A RISK-BASED APPROACH TOWARDS SETTING WILDLIFE STRIKE ALERT LEVELS

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ABSTRACT

With the growing awareness worldwide of the importance of managing wildlife risks in and around airports, there has been renewed interest from stakeholders, especially state regulators, in understanding what airports are doing to mitigate risks from bird strikes. Often, an aerodrome's safety performance and success in mitigating the wildlife risk has typically been measured via an absolute count of all wildlife strikes. Yet, the robustness of using this indicator as a measure of success ought to be questioned, as it simplistically assumes that the hazards posed to flight safety by all wildlife (regardless of size, movement patterns) are equal. In response to the limitations of this approach, wildlife hazard management experts have suggested the use of wildlife risk hazard assessments to provide a more meaningful understanding of the actual threat posed by each individual wildlife species to aircraft safety.

Using Singapore Changi Airport as a case study, this paper presents a basic framework on the practical application of wildlife risk hazard assessments in measuring an aerodrome's wildlife safety performance, and more specifically, in the setting of safety alert levels to assist airports in better measuring and mitigating the wildlife hazards. We conclude that a risk-based approach makes for a more multi-dimensional and meaningful assessment of the wildlife hazard(s) at hand, and helps airports prioritize resources to better mitigate those hazards.

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INTRODUCTION

The International Civil Aviation Organization (ICAO) states in the opening lines of Annex 14 Standard 9.4 on "Wildlife strike hazard reduction", that the presence of wildlife, encompassing both birds and animals, on and in the aerodrome vicinity poses a serious threat to aircraft operational safety, thereby signalling the universal recognition of the importance of keeping the skies safe for aircraft arriving at and departing from an aerodrome. To this end, all airports – both civilian and military – are hence required to have in place a wildlife control program to manage the impact of wildlife strike hazards on and in the vicinity of an aerodrome. Furthermore, the attention on the 15 January 2009 incident, whereby US Airways Flight 1549 carrying 155 people on board ditched into New York's Hudson River after striking at least one bird after takeoff from New York's LaGuardia Airport has played a role in bringing the risk of wildlife, and particularly birds, to the forefront of discourse on flight safety.

With the spotlight consequently shone on importance of managing wildlife risks, there has been renewed interest from stakeholders such as state regulators and in understanding what airports are doing to mitigate this risk. Often, an aerodrome's safety performance and success in mitigating the wildlife risk has typically been measured via an absolute figure count of all wildlife strikes. Yet, the robustness of using this indicator as a measure of success ought to be questioned, as it simplistically assumes that the hazards posed to flight safety by all wildlife (regardless of size, movement patterns) are all equal. In response to the limitations of this approach, wildlife management experts have thus suggested to plug the gap with the conduct of wildlife risk hazard assessments, to provide a more meaningful understanding on the actual threat posed by each individual wildlife species, to aircraft safety.

Using Singapore Changi Airport (SIN) as a case study and focusing on bird hazards, this paper seeks to present a basic framework on the practical application of wildlife risk hazard assessments in measuring an aerodrome's wildlife safety performance, and more specifically, in the setting of safety alert levels to assist airports in better measuring and mitigating the wildlife hazards. It is the contention of this paper that a risk-based approach would make for a more multi-dimensional and meaningful assessment of the wildlife hazard(s) at hand, and would help airports prioritize resources to better mitigate the wildlife hazards faced.

BIRDS OF SINGAPORE

SIN is situated at the eastern end of Singapore island on reclaimed land and surrounded by the sea. The airport is surrounded by a perimeter fence, on the outside of which are planted rows of trees. The runways of the airport are flanked by short grassy fields. Many parts of the airport are also intersected by drains and canals, of which are linked to the sea and the water level in the canals are thus influenced by the tides. There are service reservoirs at both the North and South ends of the aerodrome. Each of the two reservoirs is surrounded by marshy grounds and tall grasses.

The climate of Singapore is typically equatorial, showing small seasonal variations with high temperatures and high rainfall throughout the year. Singapore's climate is greatly influenced by the monsoon winds. From May to September, the winds blow mainly from the south and southeast locally, although the overriding regional direction is that of the correctly named Southwest Monsoon. Most of the rain carried by these winds is deposited on the mountains of Sumatra and this period is the driest in Singapore. From December to March winds blow from the north and northeast under the influence of the Northeast Monsoon and this produces the wettest and coolest times of the year. The intervening inter-monsoon periods in April and October / November are usually characterised by frequent thunderstorms. Many of these winds caused by air masses moving over Sumatra and becoming strongly heated, create disturbances locally termed "Sumatras". "Sumatras" bring high winds and large amounts of precipitation over relatively small areas.

By temperate standards, Singapore appears to have a uniform climate but subtle variations exist which make the weather less predictable than expected. For example, the Northeast Monsoon usually begins before Christmas with very heavy precipitation followed by a relatively dry period towards the end of March. However, long-term data show that this wet period can start as early as October or as late as January. Likewise the dry period can begin as early as January or as late as March. Even during the relatively dry Southwest Monsoon, short periods of heavy precipitation can be experienced. While these variations are small, they are significant and make their influence felt on the flora and fauna.

The grassy fields at SIN provides good habitat for ground-dwelling birds such as Spotted Doves (*Streptopelia chinensis*), Zebra Doves (*Geopelia striata*) and Paddyfield Pipits (*Anthus rufulus*). Javan Mynas (*Acridotheres javanicu*s) and Common Mynas (*A. tristis*) have been observed to congregate in numbers of the fields and in the trees along the perimeter of the aerodrome boundary. Munias (*Lonchura* spp.) are also attracted to the grasses, especially where the grass has been left uncut. At the perimeter of the airport where woody trees can be found, it is not uncommon to find birds such as Blue-throated Bee-eater (*Merops viridis*) and Blue-tailed Bee-eater (*M. philippinus*) which are fond of perching on open exposed branches. An occasional party of Long-tailed Parakeet (*Psittacula longicauda*) can sometimes be seen flying over the airport vicinity. At the reservoir marshy areas, Grey Herons (*Ardea cinerea*), Purple Herons (*A. purpurea*), Little Egrets (*Egretta garzetta*) are often found. A small colony of Grey Herons nests in the nearby golf course South of the aerodrome. Another colony of the Black-crowned Night Herons (*Nycticorax nycticorax*) nest in the mangroves of Sungei Tampines at Pasir Ris and it is possible that these nocturnal birds might feed in the marshy areas in the vicinity of the airport. During the day, Brahminy Kites (*Haliastur indus*) and White-bellied Fish Eagles (*Haliaeetus leucogaster*) are often seen soaring over the runways and open fields. These larger birds, especially the Brahminy Kites often fly very low over the runway, as such posing a potential hazard to aircraft operations.

MEASURING WILDLIFE SAFETY PERFORMANCE FOR AERODROMES

Case-based approach

In accordance with ICAO Annex 14, Standards 9.4.2, wildlife strikes reports are to be collected and forwarded to ICAO at appropriate intervals, for inclusion in the ICAO Bird Strike Information System (IBIS) database. In line with this practice, aerodrome's worldwide most commonly measure their safety performance and success in mitigating any wildlife risks through a count of the total number of collisions between aircraft and wildlife for a given period of time. In this approach, aerodromes may conduct month-on-month or year-on-year comparisons of the recorded number of wildlife strikes, and a graph similar to that in Annex 1 is produced. These wildlife strike figures are closely monitored to ascertain if there has been any increase or decrease in wildlife incidents for the period of time. The widely accepted logic governing this approach is that the lower the number of wildlife strikes reported for an aerodrome, the better the aerodrome's safety performance.

The case-base approach may be furthered by the normalization of wildlife strikes recorded against the total aircraft movements for a period of time – usually either a month or a year, depending on the length of time in analytical focus. Not dissimilar to the above, it is also generally considered that the lower the wildlife strike rate, the better an aerodrome's safety performance. Wildlife strike alert levels (or safety targets) at SIN are currently developed and set based on this normalized figure, and any transgression of the safety target indicates to the aerodrome operator on the need to promptly act to arrest the transgression and bring the wildlife strike rate below the alert level. At SIN, measures taken to bring the wildlife strike rate below the safety alert level encompass habitat modification, bird repellent and bird removal strategies, in addition to the collection of information on the state of wildlife within the aerodrome.

The case-base approach is a fairly straightforward wildlife management monitoring method. Through a consistent collation of all reported wildlife strike cases, all aerodromes can easily generate the required data, which in turn provides aerodromes an indication of their wildlife safety performance. Furthermore, strike frequency is an important component to aerodromes because of the requirement to close the runway after a reported strike to potentially recover a carcass, an operational safety requirement which invariably adds to aerodrome and airline costs and congestion. The monitoring of strike cases is therefore an important consideration for aerodrome's seeking an indication of their operational efficiency. The case-based approach is as such, versatile in its potential for use as an indicator of both safety and operational efficiency, and ought to form the baseline of any aerodrome's wildlife management programme.

Risk-based approach

In the United States, triggering events are used to determine which airports are required to conduct a wildlife hazard assessment. These assessments include wildlife, habitat and land use surveys of the airport and surrounding area leading to a professional judgment about the degree of hazard to aircraft followed by recommendations to mitigate hazards. Due to the potential for significant individual variation in risk assessment, individual conducting the assessment are required to attend an FAA approved training program. Canada takes a similar approach but requires most major and secondary airports to produce a wildlife management plan and provides a risk assessment methodology guideline in lieu of required training to perform hazard assessments. However, alternate approaches are acknowledged and are acceptable. In many countries, there are no formal requirements to conduct either a hazard assessment or produce a management plan.

Regardless of hazard assessments, most airport wildlife control programs are driven by the case-based approach and hence bird strike numbers. While strike frequency can potentially impinge on the efficiency of airside operations and add to both airline and airport costs due to the requirement to close the affected runway after a reported strike to potentially recover a carcass, more strikes do not necessarily contribute to increased risk at airports. Furthermore, risk is not a static statistic and may vary greatly by month and considerably from year to year. Therefore, the conduct of a risk assessment once at the start of the management program or only every 5 years with program updates tends not to capture the dynamic nature of the wildlife strike risk.

Risk is defined as the product of the severity and probability of wildlife strikes during a predefined period (Allan, 2001). Dolbeer et al. (2000) demonstrated that birds with higher mass had a greater probability of causing damage to aircraft in the event of a bird strike. In using the mass of birds as a measure of severity, the higher the mass of each strike, the more severe the strike is likely to be, with the probability based on the frequency of strikes. The singular consideration of strike frequency leads to issues of bird size, as the difference between strikes involving swallows and sea eagles is large but may not be captured in a simple tally of strikes over a period of time. However, a consideration of mass in addition to strike numbers yields us an effective tool for measuring probability. With this approach, the total mass of birds struck during a time period equates to the probability of hazardous bird strikes. The risk assessment approach used here generally follows that presented by Searing (2005) but is based on that author's further and on-going development of the risk assessment process.

Using these criteria for severity and probability, one may then use Allan's risk matrix as a measure of risk simply by calibrating the cells appropriately (Annex 4). In order to make this parameter robust when used under different conditions (e.g. time periods, airports), the probability measurement of mass is based on the number of aircraft movements. While this approach produces an objective and reliable measure of risk for a defined time period, it requires a consideration of the strikes that have been recorded for this period of time. Should aerodromes wish to determine "real-time" risk using the total and average mass of birds present on and near the aerodrome, this risk assessment method would need to be modified to be based on regular, systematic surveys of birds. Again, with appropriate calibration, one would be able to assess the existing risk of each species or group of species on and near the airport at any point in time or over any period of time. While one might argue that the calibration may be somewhat subjective, it is well documented and can (and should) be adjusted as more information is collected. For example, by examining the risk measurements based on strikes and on bird surveys, it is often possible to determine where risk thresholds should be to achieve consistent results between these two methods of risk assessment.

CONDUCTING A RISK ASSESSMENT

The key to conducting a risk assessment is data. While it is likely that no strike data set will ever be complete, the more complete the strike data the better. Not only is it important to have as many strike as possible reported, it is also important to have as many strikes as possible identified to species. Aerodromes may choose this to be carried out through various means such as visual identification or DNA analysis. At SIN, in partnership with the National University of Singapore's Department of Biological Sciences, wildlife carcasses that cannot be easily identified visually are sent to the latter for scientific identification. Further to this, pilots play a key role in risk assessment for not only are aerodromes reliant on them to report strikes, the pilots may be the only ones to actually see what was or may have been struck. While chances are that pilots may not be able to identify the exact species of birds struck, they may be able to minimally place them into size categories. The ability to gather such limited details would ultimately be more useful to an aerodrome rather than the label of an "unknown bird".

Not only is accurate and complete data necessary for a wildlife risk assessment, having a long-term series of data would also prove useful in calibrating the risk model and interpreting risk levels for an aerodrome. This is especially true for conducting risk assessments based on bird survey data because while the mass of birds present on and near an airport is indicative of the risk of bird strikes, the relationship with the actual number of reported bird strikes is not always linear. Several years of survey data may be required to begin to understand this relationship and better calibrate results of bird surveys to actual risk levels.

Conducting a risk assessment is very straight-forward and has many options. Risk assessments may be conducted for:

1. Monthly or annual bird strikes at the airport;
2. Monthly or annual bird strikes by runway;
3. Annual bird strikes by time of day;
4. Annual bird strikes by species;
5. Current, monthly or annual risk posed by birds present on and near the airport; and / or
6. Current, monthly or annual risk posed by individual species or bird groups present on and near the airport.

Risk Assessments based on Bird Strike Data

Undoubtedly, individual aerodromes would also be able to devise risk assessments and thus modify the risk model for other parameters which they find useful to assess at their particular aerodrome. The availability of data required for a risk assessment would be the only potentially limiting factor, as the data available would directly determine what type of risk assessment that an aerodrome may conduct. Risk assessments based on strike data require:

1. Bird strike data which is as accurate and as complete as possible, and should include the identity of species struck for as many strikes as possible, weight of any intact carcasses

struck (or of any birds culled at or near the airport), runway whereby the strike occurred and time of strike.

2. The mass of birds struck is critical for the risk assessment. At the initial stages, an aerodrome first conducting a risk assessment may rely on the list of bird weights from data contained in Dunning (2008). Eventually, local weights from intact birds obtained from the airport should be used. This data may be supplemented by museum records if so desired. The mass of a bird strike is considered to be the mass of all birds struck relating to a single bird strike report. If the remains of all birds struck are intact, the remains may be weighed together, otherwise, the number of birds struck would need to be multiplied by the mean weight of the identified bird species.

3. "Unknown" species of birds struck by aircraft pose a challenge because their mass is not known. If pilot are able to provide an indication of the size of the birds (e.g., small, medium, large) in their reports, this would allow the mass for these categories to be arbitrarily set (e.g., 50 g, 400 g, 2000 g) according to the typical birds of those sizes present at and near the airport, or according to the typical birds struck at the airport if a suitable data series is available. Where no additional information is available as to the size of the bird struck, one suitable approach is to use the average mass of **known** species struck during the current month in the previous year for which data is available. If the number of birds struck is known, this figure may be derived by multiplying the average mass with the number of birds struck. If the number of birds struck is not known, the average mass of strikes (i.e., sum of mass of birds involved in each strike) of known species may then be taken.

Risk Assessments based on Bird Survey Data

Risk assessments based on bird survey data simply require the number and species of individual birds observed to be captured. The mass of each bird observed will be determined either using the list provided in Dunning (2008) or the airport's data base of bird weights described above. Where bird mass differs substantially by sex or age, these categories should be separated in the data collection and analyses phases of the assessment. The major anomaly with conducting risk assessments using survey data is that the mean mass needs to be calculated by taking the mean of the mass of species present in the survey, rather than simply dividing the total mass of birds observed by the number of birds observed, which is the typical method of calculating a simple mean. The latter method biases the mean mass by the myriad of small birds present whereas the recommended method produces a more representative figure for risk assessment.

The calibration of the risk assessment model is critical. While considerable work has already been done to calibrate the bird strike risk assessment matrices, the matrices' true robustness can only be determined after it has been tested at many and diverse aerodromes. This is certainly an area of research that the international bird strike community could work collaboratively to develop standard calibrations for the risk assessment models that may be applicable at aerodromes worldwide.

Case Study: Singapore Changi Airport

We conducted two risk assessments for SIN which can stand as examples of the risk assessment process. The risk matrix based on the work of Allan (2001) has been modified substantially to accommodate the use of mass as a measure of probability and severity as per Searing (2005). A sample of bird strike risk assessments is presented for SIN from January 2008 to June 2009. The data on which the risk assessments are based on are presented in Annex 2, and followed by the risk assessment in Annex 3. Using bird strike numbers from January 2008 to June 2009, and estimated weights for each species struck as well as calculated weights of unknown or unidentified species struck, total and mean weights are calculated in Annex 2. Transferring the data to a template similar to that in Annex 3 and dividing the total mass by the number of movements (x 1000), we can simply look up the values in the risk matrix Annex 4 to determine the level of risk posed by bird strikes during the month or year of interest.

A second risk assessment was conducted using bird survey data from a series of surveys conducted by the National University of Singapore at SIN. Please see Annex 5. Bird mass densities were calculated from monthly surveys of birds using point count methods and average bird mass was calculated by taking a simple average of the mean weight of each species observed at least once during the monthly survey. The resulting risk was determined by consulting the matrix in Annex 4.

Risk assessments used in this fashion provide a simple and relatively objective method for analyzing the diverse data collected in airport wildlife management programs. A valuable tool for interpreting wildlife data collected by aerodromes, the risk-based approach behooves aerodromes to collect and report strike data based on mass as well as numbers which in turn allows aerodromes to track their risk over time, to compare risk based on birds present versus risk based on strikes (a component of assessing the effectiveness of wildlife control programs), and among airports throughout the world.

PRACTICAL APPLICATIONS OF A RISK-BASED APPROACH

The next logical question is one of how the risk-based approach can best be implemented on ground, and how aerodromes may use this approach to justify their expansion and allocation of resources to wildlife control. This section seeks to further elaborate on the possibility of this, with reference to how the risk-based approach has been adopted and implemented at SIN.

While two types of risk assessments are conducted for SIN, the risk assessment matrix in Annex 4 is most heavily used as an indicator for decision making. This is because this indicator is generated every month, and gives a good indication of the types of birds which the aerodrome ought to work with to bring down the eventual strike rates.

The risk assessments in 2008 and early 2009 revealed strikes involving grey herons – medium-sized birds. These strikes translated into a moderate level of wildlife risk in the months in which they were occurred, prompting the need to further understand how the level of risk could be brought lower. Further investigation revealed that the grey herons had been fond of feeding at a canal which ran at almost a right angle to one of the runways, and beneath the flight path of aircraft utilizing the runway. As such, the decision to cover the entire stretch of canal was undertaken and completed in October 2009, and SIN has not had any strikes involving grey herons thus far.

For 2010, despite a notable number of strikes recorded for the months of June and July, the risk assessments conducted revealed that the wildlife risk level at SIN for these months was generally low. Further analysis carried out showed that most of these strikes had been due to swallows and mynahs which had generally low mass, with these incidents occurring most frequently at dawn and dusk. The decision was thus made to deploy measures targeted at reducing strikes involving these smaller birds. Two units of propane cannon and distress call systems were procured and deployed at locations along the runway where larger concentrations of these birds were observed to congregate. Small-scale trials involving irri-tape were carried out to ascertain the effectiveness of the measure against these birds. As wildlife inspections had found swallows to be attracted to grass cutting activity, schedules for the cutting of grass adjacent to the runway were also modified and timed concurrently with scheduled runway closures to further reduce the chances of strikes involving swallows. SIN is also working with adjacent landowners and authorities through a wildlife management committee forum to relocate a pre-existing mynah roosting site in close proximity of the aerodrome.

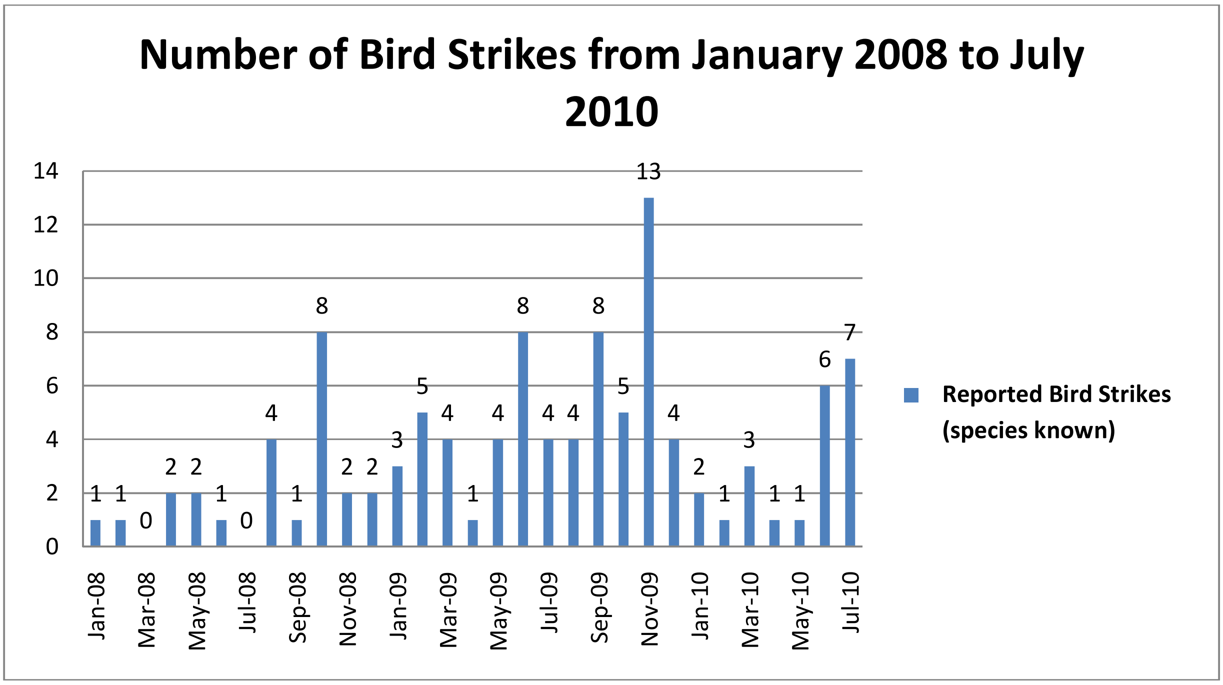
CONCLUSION

As Nicholls & Bell note, "Risk can be evaluated using many different measures (and no) single measure provides a complete picture." (Nicholls & Bell, 2005) The case-base approach has served aerodromes worldwide well since its conception, and we opine that this approach will continue to be a powerful basic and fundamental wildlife indicative tool. The risk-based approach which has been put forth in this paper is not intended to replace the former approach. Rather, it is intended to supplement and enhance the case-based approach, with the view of providing aerodromes a more well-rounded and multi-dimensional assessment of the wildlife hazard at hand, thus allowing them to better prioritize and optimize resources.

Speaking in support of the risk-based approach, Allan opines that the approach is a good and robust one, as it "employs an accepted methodology and is defensible in the event that a serious wildlife strike does occur and subsequent legal action results." (Allan, 2000). SIN has reaped the rewards of this dual-pronged approach in the ways in which have been elucidated above. It is our sincere hope that the sharing of this best practice will serve to support and benefit aerodromes worldwide, as we industriously continue our efforts to manage wildlife hazards.

ANNEX 1

Reported Bird Strikes (Species Known) at SIN from January 2008 to July 2010



ANNEX 2

Strike Data from Singapore Changi Airport used in Risk Assessment (January 2008 to June 2009)

Year	Month	Mass of Unknown	Unknown	Swallow	Egret	Brahminy Kite	Bee-eater	Myna	Dove	Eagle	House Crow	Sparrow	Barn Owl	BCNH	Bat	Total Strikes	Total Mass Struck	Mean Mass
		Mass (g)		17.8	366	529	34.4	116	159	2865	293.5	21.4	355	810	25			
2008	Jan	110	1	1												2	128	64
2008	Feb	127	2		1											3	621	207
2008	Mar	31	1													1	31	31
2008	Apr	529	8			1										9	4761	529
2008	May	525	4				1	1								6	2252	375
2008	Jun	651	3						1							4	2111	528
2008	Jul	79	3													3	236	79
2008	Aug	1120	4	1						2	1					8	10521	1315
2008	Sep	597	7	1												8	4200	525
2008	Oct	291	7	6	2											15	2873	192
2008	Nov	21	10	1												11	223	20
2008	Dec	724	4							1						5	5759	1152
2009	Jan	110	5	1							1					7	860	123
2009	Feb	127	4	1				2				1				8	781	98
2009	Mar	31	2	4				1							1	8	275	34
2009	Apr	529	1													1	529	529
2009	May	525	6					1		1		1			1	10	6180	618
2009	Jun	651	2	1				5		2		1				11	7651	696

ANNEX 3

Results of Risk Assessment based on Reported Bird Strikes at Singapore Changi Airport (January 2008 to June 2009)

Year	Month	Movements	Mean Mass	Total Mass	Probability (Total Mass/Movements)	Risk
2008	Jan	18,868	64	128	7	VERY LOW
2008	Feb	18,104	207	621	34	LOW
2008	Mar	19,370	31	31	2	VERY LOW
2008	Apr	18,884	529	4761	252	MODERATE
2008	May	19,590	375	2252	115	MODERATE
2008	Jun	19,103	528	2111	111	MODERATE
2008	Jul	19,697	79	236	12	VERY LOW
2008	Aug	19,673	1315	10521	535	VERY HIGH
2008	Sep	19,009	525	4200	221	MODERATE
2008	Oct	19,664	192	2873	146	LOW
2008	Nov	19,193	20	223	12	VERY LOW
2008	Dec	20,771	1152	5759	277	HIGH
2008	Total	231,926	450	33716	145	MODERATE
2009	Jan	20,373	123	860	42	LOW
2009	Feb	17,615	98	781	44	VERY LOW
2009	Mar	19,559	34	275	14	VERY LOW
2009	Apr	19,625	529	529	27	LOW
2009	May	19,711	618	6180	314	MODERATE
2009	Jun	19,071	696	7651	401	HIGH

ANNEX 4

Risk Assessment Matrix for Wildlife Strike Analysis

Severity Category	Probability of Damage					Mean Mass (g)
Very High	High	Very High	Very High	Very High	Very High	>1800
High	Moderate	High	High	Very High	Very High	>1000-1800
Moderate	Low	Moderate	Moderate	High	High	>300-1000
Low	Very Low	Low	Low	Moderate	Moderate	>100-300
Very Low	Very Low	Very Low	Low	Low	Low	<=100
	<=100	>100-200	>200-400	>400-750	>750	
	Total Mass (g) of Strikes per 1000 aircraft movements					
	<=2.5	>2.5-5	>5-7.5	>7.5-10	>10	
	Total Mass (kg) of Birds Surveyed on the Airport/km^2.					

ANNEX 5

Bird Survey Data (Mass) from Singapore Changi Airport used in Risk Assessment

Date	Total Mass (kg)/km^2	Mean Mass (g)	Risk
Feb-2006	33.3	383	MODERATE
Jun-2006	39.4	277	LOW
Oct-2006	10.1	132	VERY LOW
Nov-2006	13.3	328	LOW
Dec-2006	37.3	353	MODERATE
Jan-2007	27.6	344	MODERATE

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