (environmentally friendly)	NAC / BARN-P	Ongoing

Risk Assessment

This was adapted from methodologies in Short *et al.* 2000, Davis *et al.* 2002, Anagnostopoulos 2003, WSP-Walmsley 2003, Allan 2006, Vincoli 2006, Sowden *et al.* 2007, Hauptfleisch 2009 and van der Meide & Pieterse 2013). Each of these references has a variation on scoring of hazards, therefore a workshop on 9 June 2011 (consisting of managers and staff of NAC, five major airlines, airport neighbours (around the study airports), conservation organisations and academic institutions developed the scoring system below.

Not all hazards pose an equal risk to aircraft and passenger / personnel safety. It is further acknowledged that prioritisation of hazards is necessary, therefore the matrix below assists in assigning a risk rating to identified hazards. The risk is determined by multiplying the probability of a hazard causing an accident by the severity of possible consequences if a collision ensues.

Probability of hazard causing an accident

1- Improbable

2- May occur on the ground

3- May occur infrequently (in the air)

4- May occur frequently (in the air)

5- Will occur (in the air)

Severity of consequences

1- No consequence

2- Minor damage, collision only possible on the ground

3- Slight damage, possible emergency situation

4- Possible emergency situation, threat to life possible

5- Threat to life probable

Risk Score of Hazards (Multiply Probability and Severity of Consequence) (Figure 7.2)

1-6 – Low risk

7-12 – Moderate risk

13-25 – High Risk – Management plan required

Probability						
Consequence		**1**	**2**	**3**	**4**	**5**
	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

Figure 7.2: Risk scoring matrix.

Hazards should then be recorded in the form below. This form should be displayed where all airport personnel and aircraft operators can view it.

Hazard	**Cause**	**Risk Rating**	**Risk**

Hazards rated as having a high risk (matrix score of 13 to 25) need to be managed as a matter of urgency. Other hazards need to be managed within a management tracking plan, described below.

Management Tracking Plan

A management tracking plan needs to be drawn-up for each identified risk hazard, to establish mitigation or minimization actions for the hazard. It should take the form of the form below:

High Risk	**Qualification**	**Mitigation / minimization measure**

High Risk	Qualification	Mitigation / minimization measure

Activity Plan

A specific activity plan for who, when, where the management actions are to be completed needs to be established. This builds on the activity plan developed during the hazard assessment workshop mentioned above. It should take the form of the form below:

Risk Mitigation Measure	Action	Responsible person

Monitoring programme

Monitoring is an important management action as it acts as an early warning system for possible aircraft-wildlife hazards (van der Meide & Pieterse 2013). It also informs whether management actions taken are effective (see Figure 7.1). It needs to be concise and user friendly.

As airport personnel in southern Africa responsible for wildlife hazard management may not have access to (or proficiency in) computer software to manage monitoring information, a monitoring system applied in Namibia's conservancy programme (The event book system - Stuart-Hill *et al.* 2005) was adapted to produce a set of monitoring sheets for the purpose of airport wildlife management. The system is recognised as best practice in wildlife monitoring where responsible personnel are inexperienced and often not computer literate (Constantino *et al.* 2012). Examples of these sheets are appended.

Aspects that need to be managed are:

Aircraft-wildlife collisions as per the requirements of IBSC (2006)

Damage causing collisions

Near miss incidents

Wildlife sightings (identified risk species as required under certain circumstances)

Waste management

Water management

Managing perch and nesting sites

Vegetation management (grass and bush)

Runway inspections

Maintenance

Airport Neighbour relations

The above parameters should be collated monthly, and graphed to illustrate increases or decreases. The data should also be used to calculate the following key indicators (Dolbeer & Wright 2008, Dolbeer 2011):

i) Collisions per 10 000 flights

$$= \frac{\text{Number of collisions (over a set time period)}}{\text{Number of flights (same set time period)}} \times 10\,000$$

ii) Ratio of damage causing collisions to collisions

$$= 1/ \frac{\text{Number of damage causing collisions (over a set time period)}}{\text{Number of total collisions (over a set time period)}}$$

7.10 Preventative wildlife management

It is generally accepted that actions aimed at preventing a problem are more effective than reactive actions (Berry & Rondinelli 1998, IBSC 2006, Blackwell *et al.* 2009). The following preventative actions can be taken to avoid aircraft-wildlife collisions:

7.10.1 Vegetation management

Systems modelling of the bird strike problem (Chapter 6) identified that reduction of airport ecological carrying capacity is most effective in reducing aircraft wildlife collisions. This can be achieved by altering the productivity (and thus attractiveness) of vegetation. Barras & Seamans (2000), Deacon & Rochard (2000), Dekker (2000) DeVault *et al.* (2009) and Linnell *et al.* (2009) describe it as habitat management, and notes that it is very important to control wildlife at airports. It can further be achieved by altering the structural diversity of vegetation at airports (by mowing grass to one height, or removing woody vegetation). Research (Deacon & Rochard 2000, Dekker 2000, Froneman 2000, Seamans *et al.* 2007, DeVault *et al.* 2009, Blackwell *et al.* 2013) has warned that no one vegetation management method is effective in all environments. It is therefore essential that methods used and tested in European and North American conditions be evaluated by ecological specialists before being implemented in southern Africa. Overall a vegetation at an airport should provide limited food for wildlife, be aesthetically pleasing, lower fire risk, be relatively drought resistant and require minimal maintenance (Washburn & Seamans 2004).

<u>Grass management</u>

Research has found conflicting results on the effectiveness of grass mowing to reduce wildlife hazards at airports (Deacon & Rochard 2000, Dekker 2000, DeVault *et al.* 2009, Hesse *et al.* 2010). This is important to know prior to employing either a short grass or long grass policy, what you want the policy to achieve. Merely changing from one policy to another to reduce wildlife at airports in general may result in risks being replaced by equally or more hazardous wildlife. Successes achieved in reducing wildlife hazards through a long grass policy have largely been in temperate climates, where long grass pastures have a high density of grasses, making it difficult of raptors to penetrate these areas in order to take advantage of increased numbers of small mammals in long grass pastures. Much of southern Africa is semi arid, or has long dry seasons (Dube 2002), consequently grass density is lower, and increased small mammal numbers in long grass areas are more accessible to raptors. Grass mowing should be done at the end of summer, which results in slower recovery of the grass sward than any other time (Chambers & Samways 1998).

A key consideration for grass management in southern African is the relationship between pasture (veld) and grazing herbivores (Savory 1999). Rangeland expertise are useful to involve in the development of a grass management strategy at an airport. Incorrect grass management could result in an improved grass (palatability and density) at airports which could attract grazing herbivores from neighbouring areas which may have large populations of domestic or wild large ungulates, thereby increasing risk of collisions with aircraft on take-off or landing.

Cut grass should be removed as it can pose a fire hazard and attract harvester termites (families Hodotermitidae, Termitidae and Rhinotermitidae). In the semi arid areas it can also act as a mulch which allows for moisture retention by the soil and provides refugia (shelter) for small mammals, birds and insects.

An airport could consider leasing property for agriculture (grazing or cropping) if it proves to be a lower wildlife risk than unmanaged veld if resources to manage grass are inadequate (DeVault *et al.* 2013). As far as could be determined, this practice is untested in southern Africa. Common practice in Namibia (NAC pers comm., personal observation) has been to invite farmers to cut and bale airport grassland for use on neighbouring properties.

Shrub and tree management

Shrubs and trees provide roost, nesting, shelter and food for wildlife (IBSC 2006). As with grass, there are healthy populations of browsing herbivores in southern Africa relying on leaves and twigs for food. In or around towns and villages this may be predominantly domestic goats, while airports surrounded by wilderness areas (including on the outskirts of large cities such as Gaborone, Mbabane and Windhoek) kudu, springbok, impala, bushbuck, elephant and giraffe may be encountered. Collisions with some of these species have been recorded. Removal of all woody vegetation in the airport perimeter is recommended. This can be achieved through mechanical removal and / or application of arboricides.

Wildlife deterrent vegetation

Airports in Europe and North America have experimented with plant species which deter wildlife (Deacon & Rochard 2000, Washburn & Seamans 2007, Linnell *et al.* 2009, Blackwell *et al.* 2013). These include *Calluna vularis* (heather), *Ulex europaeus* (gorse), *Wedelia trilobata* and *Fescuta arundinacea* (Fescue). It is recommended that the planting of exotic species be avoided as they may become invasive (Washburn & Seamans 2004). In southern Africa, species with the potential to deter birds and other wildlife are of the genus *Aristida* and *Cymbopogon* (B. Strobach, National Botanical Research Institute of Namibia. personal communication). This has however not been trialled.

Research in New Zealand (Pennell & Rolston 2007) suggested the use of an endophytic (internally growing) fungus which creates toxins in grass plants to be used at airports to cause vegetation to be less attractive.

Application of fertilizers to airport grass stands can be used in temperate areas to increase grass density and hamper access for birds to forage or hunt (Blackwell *et al.* 2013).

7.10.2 Arthropod (Insect and Spider) management

Arthropods account for the majority of animal species and biomass in most ecosystems (Groombridge 1992 in Simmons *et al.* 1998, Dennis 2003). At airports insects provide food for birds and other wildlife (Bernhardt *et al.* 2010), were found to be attracted to the heat of runways and taxiways (Pennell & Rolston 2007), and use airport grasslands as shelter (Kutchbach-Brohl *et al.* 2010). In addition to managing vegetation (as above), insect numbers at airports can be reduced through the use of insecticides (Blackwell *et al.* 2013). The effect needs to be carefully considered, as insecticides can affect non-target species, and become problematic for neighbouring land users.

7.10.3 Waste management and good housekeeping

Landfills and waste dumps are considered key wildlife hazards near airports (Ladd 1970, Harrison 1976, IBSC 2006). In addition to avoiding constructing landfill sites at airports or in their vicinity, waste management at airports is equally important. Good practice in waste management (generally included in Environmental Management Plans) will ensure minimal waste is produced at airports, and that it is less likely to cause a scavenging risk (Hauptfleisch 2009). The waste management principles of reuse and recycling should be encouraged and all waste skips should be covered and inaccessible to wildlife. Food waste is of particular concern and the management thereof should follow best practice available at leanpath.com (Leanpath undated). This includes source reduction, reuse (through food donations), and recycling or composting. Of particular concern in southern Africa is the attraction of scavenging species such as Chacma Baboon, Black-backed Jackal, Marabou Stork, Black and Pied Crow and White-backed Vulture (see Chapter 2 and 3).

Poor housekeeping (also normally addressed under Environmental Management) can contribute to wildlife hazards (Hauptfleisch 2009). Inefficient stacking of equipment and materials creates crevices for rodents and reptiles, increasing wildlife hazards. Unhygienic conditions attract scavenging insects and rodents, again creating prey species for birds and other wildlife which may be a collision risk (Hauptfleisch 2009).

7.10.4 Infrastructure management

<u>Buildings</u>

As stated in the section above on airport planning, buildings attract wildlife for shelter and nesting sites. The design of buildings should consider best practice where the Game Lodge Industry has taken the lead in southern Africa (www.ecoawards-namibia.org). Design should also consider the effects landscaping of gardens will have on attracting wildlife (Washburn & Seamans 2004).

<u>Lights</u>

Lights are insect attractants (Robinson 1952, van Tets 1969). This attraction to lights however, causes arthropods to become easy meals to birds and bats (van Tets *et al.* 1969. Birds quickly learn to make use of these artificial feeding stations (Van Langevelde *et al.* 2011). Lights of different colours (or screened with coloured screens) have differing effectiveness in attracting insects. A study by Ashfaq (2005) found that red lights (low frequency, high wavelength) attract the least number and diversity of insects. It is recommended that airports consider colour experiments (visibility for safe work and security taking priority) to reduce insect attraction. Flood lights should be shaded to prevent unnecessary light from being emitted beyond the required area.

Towers, antennae, windsocks, signs, weather stations

Airports structures such as radio towers, antennae, windsocks, weather stations and sign posts provide perch sites for birds (WARN 2011). They are used as vantage perches for raptors, display perches, and roosts for a variety of birds. These structures should be managed (e.g. with spike strips) to prevent frequent use for perches.

Fencing

Fencing can be a double edged sword for wildlife management at airports. In areas where heavy grazing use predominates surrounding land use (much of the region – Mendelsohn *et al.* 2002), airports act as islands of palatable grazing (Chapter 3 and Chapter 5). This likely attracts wildlife and domestic livestock, thereby creating a collision risk.

On the other hand fencing is important to prevent livestock and wildlife from accessing airport manoeuvring areas (DeVault *et al.* 2008). Fencing type and height is dependent on the number of crawling or jumping ungulates in the vicinity, and needs to be informed by wildlife experts. Crawling species likely to be encountered at arid to semi-arid southern African airports include Springbok, Oryx and Hartebeest. Jumping ungulates include Kudu, Eland and Impala.

Warthog and Aardvark often burrow under fences creating pathways for other species. It is recommended that in areas where these species occur, fences are buried and cemented into the ground up to a depth of 60cm.

7.10.5 Water management

In much of southern Africa open water is a particular attractant to wildlife, as little open freshwater is available in general. Any dams or open reservoirs are likely to attract wildlife (waterfowl and mammals) at any airport (DeVault *et al.* 2009), but particularly in southern Africa. Water points in arid savannas are known to influence wildlife and livestock movements in rural areas (Mphinyane & Rethman 2006). Airports should therefore avoid open water storage and sewage systems.

7.11 Responsive wildlife management

Even if effectively applied, it is impossible for preventative actions to stop all risk species of wildlife from occurring at or near the airport (IBSC 2006). An integrated approach is recommended (IBSC 2006, DeVault *et al.* 2009) when responsive action should be taken to remove them from areas where collisions may occur. There is an exhaustive list of products available to airport wildlife controllers, as a general guide the options listed in Table 7.2 could be considered in southern African conditions:

Table 7.2: Airport wildlife control methods and their effectiveness.

No.	Method	Equipment required	Effectiveness	Cautions	Use for	Environmental consequences
			Sight			
1	Laser lights	Laser emission devices	High	Only effective at night	Nocturnal birds and mammals	Visual disturbance
2	Dummy raptors	Rubber / concrete dummy raptors	Moderate	Habituation	Prey birds and wildlife	None
3	Scarecrows	Scaring device	Moderate	Habituation	All birds	None
4	Glimmer plates	Metal plates on wire swivels	Moderate	Habituation	All birds, some mammals	Visual disturbance
5	Dogs	Trained dogs, dog handlers	High	None	All birds, most mammals	None
6	Aircraft	Pied	Moderate	None	Slow-	None

	augmentation to make them more visible (e.g. lighting, or pied propellers)	propellers, painted nosecones			moving birds	
Sound						
4	Pyrotechnics	Shotgun / flare launcher and pyrotechnic cartridges	Very high (if methods are alternated to prevent habituation)	Risk of causing veld fires	All birds and wildlife	Sound pollution, possible fire risk
5	Gas canons	Gas canon and LPG Gas cylinder	Very high (if regularly alternated with other methods to prevent habituation)	Habituation	All birds and wildlife	Sound pollution
6	Ultrasound	Ultrasound devices	Moderate	Unproven technology	All birds and wildlife	None
7	Predator calls	CD player, amplifier and speaker	Moderate	Habituation	Prey mammal species	Sound pollution
Culling						
8	Shooting	Rifle / shotgun and cartridges	Moderate (Species and site dependent)	Creates a population sink	All birds and wildlife	Negative impact on populations, negative public image
9	Poisoning	Chemical	Moderate	Creates a	All birds	Negative

		poisons and bait		population sink, can result in system poisonings,	and wildlife	impact on populations, soil / groundwater contamination, secondary poisoning, persistent organic pollutants
10	Falconry	Trained falcons	Moderate	Create a population sink	Slow flying birds	Negative impact on populations

Choice of responsive methods

Many factors influence the effectiveness of each of the above methods. The decision to use any of them should consider the following aspects:

Is the method effective for managing the particular species of birds / wildlife at the airport? Most methods were developed in Europe or the USA and as such, their application is designed for a different suite of wildlife. The wildlife manager needs to decide (based on the behaviour, biology and population dynamics of problem species) the most appropriate methods to use.

Will wildlife become habituated to a control method?
As highlighted in the Table 7.2 above some of the methods are prone to lose effect as a result of wildlife / birds becoming habituated to them. Particularly sound repelling devices show this tendency. To mitigate for habituation the wildlife manager needs to integrate a number of the methods, and not rely on one only.

Methods which remove wildlife from the system (e.g. shooting, poisoning, falconry) may have a counterproductive effect on the risk of aircraft wildlife collisions and are often controversial (DeVault *et al.* 2009), although Dolbeer *et al.* (1993) found that habitat management had little effect on birds flying over the airport, and in this instance found culling successful. Dolbeer & Franklin (2013) indicate that for mammalian wildlife and non to semi resident bird populations culling is an effective management tool. Territorial birds on the airport property however defend their territoria against rivals (of the same and other species), and they are often habituated to aircraft noise and movement. As a result they are a lower risk, as they are not startled by aircraft. These individuals also tend to be most visible on the airport, and in culling operations are the first to be shot. They are then replaced by inexperienced individuals, more likely to be startled by aircraft movements, thus flying up into the path of aircraft.

7.12 Extraordinary event management

While investigating risks at the study airports, a number of possible extra-ordinary events were identified by stakeholders which, if they were to occur, may lead to a sudden heightened risk for collisions (Hauptfleisch 2008).

Extra-ordinary events for aircraft-wildlife collisions would include times where large concentrations of birds or mammals are encountered. Such congregations are caused by two factors. (i) Large concentrations of food suddenly appearing, also known as eruptions, (e.g. army worms, locusts, flying ants (termites) or, (ii) Migrations (e.g. flamingos, swallows). In many cases, as mentioned in the Table 7.3 below, it is impossible to predict such events, or to apply any management action to prevent the outbreak to occur, but monitoring of such situations and alerting aircraft where possible is most effective in limiting their risk.

Table 7.3: Extraordinary wildlife hazard events and their management at airports in southern Africa.

Event	Associated risks	Cause	Airports it may affect	Preventative actions
Army worm (Noctuidae) outbreak	Heavy outbreaks of these moth larvae attract large congregations of	Unusually high rainfall with high densities of crops or young growing	Areas of southern Africa which contain large areas of crop	Monitor marshy areas with dense vegetation for moths, larvae, spray with insecticide

Event	Associated risks	Cause	Airports it may affect	Preventative actions
	birds (e.g. sacred ibis, storks) which feed on them. This may lead to large numbers of these birds occurring on the site, or in the vicinity of the site	plants	cultivation.	
Locust outbreak	Large migrations are usually associated with large swarms of birds feeding on the locusts	A combination of climatic factors, cycles of poor rainfall, followed by effective early seasonal rains.	Arid and semi arid regions of southern Africa	Monitor any nationally identified outbreaks, assist in management of the problem off site. As the outbreak moves towards the airport, a NOTAM can be issued to aircraft operators, and special landing and take-off regulations can be put in place.
Flamingo migration	Large numbers of flamingos crossing plane flight-paths	Migrations from one water / food source to another, or migration to breeding grounds	Airports in close proximity to saline water bodies (Namibian coast, Botswana, South African	Prevent damming of water on airport properties. Monitor migratory routes and warn aircraft if noticed.

Event	Associated risks	Cause	Airports it may affect	Preventative actions
			west coast and inland salt pans.	
Armoured ground crickets	Feed on runway verges, using the runway for heat, are also attracted to tar roads.	Heavy rain synchronises their hatching causing outbreaks. (Mostly during March and April)	Most southern African airports	As they have few enemies, they generally do not attract large numbers of birds or other predators.
Small raptor congregation	Large congregations of these birds around airport are a serious collision risk	Behavioural ecology, food source concentration, roosting sites where they congregate (e.g. lesser kestrels, yellow-billed kite)	Most southern African airports	Monitor for large concentrations of rodents, remove large trees which may attract congregations to roost. Monitor for individuals roosting in the vicinity of airports, as large congregations may follow in time. Information on such congregations can then be given to airport personnel and incoming aircraft, but such a situation is largely unmanageable

Event	Associated risks	Cause	Airports it may affect	Preventative actions
Termite dispersal	Attract large densities of birds which prey on the emerging termites	Synchronised emergence of flighted termites, usually associated with early summer rains, to disperse and start new colonies	All southern African airports	Monitor occurrence of termite nests on airport properties, control with pesticide if necessary. It is recommended that at the start of the growing season (i.e. Spring) an inspection of the runway surroundings and aprons are made to identify termite nests. The nest should be treated with a systemic insecticide. This process should be repeated at the height of summer (January).

General precautions for control of extra-ordinary events:
• Environmental expert monitors for any outbreaks, and reports to airport authorities monthly. Resources such as bird migration research projects, agricultural pest monitors and environmental ministerial briefs could be used as early warning systems. • A site inspection by an environmental expert is conducted at the start of the rainy season each year, to identify the risk for extra-ordinary events (e.g. identify the density of termite nests, larvae, rodents etc.) Use control measures if necessary.

- Training of key airport personnel to identify signs of problem events (e.g. high numbers indicator birds) and to employ effective control measures.
- Each airport to keep a store of broad-spectrum pesticide, and undergo training in its use, for urgent applications when required.

7.13 Wildlife identification

Identification of wildlife responsible for collision hazards is an important part of wildlife management at airports (Allan 1994, IBSC 2006, Bitebekezi 2007). It is not sufficient to classify birds as large, medium or small as is done in some cases. Information such as diet, feeding habits, nesting and breeding behaviour, and flight dynamics may provide clues to the management of different species of wildlife at airports. A basic understanding of broad taxonomy of bird (Class: Aves) and animal (Class: Mammalia) orders will allow any person (responsible for managing wildlife at an airport) to use guide books and posters in order to identify individual species in southern Africa.

In addition, most Capital cities in southern Africa have active Museums of Natural History or Zoological academic faculties. These institutions have research collections and expertise which can be referenced to identify species.

Table 7.4: Southern African countries' institutions that can provide identification and information on risk wildlife species at airports.

Country	**Institution**
Angola (Luanda)	National Museum of Natural History
Botswana (Gaborone)	Botswana National Museum
Democratic Republic of Congo (Kinshasa)	University of Kinshasa, Private Museum of Zoology
Lesotho (Maseru)	National University of Lesotho – Department of Biology Ditsong National Museum of Natural History (Pretoria) National Museum Bloemfontein (Bloemfontein)

Country	Institution
Madagascar (Antananarivo)	University of Madagascar Museum of Zoology
Malawi (Blantyre)	Museums of Malawi (Chichiri)
Mauritius (Port Louis)	Mauritius Natural History Museum
Mozambique (Maputo)	Museo de Historia Natural Maputo
Namibia (Windhoek)	National Museum of Namibia
South Africa (Pretoria) (Bloemfontein) (Cape Town)	Ditsong National Museum of Natural History National Museum Bloemfontein South African Museum, Iziko Museums; Percy FitzPatrick Institute of African Ornithology, University of Cape Town
Swaziland (Pretoria)	Ditsong National Museum of Natural History
Zambia (Livingstone)	Livingstone Museum
Zimbabwe (Bulawayo)	Natural History Museum

The following reference books are the most comprehensive and accurate regarding information about mammals and birds in southern Africa:

Mammals of the Southern African Subregion (IIIrd Edition) – Skinner & Chimimba (2005).
Roberts Birds of Southern Africa (VIIth Edition) – Hockey *et al.* (2005).

A number of field guides are available, and it is recommended that copies of these are made available to field staff. These include:

- A Field Guide to the Tracks & Signs of Southern and East African Wildlife – Stuart & Stuart (1994);
- Mammals of Southern Africa – Apps (2000);
- Mammals of Namibia – Comley & Meyer (1997); and
- Roberts Bird Guide – Chittendale (2007).

Table 7.5 and 7.6 below are simple guides on the important orders of mammals and birds which will enable airport wildlife controllers to use reference or guide books in order to conduct identification down to species level. The tables were constructed with information from Griffin (1998), Apps (2000), Froneman (2000), Froneman (2001), Kok & Kok 2002a, Froneman & van Rooyen (2003), Hockey *et al.* (2005), Skinner & Chimimba (2005) and Hauptfleisch *et al.* (2013).

Table 7.5: Mammal orders which would possibly constitute (or lead to) hazardous wildlife at or in the vicinity of airports in southern Africa. Taken from a literature study of the abovementioned references.

Order	**Description**	**Possible hazardous species**
Artiodactyla	(Even-toed hoofed animals), includes most ruminant and non-ruminant herbivores (all antelope, domestic livestock)	Cattle, goats, sheep, kudu and eland (fence jumpers), warthog (burrowing under fences), oryx and springbok (fence crawlers)
Carnivora	Meat eaters (lion, leopard, cheetah, hyena, jackal, mongoose, civets, dogs)	Domestic dogs, jackal
Chirpoptera	Bats	All species if in large numbers, especially larger species such as fruit bats
Hyracoidae	Hyrax or dassie	All species as they are important prey species for large raptors
Lagomorpha	Rabbits and hares	All burrowing species, as they can create fence breaches for larger wildlife, and are important raptor prey species
Perissodacytla	(Odd-toed hoofed animals) Horses, donkeys, zebra	Donkeys breaking through fences (especially in rural overgrazed pastures)
Primates	Baboon, monkey	Baboon (fence climbers, scavengers)
Proboscidea	Elephant	Fences are not barriers to

Order	Description	Possible hazardous species
		elephant
Tubulidentata	Aardvark	Aardvark burrow under fences, creating access to other mammals

Table 7.6: Bird orders which would possibly constitute (or lead to) hazardous wildlife at or in the vicinity of airports in southern Africa.

Order	Description	Possible hazardous species
Struthioniformes	Ostrich	Erratic running behaviour when startled (hazardous only at unfenced airports)
Galliformes	Ground foraging, lethargic in flights, heavy birds	Guinea Fowl, Francolin, Spurfowl, Quail
Anseriformes	Ducks and Geese, living in wetlands, near dams and rivers. Often flock if flight	Egyptian Goose, Spur-winged Goose, all duck species
Buceratiformes	Hornbills	Red-billed Hornbill, Yellow-billed Hornbill are plentiful in southern African savannas, Ground Hornbill are large and ground-living
Apodiformes	Swifts	Most species occur in large flocks hunting insects in flight (often around buildings / aprons)
Musophagiformes	Louries, Turacos	Grey turaco (Go away bird)
Strigiformes	Owls, Nightjars	Barn Owl, Marsh Owl, Spotted Eagle Owl, Giant Eagle Owl, nightjars can settle on runways / taxiways for heat at night
Columbiformes	Pigeons and Doves	Feral Pigeon (in cities), Rock

Order	Description	Possible hazardous species
		Pigeon, Laughing Dove
Gruiformes	Crakes, Flufftails, Moorhen, Coot, Crane, Korhaan, Bustard	All water-fowl mentioned near large water bodies or wetlands, Korhaan and Bustard in terrestrial grassland
Charadriformes	Small to medium sized birds, some waders, some terrestrial ground living birds	Lapwings (Crowned, Blacksmith), Oystercatchers, Gulls, in coastal habitats,
Falconiformes	Birds of prey	All, especially White-backed Vulture, Lappet-Faced Vulture, Palm-Nut Vulture, Martial Eagle, Buzzards
Ciconiiformes	Waders and storks	Greater and Lesser Flamingo, Pelican, Hamerkop, Spoonbill, Saddlebill Stork, White Stork, Abdim's Stork, Marabou Stork, Hadeda Ibis, Sacred Ibis
Passeriformes	Song birds	These are mostly small birds, but species flocking in large groups could be a problem. For example Red-billed Quelea

7.14 Monitoring / auditing wildlife reduction programmes

Airport performance scorecard

The following Airport Performance Scorecard is designed to test compliance of airports to ICAO regulations (ICAO 1991) and International Bird Strike Committee standards (IBSC 2006). It takes the form of an "internal audit" and can be adopted by a country's civil aviation authority, or used internally. It is useful for an airport to identify gaps in their Wildlife Management Programme, and to monitor performance of the Wildlife Management Programme year on year.

Each aspect of the scorecard is weighted as the lack of, or inadequate implementation of some wildlife control measures at airports will result in a higher risk than others. For each scored aspect, documented proof or physical inspection is required to qualify the score. It is recommended that the scoring be conducted during a workshop involving airport staff, wildlife experts, the civil aviation authority, airline operators and air traffic control. The scorecard structure is simple while being robust, allowing for as little subjectivity as possible. Each question of the scorecard is accompanied by a clarification and explanatory note to exclude the possibility of different interpretations by different evaluators.

Performance scorecard for Control and Reduction of Wildlife at Airports in Southern Africa

The scorecard consists of 17 questions, clustered under 8 headings coinciding with the IBSC guidelines for the management of wildlife at airports (IBSC, 2006), but have been adapted for southern African conditions. Important to note is that guidance is provided so that scoring is consistent. This will hopefully reduce subjectivity by the scoring team and help focus the discussions that the team holds during the scoring workshop.

Airport Ecosystem / habitat / veld management

Is drainage controlled and infrastructure designed to not allow for surface water to collect within the airport property?

Scoring:

If there are no control measures – score 0

If some surface runoff control exists – score 1

If there is runoff control throughout the airport property – score 2

If there is complete runoff control and no open reservoirs or dams exist– score 3

Does grass management take place at the airport?

Scoring:

If there is no grass management, score 0

If the verges of runways are mown – score 1

If all areas around runways, taxiways, manoeuvring areas are mown, score 2

If all grass is mown – score 3

If grass management is conducted according to ecological monitoring criteria – score 4

How are trees and shrubs managed at the airport?

Scoring

No tree and shrub management - score 0

Trees that may act as perches or nesting sites are removed – score 1

All trees except shade trees and decorative trees are removed - score 2

Most trees and shrubs are removed from the property – score 3

All trees and shrubs are removed and any regrowth cut annually - score 4

Are buildings designed and managed to minimise bird / wildlife shelter / nesting / roosting?

Scoring

No management of buildings to reduce wildlife occurrence - score 0

Nests are removed and / or rodents are removed and birds chased out if seen – score 1

Netting, spike strips or other measures are in place to keep birds/wildlife out of buildings - score 2

Buildings are designed and maintained specifically to reduce wildlife occurrence – score 3

Are raptor perch sites managed?

Scoring

Perch sites are not managed - score 0

Some perch sites have been removed or modified – score 1

Risk assessment identified perch sites, and these have been removed or modified - score 2

Risk assessment and research has identified all possible perch sites, and these have all been removed or modified– score 3

How is waste management conducted at the airport?

Scoring

Waste is disposed of in an unfenced landfill on site - score 0

Waste is disposed of in a fenced off landfill on site – score 1

Waste is removed from the site - score 2

Waste is disposed off site, and stored in covered containers while on site – score 3

Waste management includes recycling, and waste is monitored to ensure no overfilling of containers, or exposure to wildlife – score 4

Reactive control measures (active control of wildlife)

Are bird / wildlife on critical airport areas timeously seen and dispersed?

Scoring

No bird / wildlife observation and dispersal takes place – score 0

Some ground personnel try to chase away birds / wildlife - score 1

Air Traffic Control alerts ground personnel of wildlife / birds who divert from their other tasks to disperse the birds / wildlife - score 2

Ground staff divert from their tasks to do regular patrols and disperse any birds / wildlife seen – score 3

Dedicated wildlife controllers do regular patrols and disperse any birds / wildlife - score 4

Organisational and institutional arrangements

Are there dedicated staff responsible to attend to bird / wildlife control?

Scoring

No dedicated staff - score 0

Wildlife control is a secondary task of another department – score 1

Identified personnel within another department have wildlife control as a key function – score 2

The airport has a dedicated wildlife control department / person - score 3

The airport has a dedicated wildlife control department and employs wildlife experts for key areas of concern – score 4.

Do airport departments and partners understand their roles with regard to wildlife management?

Scoring

No or little communication exists between Air Traffic Control, Airport Personnel, Emergency services and Airlines regarding the management of wildlife at the airport - score 0

Air Traffic Control and Airlines occasionally (monthly or less) report wildlife issues to the airport – score 1

Air Traffic Control and Airlines regularly (at least weekly) report wildlife issues to the airport – score 2

All roleplayers understand their responsibilities and are involved in the management of the problem – score 3

A formal procedure and regular meetings exist where wildlife responsibilities are discussed and managed – score 4.

Equipment availability for wildlife control

What equipment is available at the airport for wildlife control?

Habituation of wildlife to scaring mechanisms is a problem affecting their effectiveness. It is recommended that a range of different scaring mechanisms are used alternately, this reduces habitation. Scoring for this question is therefore based on an accumulation of points regarding the availability of equipment

Scoring

No specialised equipment - score 0

Gas canon - score 1

Pyrotechnics - score 1

Ultrasonic devices – score 1

Predator calls – score 1

Dummy raptors - score 1

Other - score 1 each

What other direct control measures are used to control wildlife?

Scoring

None - score 0

Culling - score 1

Dogs or falcons - score 2

Scientific research - score 3

Recording and reporting

Is effective “birdstrike” or wildlife collision reporting taking place at the airport?

Scoring

No recording or reporting is conducted - score 0

The airport only reports bird strikes to Civil Aviation – score 1

The airport records and reports bird strikes and near miss incidents – score 2

The airport records bird strikes, near miss incidents and wildlife occurrences – score 3

The airport does all mentioned above, but has encouraged Air Traffic Control, Airlines and the public to report wildlife occurrences or incidents – score 4.

Are wildlife records and reports analysed?

Meaning that in the law a person is allowed to challenge a decision on behalf of the environmental and unborn generations, even though s/he may not be a directly affected party.

Scoring

No analysis of records and reports takes place - score 0

Civil aviation do analyses and report to ICAO – score 1

The airport monitors an increase or decrease in incidents – score 2

The airport analysis data to identify high risks – score 3

A wildlife expert analyses data giving feedback on specific wildlife risks and effectiveness of management actions – score 4.

Bird / wildlife identification

Are species of birds / wildlife involved in collision incidents identified?

Scoring

No skills exist at the airport to identify species - score 0

Broad (family level) identification is made of most birds - score 1

Over 50% of birds are identified up to species level - score 2

Over 70% of birds are identified - score 3

Over 90% of birds are identified using scientific technology where needed - score 4

Risk Assessment

Is risk assessment used to inform the airport staff of changing wildlife risks?

Scoring

No risk assessments are conducted - score 0

A risk assessment was conducted once during the past five years - score 1

Risk assessments are conducted annually by airport staff - score 2

Hazard identification and risk assessment is conducted annually by an expert - score 3

An expert and stakeholders (airport staff, neighbours, airlines, Civil Aviation) conduct an annual hazard identification and risk assessment - score 4

Off-airport bird / wildlife management

The airport cooperates with neighbouring land owners and users to reduce the risk of aircraft-wildlife collisions?

Scoring

The airport has no interaction with neighbours - score 0

The airport has informal or ad hoc interaction with neighbours - score 1

The airport has annual meetings with neighbours - score 2

The airport has 6 monthly meetings with neighbours - score 3

The airport has defined, focused meetings with neighbours on a quarterly basis - score 4

How are possible off-airport risk areas managed?

Scoring

No off-airport risks are considered - score 0

Reported off –airport risks reported by pilots are occasionally investigated - score 1

Airport staff identify off-airport risks and alert pilots - score 2

Airport staff identify off-airport risks and cooperate with landowners to minimise these risks - score 3

The airport commissions research or consultancies to identify off-airport risks, and then cooperate with landowners to minimise these risks - score 4

Scorecard Summary

Answers to each of the 16 questions above are recorded in the summary scorecard below, with qualifications (documentation or physical inspection) for each answer.

Category	No.	Question	Score	Weight	Subtotal score (score x weight)	Qualification (Evidence to qualify score)
Airport Ecosystem / habitat / veld management	1	Is drainage controlled and infrastructure designed to not allow for surface water to collect within the airport property?		2		
	2	Does grass management take place at the airport?		1		
	3	How are trees and shrubs managed at the airport?		2		
	4	Are buildings designed and managed to minimise bird / wildlife shelter / nesting / roosting?		1		
	5	Are possible		1		

		raptor perch sites managed?	
	6	How is waste management conducted at the airport?	3
Reactive control measures (active control of wildlife)	7	Are bird / wildlife on critical airport areas timeously seen and dispersed?	2
Organisational and institutional arrangements	8	Are there dedicated staff responsible to attend to bird / wildlife control?	2
	9	Do airport departments and partners understand their roles with regard to wildlife management?	2
Equipment availability for wildlife control	10	What equipment is available at the airport for wildlife control?	2
	11	What other direct control measures	1

		are used to control wildlife?	
Recording and reporting	12	Is effective "birdstrike" or wildlife collision reporting taking place at the airport?	3
	13	Are wildlife records and reports analysed?	2
Bird / wildlife identification	14	Are species of birds / wildlife involved in collision incidents identified?	1
Risk Assessment	15	Is risk assessment used to inform the airport staff of changing wildlife risks?	3
Off-airport bird / wildlife management	16	The airport cooperates with neighbouring land owners and users to reduce the risk of aircraft-wildlife collisions?	3
	17	How are possible	2

	off-airport risk areas managed?	
Total score		

Toolkit Appendix: Wildlife Hazard Monitoring Sheets (as adapted from the Event Book System – Stuart-Hill *et al.* 2005)

The monitoring forms below can be updated by either colouring in the cells following an incident / monitoring event, or by writing specific information (e.g. species names into the cells). Information should be transferred from the monthly to annual monitoring sheet at the end of each month, and from the annual to ten yearly sheet at the end of each year. This monitoring method requires no understanding of monitoring or data management, and can be maintained with basic literacy skills.

Monthly monitoring sheets:

Month | |

Species responsible for collisions

20							
19							
18							
17							
16							
15							
14							
13							
12							
11							
10							
9							
8							
7							
6							
5							
4							
3							
2							
1							
	Species 1	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**

Month [ ]

20						
19						
18						
17						
16						
15						
14						
13						
12						
11						
10						
9						
8						
7						
6						
5						
4						
3						
2						
1						
	Runway 1	**Runway 2**	**Apron**	**Approach**	**Take-off**	**Cruise**

Month [ ]

10						
9						
8						
7						
6						
5						
4						
3						
2						
1						
	Runway 1	**Runway 2**	**Apron**	**Approach**	**Take-off**	**Cruise**

Annual Monitoring sheets:

Year:

Total number of aircraft-wildlife collisions	**20**												
	19												
	18												
	17												
	16												
	15												
	14												
	13												
	12												
	11												
	10												
	9												
	8												
	7												
	6												
	5												
	4												
	3												
	2												
	1												
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**

Year:

Total number of "near miss "aircraft-wildlife collisions	**20**												
	19												
	18												
	17												
	16												
	15												
	14												
	13												
	12												
	11												
	10												
	9												
	8												
	7												
	6												
	5												
	4												
	3												
	2												
	1												
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**

Year:

Total number of sightings of (risk species)

20												
19												
18												
17												
16												
15												
14												
13												
12												
11												
10												
9												
8												
7												
6												
5												
4												
3												
2												
1												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**

Ten yearly monitoring sheets:

Period 2012-2021

Total number of aircraft-wildlife collisions	**100**										
	95										
	90										
	85										
	80										
	75										
	70										
	65										
	60										
	55										
	50										
	45										
	40										
	35										
	30										
	25										
	20										
	15										
	10										
	5										
		2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**

Years:

Total number of "near miss "aircraft-wildlife collisions

100										
95										
90										
85										
80										
75										
70										
65										
60										
55										
50										
45										
40										
35										
30										
25										
20										
15										
10										
5										
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**

Years:

Total number of sightings of (risk species identified at specific airport)

100										
95										
90										
85										
80										
75										
70										
65										
60										
55										
50										
45										
40										
35										
30										
25										
20										
15										
10										
5										
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021

CHAPTER 8: A MULTI-STAKEHOLDER APPROACH TO MITIGATE THE RISK OF AIRCRAFT WILDLIFE COLLISIONS AT NAMIBIAN AIRPORTS

Abstract

A multi stakeholder approach is considered to be most effective in managing human wildlife conflicts, particularly aircraft-wildlife collisions. It not only results in better communication and coordination in responding to wildlife hazards at airports, but also ensures a holistic approach to the management actions and methods selected to minimize wildlife collisions at airports. The Namibia Airports Company, responsible for management of Namibia's eight main airports, now applies this approach in collaboration with the Wildlife and Aircraft Research Namibia project. This collaboration includes key role players from the aviation, conservation, scientific and academic sectors who assist in identifying and addressing wildlife hazards at Namibia's airports. It has led to an improved understanding of the problem of aircraft-wildlife collisions in Namibia, resulting in a cooperative attitude of pilots, airport personnel and the general public in addressing it. It has further resulted in resources being made available for focused applied research into priority wildlife hazards at Namibian airports. This paper demonstrates the approach used to address wildlife concerns at airports multi-sectorally, and also illustrates the resultant change in prevention and control measures used to address specific wildlife hazards at airports in Namibia.

Key words: Aircraft-wildlife collisions, airports, bird strike, multi stakeholder, Namibia

8.1 Introduction

The International Civil Aviation Organization (ICAO) recognizes collisions between aircraft and wildlife (birds in particular) as a priority safety risk (Buurma and Den Haag 2004, IBSC 2006). Greater flight volumes and increasing wildlife populations (as a result of successful conservation efforts) are leading to an increased risk of collisions between wildlife and aircraft (Cleary *et al.* 2006, Froneman 2000, Robinson 2000). The Airport Services Manual (ICAO 1991) dedicates Chapter 9 of Part 8 to the reduction of bird hazards. In order to reduce this risk the International Birdstrike Committee (IBSC) [since 2012 known as the World Bird Strike Association (WBA)] was formed, which has produced a set of nine standards for the control of wildlife hazards at aerodromes (IBSC 2006). Recommendations within these standards imply that wildlife control at airports cannot be conducted by airport staff in isolation. Standard 2 (concerned with the identification of wildlife attractants at airports) recommends that biological expertise is included and Standard 4, regarding bird control, recommends that airport staff receive specialist training. Henshaw (2003), Leshem & Froneman (2003), Bitebekezi (2007) and Messmer (2009) found that multi-stakeholder cooperation improved the control of wildlife risks at airports, while allowing for pooling of resources to address wildlife hazards (Curtis *et al.* 2005). Although the Namibia Airports Company (NAC) is committed to minimizing the risk of aircraft wildlife collisions (AWCs), airports in Namibia were found to lack the expertise to effectively manage the problem on their own (Hauptfleisch 2008).

Human wildlife conflict management, of which aircraft wildlife conflict is a part, is notoriously complex mostly as a result of the wildlife value orientation of stakeholders (Manfredo and Dayer 2004). The orientation is either (i) wildlife protection, (ii) wildlife use, (iii) wildlife appreciation, or (iv) human safety first. This influences their perception of the acceptability of various control measures (such as culling or capture) and the severity of wildlife hazards. It also results in studies on human wildlife conflicts being isolated to a discipline specific perspective (White *et al.* 2009). The isolated manner in which NAC airport staff approached the management of aircraft-wildlife collisions (AWCs) was found to be problematic as it provided a one-dimensional and reactive response (Temby 2004). A clear, consistent, coordinated and inclusive approach to management of human wildlife conflict issues is important; since it fosters trust and communication and demonstrates a willingness among all stakeholders to address the issues. This is an important first step to reduce human wildlife conflict (Madden 2004). Also important are the inclusion of social, economic and ecological factors in human-wildlife conflict management as this builds trust and improves participatory planning (Madden 2004).

The parastatal Namibia Airports Company Ltd is responsible for the operation of eight Namibian airports, including the Hosea Kutako International Airport (Namibia's largest airport) and Eros Aerodrome (highest volume of flights in Namibia). Since 2009, the NAC forged a partnership with the Wildlife and Aircraft Research Namibia (WARN) project in order to be more inclusive in managing the problem of AWCs at its Hosea Kutako and Eros airports. The involvement of airport neighbours, aviation experts, airlines, conservation organizations, educational and research institutions and biologists has resulted in more proactive solutions to AWC hazards. This paper demonstrates the stakeholder model that was applied, and benefits that have resulted from it, at Hosea Kutako and Eros airports.

8.1.1 Study area

Hosea Kutako International and Eros Airports are Namibia's largest and busiest airports. Collisions between aircraft and wildlife in the vicinity of the airports totalled 55 and 73 at Hosea Kutako and Eros respectively over the five year period 2006 to 2010. 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 (Hauptfleisch et. al. 2013). An increase in AWCs from 2008 to 2010 was evident at Eros, and probable but not statistically proven at Hosea Kutako (Hauptfleisch *et al.* 2013).

Hosea Kutako (22°28'S; 17°28'E) is Namibia's primary international airport, situated approximately 40 km east of Windhoek, the capital city, and is the largest of Namibia's nine parastatal airports. The airport is surrounded by extensive (mostly in excess of 5000 ha) cattle and game farming enterprises supporting large numbers of domestic and natural unglutaes.

Eros Aerodrome (22°36'S; 17°04'E) is primarily a local destination airport in a suburban area of the capital city of Windhoek. This airport carries the most traffic in Namibia (+/- 32 000 flights per year – NAC internal records). On three sides it is surrounded by suburban and business properties, and by the Windhoek Golf Course (recreational area) on the other.

8.2 Methodology, philosophy and approach

The International Civil Aviation Organization (ICAO) recommends that the risk of aircraft-wildlife collisions at or in the vicinity of airports be managed by qualified and competent personnel (ICAO 1991, IBSC 2006). It further recommends that airports appoint wildlife experts to manage the problem. In Namibia, NAC is responsible for the largest and most strategic airports in the country although they would be classified as small airports in more developed or populated countries. Limited available human and other resources (a common problem at smaller airports - DeVault *et al.* 2009) dictate that airport emergency services (Fire and Rescue) are delegated the responsibility to manage wildlife collision risks, supported and guided by airport operations management (Personal observation October 2007 - February 2011).

In late 2009 this project formed the Wildlife and Aircraft Research Namibia (WARN) to integrate biological, scientific, engineering, risk and aeronautical expertise in addressing wildlife hazards at airports in Namibia. The project used the Wildlife Hazard Management Committee (WHMC) of NAC to identify key issues, and address these from a multi-sectoral perspective. The project formed a partnership with the following institutions:

i) The Polytechnic of Namibia (Academic and training institution);
ii) The National Museum of Namibia (Natural sciences research);
iii) The Southern African Institute for Environmental Assessment (Environmental and public participation experts);
iv) The Airport Operators Association (Airlines and pilots association providing aviation expertise);
v) Airport neighbours (Farmers, golf course, tourism facilities); and
vi) The Namibian Raptor Rehabilitation and Education Centre (Ornithological conservation group).

8.3 Results and discussion

8.3.1 A multi-stakeholder approach implemented

Before the establishment of the WARN project, NAC and its airport managers mostly managed wildlife risks internally (Figure 8.1), following as best they could the recommended practices as prescribed by IBSC (2006). Leshem and Froneman (2003) and White *et al.* (2009) found this approach to lead to a narrow focus in addressing hazards as managers consider factors within their sphere of expertise only. To a large degree this also isolated pilots from the identification of wildlife hazards. Figure 8.1 further shows AWCs being reported to the Directorate of Civil Aviation (DCA), with no information, analysis or interpretation of the collisions flowing back from DCA to either pilots, airline operators or airport management – a most important step to inform airlines and airports about risk relating to wildlife (IBSC 2006, Klope *et al.* 2009, van der Meide & Pieterse 2013).

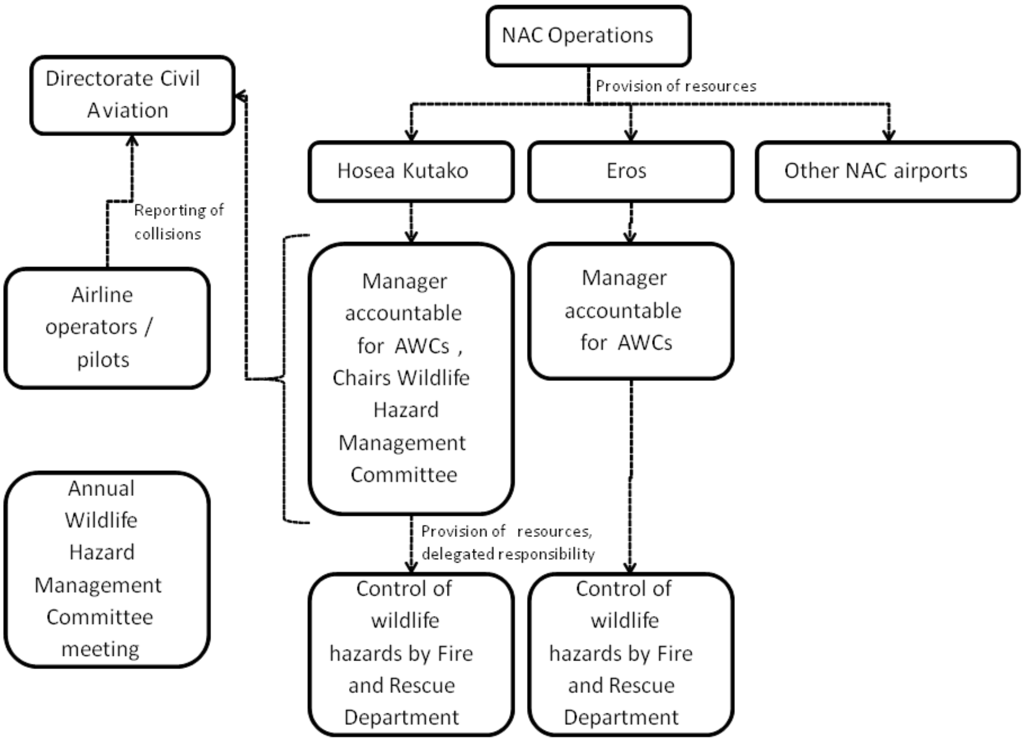


Figure 8.1: Management and organization in addressing wildlife hazards at Hosea Kutako and Eros airports before the establishment of the Wildlife and Aircraft Research Namibia (WARN) project (pre 2010. NAC, Namibian Airports Company).

Figure 8.2 illustrates the post 2009, multi-sectoral and multi-stakeholder approach to managing wildlife hazards at Hosea Kutako and Eros airports. Similar approaches were found to be effective in minimizing wildlife risks at airports in South Africa (Leshem and Froneman 2003, Froneman 2005), Uganda (Bitebekezi 2007), the Netherlands (van der Meide & Pieterse 2013), Canada (Henshaw 2003) and the United States (Messmer 2009). As recommended by IBSC (2006), the new approach included a contracted wildlife biologist who, apart from providing advice and recommendations regarding identified wildlife hazards, developed (in conjunction with the Wildlife Hazard Management Committee, WHMC) a list of research topics and problems for further research. The wildlife biologist is generally seen as neutral party among aviation stakeholders (Leshem & Froneman 2003), and can facilitate meetings and investigate problems transparently and with minimal bias. This, further, likely results in a more consistent approach, as people generally change their beliefs and behaviour to suit changing circumstances or interests (personal, scientific, social and economic - Lynam & Stafford-Smith 2004). The involvement of a biologist alone is however insufficient as

Madden (2004) warns that biological science alone does not provide a complete understanding of the problem, or provide all the solutions.

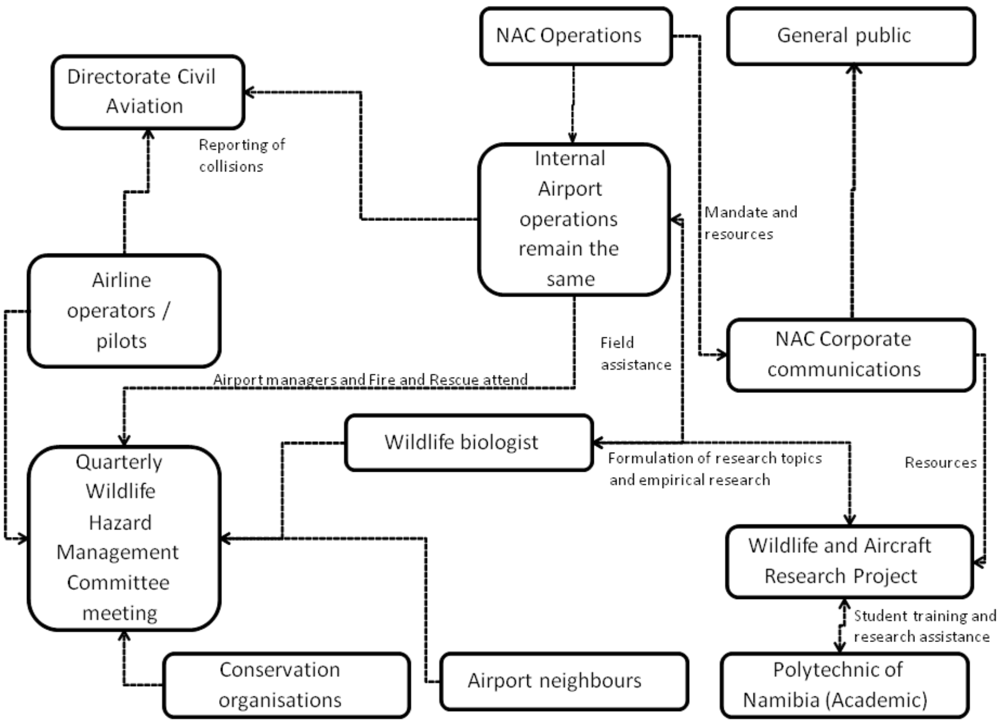


Figure 8.2: Management and organization in addressing wildlife hazards at Hosea Kutako and Eros airports since the establishment of WARN (end of 2009).

Other benefits of the collaboration included, amongst others, access to the conservation organizations' research networks, which could be deployed to research specific wildlife hazard concerns and provide inputs on the effects of wildlife control on conservation concerns (e.g. loss of biodiversity, diminishing wildlife populations) (Leshem & Froneman 2003, Madden 2004). The involvement of neighbouring land users took advantage of their knowledge of identifying wildlife hazards, indigenous knowledge of the area, views on possible solutions, and also reduced conflict between airport management, the airlines and neighbouring landowners. Unfortunately the regulating authority, the Directorate of Civil Aviation (DCA) remained unengaged in the process.

During the observation period (November 2009 to April 2012) the WHMC (now facilitated by the wildlife biologist) met quarterly, and comprised of an inclusive committee with representatives of airlines, airports (including those individuals directly involved in wildlife control), airport neighbours, wildlife experts and conservation organizations. This multi-stakeholder approach led to collective prioritization of hazards instead of individual prioritization based on one decision maker's experience and bias, as observed in similar cases by Lynam & Stafford-Smith (2004), Manfredo and Dayer (2004), and Temby (2004).

Public awareness of flight safety in general, and management of wildlife hazards specifically, is relatively low in Namibia. Once established, WARN lobbied with NAC and received considerable financial and logistical support from NAC's corporate communications department. The relationship enabled corporate communications to provide proactive media coverage on the management of wildlife hazards at Namibian airports. In addition, the web-based quarterly newsletter (produced by WARN and supported by corporate communications) kept airlines and other aviation stakeholders informed of developments and recommendations for specific research on wildlife hazards at airports. This provided capacity development which is considered to be important for successful human wildlife conflict management in general (Madden 2004), and AWC risk management in particular (Curtis 1999, Leshem & Shamoun-Baranes 2000).

IBSC (2006) warns against only using the number of AWCs to determine the risk of collisions, however the trend in AWC incidents over 76 months for the Namibian airports was considered a rudimentary measure of success of the altered approach to AWC mitigation. Figure 8.3 shows no notable reduction in AWCs at Eros, while Figure 8.4 indicates a reduction in the number of AWCs at Hosea Kutako since implementation of multi-stakeholder wildlife management in late 2009.

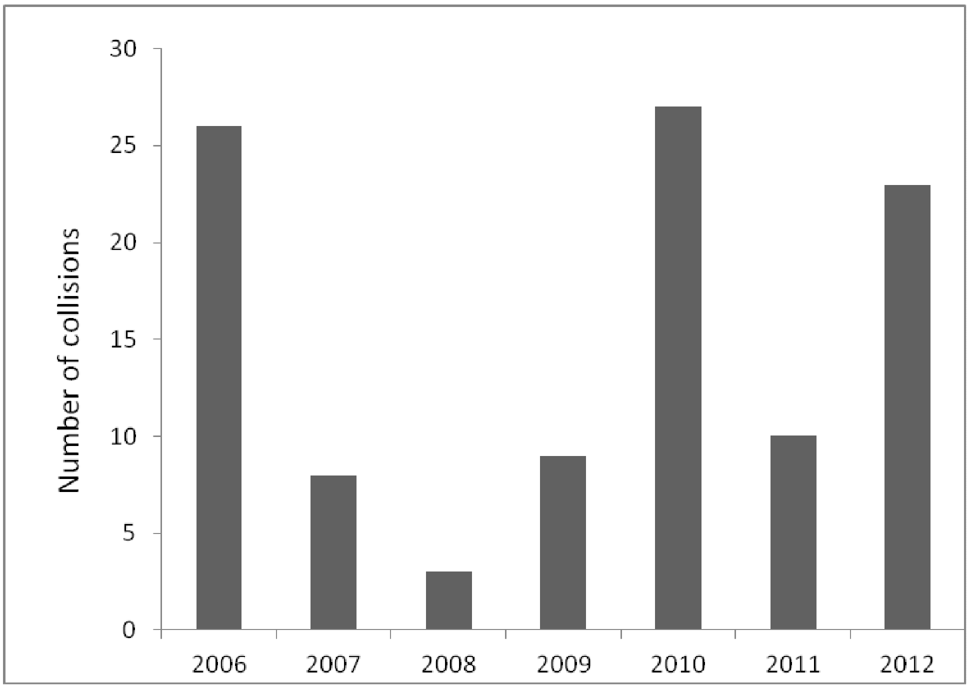


Figure 8.3: Number of aircraft-wildlife collisions (AWCs) at Eros airport from 2006 to 2012.

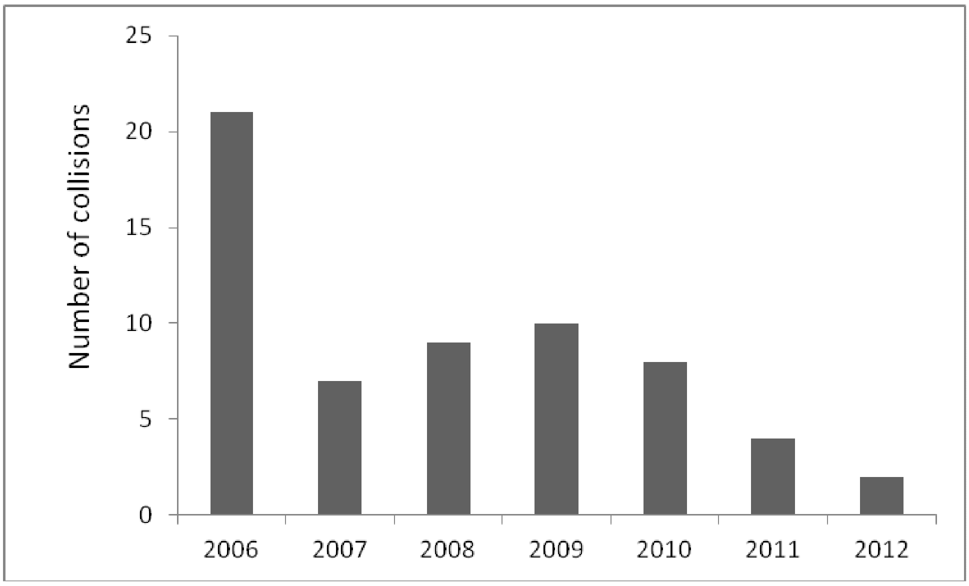


Figure 8.4: Number of aircraft-wildlife collisions (AWCs) at Hosea Kutako airport from 2006 to 2012.

Apart from a decrease in AWCs at one airport specifically, the multi-stakeholder approach resulted in a number of qualitative benefits for the management of wildlife hazards at airports both airports, as illustrated in Table 1.

Table 8.1: Recent changes in the approach towards wildlife hazards at Eros and Hosea Kutako airports (Personal observations 2007 – 2012).

Hazard identified	Airport	NAC response (pre 2010)	Multi-stakeholder response (since 2010)
Crowned Lapwing (*Vanellus coronatus*) frequenting runway verges	Eros	• Culling ; • Chasing with vehicles; • Increased runway inspections.	• Stomach content analysis of struck birds; • Poisoning of termites; • Change in grass management strategy (grass allowed to grow taller).
Frequent White-backed Vulture (*Gyps africanus*) sightings in the vicinity of airport	Hosea Kutako	• Warning communicated to operators.	• On site landfill closed, all waste removed to municipal landfill; • Consultation with neighbouring farmers regarding the management of animal mortalities; • Research project identifying vulture-feeding establishments, and their effect on vulture movements in the vicinity of the airport.
Large numbers of Red-footed Falcon (*Falco vespertinus)* and Yellow-billed Kite (*Milvus aegyptius)* on parking apron for first hour after dawn	Hosea Kutako	• Regular gas-canon detonations on the apron; • Shooting .	• Airport apron lights found to be attracting large numbers of insects at night; • Lights to be shaded and filtered in 2013 to reduce insect attraction; • Regular gas canon

Hazard identified	Airport	NAC response (pre 2010)	Multi-stakeholder response (since 2010)
			detonations on the apron.
Marabou Stork (*Leptoptilos crumeniferus)*, White Stork (*Ciconia ciconia*) and Abdim's Stork (*Ciconia abdimii)* frequent the airport following significant rain events	Eros	• Shooting; • Gas canon detonation; • Increased runway inspections;	• Shooting; • Stomach content analysis identifies frogs as a major component (found in standing water puddles); • Improved management of runoff water (drainage installed to prevent water collecting on airport property).

8.3.2 Altered approach to identified hazards

The approach to managing identified hazards became more proactive, and sought to address problems as close as possible to their root causes (Table 1). Where culling, shooting and chasing away were previously common practice aimed at the four major damage-causing bird groups (Chapter 3), research into dietary behaviour, learned behaviour, prey distribution and densities, and the causes for higher prey and predator population numbers and fluctuations led to a combination of preventative and control actions. Numbers of wildlife and their prey are now kept low through holistic management of their habitat (e.g. grasslands and water puddles on the apron; landfill on neighbouring territory) and less frequent but more effective chasing methods. Measures such as culling and poisoning, which have become less acceptable over time (Messmer 2009), are now considered a last resort.

8.3.3 Attitude of stakeholders

The inclusive approach improved relationships and fostered communication and cooperation between NAC and their stakeholders, a key requirement for an integrated management approach (Western 2004). Airline operators have previously been critical of NAC's perceived complacency in managing AWC risk (Airline Operators Association pers. comm.). By drawing operators into discussions regarding wildlife hazards, and enabling simpler reporting procedures for collision and near-miss incidents, airline operators now have more assurance that the problem is being addressed and are more vigilant regarding reporting incidents to airports (Airline Operators Association pers. comm.).

Airport neighbours were found to be apathetic to the risk that their activities may pose to aircraft safety, and airport staff were frequently blamed for trespassing and poaching of wildlife (Wildlife Hazard Management Committee pers.comm. June 2010). This led to poor communication and cooperation between airports and their neighbours (personal observation 2007-2009). Systematic involvement of neighbouring landowners in discussions involving wildlife risks through quarterly meetings resulted in improved trust between the parties. Landowners were not only more approachable regarding their impact on the risk of aircraft-wildlife collisions, but their knowledge regarding local habitats and ecosystems provided valuable insight into designing solutions for wildlife hazards in general around the airports.

8.3.4 Species conservation

Conservationists understood the serious threat wildlife pose to aviation safety in Namibia, but were critical of the reactive measures used by airports to address the problem (J. Mendelsohn pers comm). Especially the culling of birds (sometimes protected species such as Abdim's Stork *Ciconia abdimii*, Greater Flamingo *Phoenicopterus roseus* and Hamerkop *Scopus umbretta*) was in direct conflict with national conservation efforts. Local (Weaver and Skyer 2003) and global (Jackson & Allan 2000) conservation efforts are known to be increasing wildlife populations (particularly migratory bird species). The risk of aircraft-wildlife collisions is therefore also increased, further emphasizing the antagonistic effect airport activities and conservation efforts are having on each other. By including conservationists in the management of wildlife risks at airports, less invasive techniques (see Table 1) have been designed to reduce the AWC risk. Increased understanding of conservation priorities has also enabled airports to contribute to preservation. Airport properties are, today, used as training grounds for Nature Conservation students from the Polytechnic University. Wildlife is also translocated from airport properties to suitable conservation projects in the vicinity. Focused research into ecological causes of aircraft-wildlife collisions has, further, provided data and knowledge of grazing systems, plant and mammal diversity, bird habitat and prey preference, and seasonal ecosystem functioning valuable to the conservation cause.

8.3.5 Contribution of scientific research

The value of empirical research in managing wildlife hazards at airports is often underestimated (Froneman 2000, Short *et al.* 2000, Allan 1994). Manfredo and Dayer (2004) found scientific understanding of any human wildlife conflict to be critical to its management, and Madden (2004) described the need for applied research to understand complexities of human-wildlife conflicts in general. To ensure relevant and targeted research (White *et al.* 2009), research topics were formulated during the observation period at WHMC meetings, involving pilots, airline operators, airport managers, conservation organizations and airport neighbours. In this case, it availed the opportunity for funding of research by aviation stakeholders. WARN involved the Polytechnic of Namibia's School for Natural Resource Management in assisting with research and academic guidance. WARN also provided internships for and mentoring of four final year students from the Polytechnic of Namibia, resulting in a more synergistic relationship (WARN 2012).

8.4 Conclusion

A multi-stakeholder approach resulted in more proactive, and less intrusive, measures to control wildlife hazards at Hosea Kutako and Eros airports. It further resulted in greater awareness of the problem, an improved sense of trust among aviation stakeholders and airport neighbours, and the active participation of conservation institutions and scientists. Effective, cooperative, solution based engagement in addressing wildlife hazards, based on different stakeholder values, attitudes and perceptions, were therefore achieved. As a result of a greater understanding of the need for empirical research, NAC is in the process of establishing a Bird Strike Centre at Eros airport from where it can engage on a day to day basis with aviation stakeholders.

CHAPTER 9: GENERAL CONCLUSIONS AND RECOMMENDATIONS

9.1 The extent of aircraft-wildlife collisions at the study sites

An initial assessment of AWC incidents was conducted for the five year period 2006 to 2010. A total of 55 and 73 AWC incidents were reported at Hosea Kutako and Eros airports respectively during this period. 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 all possible 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. Mammals were only involved in incidents at Hosea Kutako, accounting for 20% of all AWC incidents.

The assessment highlighted disharmony in reporting of AWCs in Namibia exists among airport staff and airlines, and that less than 25% of all collisions are reported. The information provided in reports and the reporting procedure differed for each airline or airport, 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 standardised, industry-wide reporting procedure should be developed, based on IBSC Standard 7 (IBSC 2006). Near-miss incidents should become a requirement of the standardised 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.

9.2 Avifaunal risk species at the study sites

This study proposed a weighting system for inclusion in accepted AWC risk assessment methodology. The results of the risk assessment correlated closely to pilot risk perception, but not to AWC history or frequency of occurrence of bird species. The risk analysis rated six species (*G. africanus*, *C. capensis*, *N. meleagris*, *E. caeruleus*, *S. serpentarius*, and *M. canorus*) as high risk at Hosea Kutako International Airport, and six species at Eros Airport (*G. africanus*, *N. meleagris*, *P. bellicosus*, *M. aegyptius*, *A. aegyptiaca* and *V. coronatus*). The fact that only two species were rated as high risk at both airports supports the findings of Chapter 4 and Chapter 5 that although the airports are in close proximity to one another, their ecosystems and AWC risk are quite different.

By comparing the four variables of risk rating, pilot perception, avian species occurrence and AWC history an improved picture of avian dynamics for Hosea Kutako and Eros could be obtained. Observations on habituation and behaviour of specific species also greatly added to this understanding, and motivated for further investigation regarding their inclusion in risk assessment analyses (Chapter 3). The fact that pilot perception was found to be accurate in predicting AWC risk species or groups, may play an important role in management plans for southern African airports where no formal risk assessments have been done, as it provides a rapid indication of AWC risk. Habituation or learning behaviour by birds (as described in Chapter 3 and modelled in Chapter 6) at the airports meant that birds most frequently observed at the airports were not necessarily most likely to collide with aircraft. A factor for the consequence of collisions needs to be included in AWC records at the study sites, and for this to be achieved the airports need to more accurately record damage caused, or change in flight path etc. for each AWC. It is further recommended that factors affecting the occurrence of the high risk species found in this study be addressed by NAC management as a matter of priority.

9.3 Small mammal abundance and diversity at the study sites, and its effect on the likelihood of AWCs

A total of 2150 small mammals (3 orders, 11 species) were captured over four trapping seasons from 2011-2012 at and in the vicinity of the two airports; 1570 at Hosea Kutako International Airport and 580 at Eros Airport. Small mammal abundance was significantly higher in the growing season than in the non-growing season at both airports. The dominant nocturnal and diurnal species at both airport were *Mastomys coucha* and *Rhabdomys pumilio,* respectively.

Small mammal abundance was higher at the rural airport (Hosea Kutako) compared to the urban-situated Eros, indicating that they are a more important attractant for risk bird species, and need to be considered as part of the wildlife hazard management at rural airports. At Hosea Kutako, high concentrations of small mammals (especially the diurnal *R. pumilio*) when compared to outside the airport fence suggest the airport is a sanctuary against grazing, fire and non-volant predation. At both airports late summer mowing reduced small mammal abundance and diversity through the non-growing season, but without additional early growing season mowing the effectiveness of mowing was greatly reduced through the growing season. Patchy mowing (where some areas of grassland around runways are mown and others not) was found to increase small mammal densities in the unmown areas (moving from mown areas), resulting in localised hotpots of exceptionally high small mammal abundance to which raptors are drawn to hunt. Furthermore surrounding land use had an effect on small mammal abundance and diversity.

In addition to providing a greater understanding of this important prey component for raptors at the airports, the comparison of species occurrence, richness and diversity gave an indication of the productivity of ecosystems at the airports and in surrounding land uses, and an indication of the effectiveness of grass mowing as an AWC control measure.

The results indicated that small mammal abundance and consequently their predatory raptor species could be reduced at the airports by more frequent mowing (once in early summer and once in late summer at least) as well as complete (not patchy) mowing of all grassland areas on the airport properties.

The findings indicated that (especially at the rurally situated Hosea Kutako) the airport fence caused a sanctuary effect with significantly higher densities of small mammals within the airport property compared to outside, where flightless predators [e.g. Caracal (*Caracal caracal*), Serval (*Leptailurus serval*) and Black-backed Jackal (*Canis mesomelas*)] are known to be common (F. Weiss, pers. comm.).

The sanctuary effect is difficult to eliminate but has been mitigated at golf courses and crop fields in other instances through installation of owl nest boxes and raptor perches. In this particular case such a measure, however, is likely to be counter-productive, as it is likely to increase collision risk.

9.4 Other ecosystem factors at the study sites and their influence of AWC risk

An understanding of vegetation, small mammals and arthropods made an important contribution to understand wildlife hazards and their mitigation at the two study airports. It indicates the relative higher ecosystem productivity of a rurally situated airport compared to an urban airport, an important consideration when planning airport locations (a result confirmed by the avian assessment (Chapter 3) and small mammal specific assessment (Chapter 4). Airport grassland was found to provide a definite refugia for small mammals against flightless predators. Mowing as an ecosystem tool for reducing AWCs did not have a significant effect on diversity in general, but arthropod biomass and small mammal abundance was reduced, resulting in a lower attraction risk for birds of prey.

This study also pointed out the dearth of information related to ecological integrity measurement in the Namibian savanna. Here, no studies have been done on the indicator variables coupled to taxa such as arthropod and small mammal communities, and how these relate to vegetation variables such as Ecological Index (EI) score and relative abundances of Decreasers and Increaser IIc species. Simple indicator variables would also be a consideration for airport planning and biological investigations into the causes of chronic bird strike risk at airports.

While interpretation of rangeland condition already proved useful when studying the relative densities of damage-causing species that different areas on the airport properties and surrounding areas can lure and or "house", the shortage of information regarding arthropod and small mammal integrity indicator variables indicated that, currently, we can only learn from their relative biomass in differently managed and used land areas.

As small mammal abundance is related to primary productivity, but also a number of habitat variables, the relationship between vegetation and small mammal variables on airports is more difficult to assess compared to more natural areas. Small mammal numbers were, therefore, the most useful small mammal indicator studied. Studying small mammals also proved to be the most practical, affordable and realistic approach of the three factors studied; where both vegetation and arthropod sampling are time consuming, heavily dependent on the availability of specialists in these fields, and limited to specific periods of the year, assistants can be trained to sample small mammal populations and communities on fixed transects using standard methods. Where time, funding and the availability of expertise is not an issue, it remains most valuable to study airport ecosystems at more levels, including more taxa. The value of the latter approach is expected to become increasingly clear as the ecosystems, ecosystem variables and their relation to each other are better understood.

9.5 The use of systems modelling as a tool for predicting AWC risk

Linear and spatial models currently used by the aviation industry to identify and rank the risk of AWCs have been described as inadequate in considering the complexity and interlinked causality of AWCs (see Chapter 6). This study proposes the application of systems thinking (particularly systems modelling) to illustrate the dynamics of aircraft-wildlife collisions, considering the inter-connectedness of various ecological and anthropogenic causes of the problem. It was found that due to the site specific nature of ecological dynamics at each airport (as mentioned in Chapters 3, 4 and 5) it was impossible to produce a generic systems model. A model was therefore developed for Eros Airport only (Chapter 6), considering only influences on AWC risk of the most common collision culprit (*V. coronatus*). The model was subjected to a sensitivity analysis of preventative and control wildlife reduction actions. This analysis found that AWC control measures that reduce the ecological carrying capacity of an airport are more effective than lethal control measures in reducing the likelihood of AWCs. Also, a combination of lethal control and habitat management resulted only in a lower risk of AWCs in the short term; while in the long term the risk was found to increase. Application of this model to other airports and for other species will require careful study of species reaction to aircraft and lethal control and will not necessarily produce a similar result.

The systems modelling process suggests it is possible to model the complexity of AWCs. It also highlighted that no factors influencing the risk of AWCs, or the extent of their influence, are expected to be the same at any two airports. Individual airports, therefore, need to identify and use their particular understanding in conducting simulations of risk using the systems model. In the current study the modelling process informed recommendations to increase habitat management effort, and reduce the reliance on culling for the management of the AWC problem at Eros airport.

Systems modelling is therefore a valuable tool to graphically demonstrate to airport management (and all other AWC roleplayers) the dynamics of AWCs, considering the interconnectedness of various ecological and anthropogenic causes of the problem, and the different effects that management practices (such as culling of Crowned Lapwing) may have over short to long periods.

9.6 A toolkit for implementation of systematic and preventative wildlife hazard management at airports in southern Africa

The obligation placed on airport staff to control wildlife hazards in the vicinity of airports (ICAO 1991) is often difficult to fulfil, especially at smaller airports or in countries with inadequate resources and capacity. In addition to this, research into wildlife habitat, species and habits at airports has predominantly originated in Europe and North America, and hence mitigation measures are most effective in these conditions, and possibly less effective elsewhere.

Chapter 7 is a proposed toolkit designed to guide airports in southern Africa to minimise risk of aircraft-wildlife collisions. It is based on the understanding of ecosystems in the vicinity of the two airports on which this study was based, but also takes note of other studies in sub-Saharan Africa. It further considers the recommended practices of ICAO (ICAO 1991) the World Birdstrike Association (IBSC 2006), and global best practice.

9.7 The usefulness of a multi-stakeholder approach in addressing AWCs at airports where capacity and resources and limited

The study resulted in the adoption of a multi-stakeholder approach at the two study airports (Chapter 8). The approach resulted in more proactive, and less intrusive, measures to control wildlife hazards at Hosea Kutako and Eros airports (as described in Table 8.1). It further resulted in greater awareness of AWCs as an aviation and human-wildlife conflict issue, an improved sense of trust among aviation stakeholders and airport neighbours, and the active participation of conservation institutions and scientists in addressing it. Effective, cooperative, solution based engagement in addressing wildlife hazards, based on different stakeholder values, attitudes and perceptions, were therefore achieved. As a result of a greater understanding of the need for empirical research, the study led to the establishment of a Bird Strike Centre at Eros airport (see Appendix 1) from where it can engage on a day to day basis with aviation stakeholders. The centre is funded by NAC.

9.8 Effectiveness of implementation of some of the above recommendations by NAC

This study was conducted over a five year period (2009-2013) and practical recommendations were made to NAC as the study progressed. These recommendations are recorded in Appendix 1.

IBSC (2006) warns against only using the number of AWCs to determine the risk of collisions, and chapter 2 cautions the completeness of AWC reporting. However, the trend in AWC incidents over the study period could be considered a rudimentary measure of the impact of the study. No notable reduction in the number of AWCs was evident at Eros (Figure 8.3), while Figure 8.4 indicates a definite reduction in the number of AWCs at Hosea Kutako since the commencement of the study in 2009.

The multi-stakeholder approach driven by this study (see Appendix 1 and Chapter 8) resulted in more proactive, and less intrusive, measures to control wildlife hazards at Hosea Kutako and Eros airports. It further resulted in greater awareness of the problem, an improved sense of trust among aviation stakeholders and airport neighbours, and the active participation of conservation institutions and scientists. Effective, cooperative, solution based engagement in addressing wildlife hazards, based on different stakeholder values, attitudes and perceptions, were therefore achieved. As a result of a greater understanding of the need for empirical research, NAC is in the process of establishing a Bird Strike Centre at Eros airport from where it can engage on a day to day basis with aviation stakeholders.

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APPENDIX 1: NEWSLETTERS PRODUCED FOR THE DURATION OF THE STUDY

To support the goal and objectives of this study, eleven newsletters were produced. The newsletters were an important tool in communicating findings of the study for the aviation industry to incorporate them into their wildlife hazard management programmes.

Newsletters produced were as follows:

Newsletter 1: January 2010

Newsletter 2: May 2010

Newsletter 3: September 2010

Newsletter 4: January 2011

Newsletter 5: April 2011

Newsletter 6: August 2011

Newsletter 7: November 2011

Newsletter 8: April 2012

Newsletter 9: August 2012

Newsletter 10: February 2013

Newsletter 11: June 2013

Newsletter 8 (April 2012) is provided below as example. All other newsletters are available online at:

http://www.saiea.com/nac.htm

WILDLIFE AND AIRCRAFT RESEARCH NAMIBIA PROJECT (WARN)

VOLUME 2, ISSUE IV

NEWSLETTER DATE:

APRIL 2012

Morgan Hauptfleisch
Wildlife and Aircraft Research Namibia (WARN) University of the Free-State Centre for Environmental Management; Southern African Institute for Environmental Assessment

In collaboration with the Namibia Airports Company (NAC), the Southern African Institute for Environmental Assessment, the Polytechnic of Namibia, the National Museum of Namibia, and the National Museum of South Africa

Detailed reports and research results are available on request, the newsletter merely gives a broad summary

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Cutting of grass to control wildlife at airports revisited

A lot of research is being conducted globally regarding the effect of different grass heights on bird and other wildlife presence at airports. To date, no definitive answer has been provided on whether short or long grass is best. A long grass policy was implemented at Durban International Airport, and resulted in a reduction of birds, particularly Ibis and Lapwing. Other research has found that species which prefer long grass are merely replaced by species which prefer short grass, when grass is cut.

Our research is indicating that the result of grass length management is very site specific. At Eros, large populations of Lapwing (see picture) are attracted to mowed areas where they can hunt for the large numbers of harvester termites, and nest on the ground where they are protected (by the strong perimeter fence) from predators compared to the sports fields surrounding the airport. We are currently testing the impact of not mowing the grass at Eros, and so far Lapwing numbers are greatly reduced.

At Hosea Kutako a number of birds of prey frequent the airport, many hunting small mammals, and in particular the diurnal (day active) four-striped field mouse (*Rhabdomys pumilio*). We found significantly fewer of this species in areas where grass is mowed, than in areas of long grass, and hence fewer raptors.

An interesting finding was that small mammal numbers (and general biodiversity) were higher in areas with a combination of mowed and unmowed grass. It results in more niches for organisms and provides greater variety of food, shelter and nesting sites for rodents, insects and birds. Hopefully the results of the insect survey (see page 2) will confirm this finding. It seems that airports should either cut the grass or leave it to grow, not both!

Right: Crowned Lapwing (*Vanellus coronatus*) enjoying the short grass habitat at Eros airport where their "hunt by sight" strategy for termites can be maximally used.

Get to know birds that may be a hazard to aircraft.

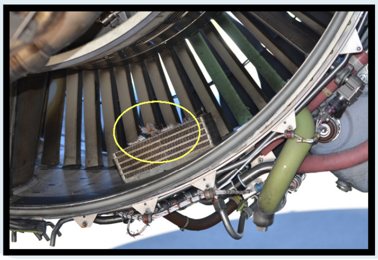
Burchell's Sandgrouse

(*Pterocles burchelli*)

A medium-sized seed eater which flocks in large numbers to waterholes . Sandgrouse are occasionally encountered at Hosea Kutako. Flocking birds are a risk as they may result in multiple strikes to an aircraft.

Recent birdstrikes and the lessons they teach

On 23 March, a British Airways Boeing 737 ingested a Steppe Eagle into its port turbine on take-off at Hosea Kutako. Luckily the plane had time to abort takeoff and avoid further damage. Remains of the bird can be seen in the picture (left).



During January 2012, three collisions with small birds (possibly Swallows or Swifts) were reported by Air Namibia. It was interesting that the collisions all occurred in the early morning or early evening. Airport apron and runway lights seem to be attracting insects and therefore birds which feed on them , and as Swallows and Swifts feed in flight they are the most likely to be struck by aircraft. We are investigating alternative light colours and shades to reduce insect attraction. Insects are attracted to artificial light because they often use the moon to navigate. Artificial light confuses their navigational system and they end up circling the light endlessly.

We would like to hear from you. Please do not hesitate to send any feedback on the newsletter or any observations which might help our research to the e-mail address on page 1.

Insect surveys at Hosea Kutako and Eros

Insects are an important component of the food chain at airports. They are also good indicators of ecosystem health and productivity.

To get a better understanding of the ecosystems at Hosea Kutako and Eros, as well as the link between insects and birds, insect diversity was sampled during the summer and winter season using pitfall traps. These are plastic tubs sunk into the ground and filled with a preservative liquid, collecting insects which crawl or fall into them. The sampling was conducted in areas of the airport where grass is cut, areas where grass is not cut, and on neighbouring properties. It enables us to compare the numbers and different types (feeding functional groups) of insects for the different areas.

Analysis of insect sampling is extremely time consuming and will be completed by the end of May 2012. It will hopefully shed light on why we find certain insectivorous birds at the airports at various times of the year. This will help us identify some new methods to reduce bird populations at the airports, and determine the impact of neighbouring land use.

Above: Insect pitfall traps being collected at Hosea Kutako

Right: Insects being sorted

International Bird Strike Committee Conference

The International Civil Aviation Organisation (ICAO) established an International Bird Strike Committee to research and manage the risk that birds pose to aircraft safety. It holds a bi-annual conference where scientists and aviation experts converge to discuss bird strike issues and present research results. With generous sponsorship from NAC, WARN will attend the conference, which will be held in Stavanger, Norway at the end of June 2012. We will learn a great deal from this global think-tank, but will also take the opportunity to share our unique research with the world. With four years of research at Eros and Hosea Kutako we have some interesting and scientifically sound observations which will hopefully make a contribution to aviation safety worldwide, and not just at our local airports.

Two research papers have been submitted to be presented at the conference:i) Ecosystem factors at two Namibian airports and their influence on the risk of aircraft-wildlife collisions (looking at insect, small mammal and plant interactions at Eros and Hosea Kutako, and how they affect bird populations); and

ii) A multi-stakeholder approach to mitigate the risk of aircraft-wildlife collisions at Namibian airports (Our case study about the involvement of scientific, academic and conservation institutions as well as airport neighbours and aviation experts in collaboratively finding solutions to aircraft-wildlife collisions).

Students assist WARN and learn about wildlife research at Namibian airports

One of the aims of WARN is to develop local wildlife management capacity to address airport wildlife concerns. So far four internships (Nature Conservation students from the Polytechnic of Namibia) have been completed. In addition to performing tasks for WARN these students conducted their own research under WARN's guidance and mentorship on:

i) Bird occurrence frequencies at Eros airport;

ii) A study of the Seeis Vulture colony adjacent to Hosea Kutako;

iii) The reaction of different bird species to aircraft; and

iv) Identifying and rating risk species at Hosea Kutako.

Sadly, the project was not able to offer permanent employment to the students, but they are applying the knowledge they gained in positions they now hold in the Ministry of Environment and Tourism, World Wildlife Fund, and Namibia Nature Foundation.

These graduates and others assist WARN voluntarily on a part time basis for major data collection events.

"thanks"

Many thanks to the following persons for assistance with this research: Norman Pule, , Mia Davids, Toska Sem, Bernard Sinvula, Johannes Vries, Oscar Hamutenya, Jason Kweyo, (and many other friendly NAC staff), Marco Konings, Will Dalling, Seth Eiseb, Apolonia Dlerks Dr. Peter Tarr , John Pallett, Gudrun Denker, Dr. Nico Avenant, Jurie du Plessis, Dr. Chris Brown, Dr. John Mendelsohn, Prof. Maitland Seaman, Dr. Daan Toerien, Dr. Willie Jankowitz, Peter Keil, Nico Kopf, Uwe Trumper, Ondekaremba Lodge, Arebbusch Lodge and the Windhoek Golf Club.

Two interesting mammal sightings were made by the WARN team in the vicinity of Hosea Kutako

A large Cheetah was seen on the morning of 27 March approximately 3km east of the Hosea Kutako terminal building on the farm Oupembamewa.

On 18 February this picture of a Pangolin (Ietermagog / Scaly Ant-eater) was taken just outside the Hosea Kutako perimeter fence near runway 26.