RISK ASSESSMENT: QUANTIFYING AIRCRAFT AND BIRD SUSCEPTIBILITY TO STRIKE.

Phil Shaw* and Jeff McKee
Avisure Pty Ltd, PO Box 404 West Burleigh, Qld, Australia (*pshaw@ecosure.com.au)

ABSTRACT

Different aircraft types have different susceptibilities to colliding with birds; larger, faster aircraft with jet engines are more likely to be struck than smaller, slower propeller driven aircraft. Similarly, different bird species present different risk levels to aircraft depending on their abundance, mass and flocking tendency. The latter are relatively easy to quantify and can be used as input variables in strike risk models. However bird susceptibility to strike is also dependent on inherent behavior traits that may vary significantly between species and are much harder to parameterize. For example flocking species have a high consequence rating if struck because of their additive biomass and increased chance of hitting critical aircraft parts, although their behavior should give them a greater ability to avoid strike in the first place as they have evolved mechanisms to match velocity and avoid collision while in formation. Here we present two simple methods of quantifying aircraft and bird susceptibility to strike. The former requires access to accurate national strike data and is based on comparing aircraft strike rates with aircraft weight and performance categories. The latter requires standardised surveys over time from several airports in a region and is based on comparing species strike rate with species survey density. The aircraft strike susceptibility index can be included in retrospective strike risk assessments and helps provide a more meaningful comparison of strike rates at airports with different aircraft movement patterns. The species susceptibility to strike index can be combined with a range of biological and spatial parameters to give a prospective and ranked risk indication for either an individual species or a whole airport. Ultimately, this alerts operators to the need for appropriate risk treatments and allows species of greatest risk to be targeted in management programs.

RISK ASSESSMENT: QUANTIFYING AIRCRAFT AND BIRD SUSCEPTIBILITY TO STRIKE.

Phil Shaw* and Jeff McKee
Avisure Pty Ltd, PO Box 404 West Burleigh, Qld, Australia (*pshaw@ecosure.com.au)

Introduction

The likelihood of a birdstrike is dependent on the density of birds and aircraft within a given air space (van Tets 1969). Whilst more aircraft movements would increase the chance of a strike, other factors such as aircraft frontal area, speed/weight category and engine type, number, size, and noise output, may affect the susceptibility of aircraft to strike independent of movement frequency.

Intrinsic bird behavioural factors, particularly vigilance, evasion and habitat preference will also alter the likelihood that a particular bird will be struck irrespective of its critical airspace population density. Some of these factors may be influenced by the age and experience of the individual bird; young and migrating birds are thought to be more prone to strike than airside residents due to their inexperience around aircraft (Kelly *et al* 1999, Jacobi 1996). Ambient conditions such as visibility, wind speed and direction determine how well birds are able to detect air traffic and thereby avoid a collision (Jacobi 1996). Some species manage all these factors in such a way that they avoid strikes better than other species (Carter 2001).

While aircraft movement frequency and bird density within aerodrome airspace are relatively easy to quantify, the intrinsic susceptibility of birds and aircraft to strike are more difficult to assess and quantify. However it is important to consider both these factors when developing strike risk models for aerodrome operators, aircraft operators and pilots so that strike mitigation resources can be accurately assigned.

In an ideal system devoid of behavioural differences equal numbers of birds would have an equal chance of being struck and this would be expressed as a relatively constant ratio of strike rate to bird abundance. However if we examine a large data set and find between-species differences in measured ratios then we propose these differences must in part reflect intrinsic avoidance behaviours. The same principle can be applied to an examination of aircraft movements and strike rate; differences in the ratio of strikes to an aircraft type against an aircraft's movement rate must in part reflect that aircraft's susceptibility to strike. Here we present a data based method for evaluating the susceptibility of aircraft types and a survey based method for numerically ranking the susceptibility of bird species to strike.

Methods

Airports

Nine Australian airports from ranging in latitude from 21^{O}S to 42^{O}S were surveyed over varying periods. Their characteristics and movements are summarised in Table 1

AIRPORT	PERIOD	SURV(n_{su})	RPTEM	SA	HABITAT
A	1997-2008	396	322471	192	Moist Sub Tropical
B	2004-2007	261	157540	301	Moist Tropical
C	1998-2008	120	112596	165	Moist Sub Tropical
D	2005-2008	27	24508	169	Moist Tropical
E	2004-2008	148	21606	114	Moist Sub Tropical
F	2006-2008	8	52368	156	Moist Tropical
G	2007-2008	15	25080	262	Cool Moist Temperate
H	2005-2007	36	24383	208	Warm Moist Temperate
I	2007	3	10317	245	Warm Dry Temperate
TOTAL		**1014**	**750869**	**1812**	

Table 1 Characteristics of the surveyed airports. **PERIOD** = the period over which the surveys took place. **SURV(n_{su})** = number of surveys over that period. **RPTEM** = aircraft movements corrected to RPT equivalents over the survey period. **SA** = Survey area in Hectares.

Aircraft susceptibility to strike

Initially we reviewed the Australian Transport Safety Bureau (ATSB) movement databases along with our own strike databases for selected regional airports. We then compared the strike rate and movement rates for aircraft less than 7000kg MTOW (light aircraft LA) against those for aircraft greater than 7000kg MTOW (Regular Public Transport or RPT aircraft). In this dataset the heavier RPT aircraft represented only 8% of the movements but accrued 61% of the strikes suggesting that RPT aircraft are 18 times more likely to be struck than LA. Since our initial review the ATSB has released an updated analysis of birdstrike in Australia (ATSB 2008). Using this much larger data set ATSB estimated that RPT aircraft are 16 times more likely to be struck than LA. We use the latter figure for all calculations presented here i.e. Regular Public Transport Equivalent Movements (RPTEM) are estimated by adding RPT (heavy aircraft) movements to LA movements divided by 16.

In Summary: $RPTEM = (H+M+Mil) + (L+RW)/16$,

Where H equals movements of heavy aircraft > 136000kg MTOW, M equals movements of medium aircraft with MTOW 7000-136000kg , Mil equals military aircraft movements , L equals movements of light aircraft with MTOW < 7000kg, RW equals helicopters.

Bird species susceptibility to strike

Between 1998 and 2008 we carried out 1014 standardised diurnal bird surveys on nine airports located in eastern Australia and ranging in latitude from 21-43^{O}S. Our surveys covered equally the early morning, middle of day and late afternoon time periods and were confined to the airside section of each airport which was divided into sectors, each of approximately 20 hectares. Larger airports had a greater number of sectors and therefore proportionally more survey time. We selected an observation point in each sector to overlook as much of the area as possible and visited these in sequence by vehicle. Bird observations were made using 10x40 binoculars while we drove to and from the observation point, and during a 5-minute stationary survey from the vantage point. During each survey, we recorded species and numbers observed in specific locations (1Ha grids) within each sector. We also noted the habitat being used and behavior of individuals observed. Airborne birds were recorded from within and outside the current survey sector. For each airport, the relative density (RD_{sp}) of each species was obtained by dividing the number (n_{sp}) of each species recorded by the number of surveys (n_{su}) and the survey area (SA) measured in hectares.

We reviewed strike data from each airport during years for which our surveys were completed. Only "confirmed" strikes (those evidenced by the presence of a carcass, feathers or other remains) and "on airport" strikes (those within the airside fence, or below 500ft on departure and below 200ft on arrival) were assessed. All strikes involving nocturnal species and mammals were excluded from the dataset as the surveys used in the comparison are only suitable for diurnal birds. Where possible, species identification was confirmed by an ornithologist and/or by forensic investigation.

For each airport the species susceptibility to strike (SSS) index was derived from the ratio of strike rate per 10^4 RPT equivalent movements ($SR/10^4RPTEM$) to the mean species survey density (RD_{sp}) and then multiplied by 1000 to allow ranking with whole numbers. When a species was not recorded during surveys but was recorded as a strike, then it was assigned a survey value of 1 to preserve the divisor.

In Summary ; $SSS = (Strikes/10^4RPTEM) / RD_{sp} \times 1000$

Where RD_{sp} equals the number of each species surveyed (n_{sp}) per survey (n_{su}) per hectare (SA)

Results

Aircraft Movement Equivalents

Regular Public Transport Equivalent Movements (RPTEM) were derived from ATSB Movement data according the example in Table 4. which is the result for Airport I.

	Movements by aircraft weight category						
AIRPORT	**H**	**M**	**L**	**RW**	**MIL**	**Total**	**RPTEM**
I	0	4562	79162	1144	736	85604	10317

Table 2 Deriving RPTEM values. **H**= aircraft MTOW > 136000kg. **M**= aircraft MTOW 7000-136000kg. **L** = aircraft MTOW < 7000kg. **RW** = Helicopters. **MIL** = Military. **RPTEM** = (H+M+Mil) + (L+RW)/16

Birds and strikes by airport

Overall, 159749 birds representing 209 species and 54 bird families were recorded from 1014 surveys at the nine airports. The mean bird density was 0.995 birds/Ha/survey/airport. The distribution of these results by airport along with strike rate per 10^4 RPT equivalent movements are summarised in Table 2.

AIRPORT	RD (all species)	FAM	SPP	NUM	% UNK	STRKS	% STRKS UNK	SR/10^4RPTEM
A	0.68	44	125	51990	1.26	189	20.6	5.9
B	0.79	43	118	62436	0.04	112	56.3	7.1
C	0.94	37	113	18648	2.33	80	8.8	7.1
D	0.83	32	67	3799	0.82	55	27.3	22.4
E	0.86	38	109	14540	2.84	53	45.3	24.5
F	1.35	25	48	1682	7.55	148	71.6	28.3
G	0.36	25	38	1415	3.67	21	38.1	8.4
H	0.43	29	65	3254	1.41	35	45.7	14.4
I	2.70	18	25	1985	0.40	14	7.1	13.6
TOTAL	**0.995 (mean)**	**54**	**209**	**159749**	**1.12**	**707**	**39.5**	**9.4**

Table 3 Bird densities and strike rates at the surveyed airports. **RD=** number of birds (all species) per Hectare per survey. **FAM** = Number of bird families recorded. **SPP** = number of bird species recorded. **NUM** = number of birds recorded. **%UNK** = percentage of surveyed birds not identified. **STRKS** = number of strikes recorded. **%STRKS UNK** = percentage of strikes not identified. **SR/10^4RPTEM** = Strike rate per 10^4 RPT equivalent movements.

Ranking species susceptibility to strike

RANK	COMMON NAME	SPECIES	FAMILY	SSS index	Total Strikes
1	Spectacled Monarch	*Monarcha trivirgatus*	Dicruridae	3071	1
2	Brown Quail	*Coturnix ypsilophora*	Phasianidae	1662	1
3	House Sparrow	*Passer domesticus*	Passeridae	1629	5
4	Australian Pratincole	*Stiltia isabella*	Glareolidae	1247	1
5	Red-capped Plover	*Charadrius ruficapillus*	Charadriidae	1030	2
6	Spotted Harrier	*Circus assimilis*	Accipitridae	931	1
7	Lesser Sand Plover	*Charadrius mongolus*	Charadriidae	879	1
8	Black Kite	*Milvus migrans*	Accipitridae	701	23
9	Crested Tern	*Thalasseus bergii*	Laridae	294	4
10	Silver Gull	*Chroicoc. novaehollandiae*	Laridae	277	4
11	Fairy Martin	*Petrochelidon ariel*	Hirundinidae	177	43
12	Ground Parrot	*Pezoporus wallicus*	Psittacidae	135	1
13	Whistling Kite	*Haliastur sphenurus*	Accipitridae	130	10
14	Australian Bustard	*Ardeotis australis*	Otididae	119	1
15	Wandering Whistling-Duck	*Dendrocygna arcuata*	Anatidae	115	3
16	Greater Sand Plover	*Charadrius leschenaultii*	Charadriidae	111	2
17	Pacific Gull	*Larus pacificus*	Laridae	92	1
18	Masked Lapwing	*Vanellus miles*	Charadriidae	88	53
19	White-throated Needletail	*Hirundapus caudacutus*	Apodidae	85	10
20	Nankeen Kestrel	*Falco cenchroides*	Falconidae	76	24
21	Pacific Golden Plover	*Pluvialis fulva*	Charadriidae	65	2
22	Wood Duck	*Chenonetta jubata*	Anatidae	60	13
23	Dusky Moorhen	*Gallinula tenebrosa*	Rallidae	60	1
24	Grey Teal	*Anas gracilis*	Anatidae	57	1
25	Swamp Harrier	*Circus approximans*	Accipitridae	52	1
26	Eurasian Skylark	*Alauda arvensis*	Alaudidae	50	3
27	Sulphur-crested Cockatoo	*Cacatua galerita*	Cacatuidae	49	1
28	Black-shouldered Kite	*Elanus axillaris*	Accipitridae	47	2
29	Welcome Swallow	*Hirundo neoxena*	Hirundinidae	47	27
30	Feral Pigeon	*Columba livia*	Columbidae	30	3
31	Latham's Snipe	*Charadrius mongolus*	Charadriidae	25	1
32	Eastern Osprey	*Pandion cristatus*	Accipitridae	21	1
33	Magpie Lark	*Grallina cyanoleuca*	Dicruridae	19	33
34	Galah	*Eolophus roseicapillus*	Cacatuidae	17	14
35	Australasian Pipit	*Anthus novaeseelandiae*	Motacillidae	15	21
36	Tree Martin	*Petrochelidon nigricans*	Hirundinidae	14	18
37	Australian Swiftlet	*Aerodramus terrareginae*	Apodidae	12	2
38	Pacific Black Duck	*Anas superciliosa*	Anatidae	12	29
39	White-breasted Woodswallow	*Artamus leucorynchus*	Artamidae	11	3
40	Spotted Dove	*Streptopelia chinensis*	Columbidae	11	3
41	Gull-billed Tern	*Gelochelidon nilotica*	Laridae	10	2
42	Intermediate Egret	*Ardea intermedia*	Ardeidae	8	2
43	Crested Pigeon	*Ocyphaps lophotes*	Columbidae	5	5
44	Cattle Egret	*Ardea ibis*	Ardeidae	5	3
45	Royal Spoonbill	*Platalea regia*	Threskiornithidae	4	1
46	White-faced Heron	*Egretta novaehollandae*	Ardeidae	4	5
47	Australian Magpie	*Cracticus tibicen*	Artamidae	3	14
48	Rainbow Lorikeet	*Trichoglossus haematodus*	Psittacidae	2	1
49	Black-faced Cuckoo-Shrike	*Coracina novaehollandiae*	Campephagidae	2	1
50	Australian White Ibis	*Threskiornis mollucca*	Threskiornithidae	2	4
51	Purple Swamphen	*Porphyrio porphyrio*	Rallidae	2	5
52	Eastern Great Egret	*Ardea modesta*	Ardeidae	1	1
53	Rainbow Bee-eater	*Merops ornatus*	Meropidae	1	1
54	Willie Wagtail	*Dendrocygna arcuata*	Anatidae	1	2
55	Bar-shouldered Dove	*Geopelia humeralis*	Columbidae	1	1
56	Torresian Crow	*Corvus orru*	Corvidae	1	8
57	Straw-necked Ibis	*Threskiornis spinicollis*	Threskiornithidae	<1	1
58	Common Myna	*Sturnus tristis*	Sturnidae	<1	1
59	151 Species	*Various*	Various	0	0

Table 4. Birds ranked by species susceptibility to strike (SSS) index. The higher the SSS the greater the susceptibility to strike. SSS is derived from the ratio of the strike rate per RPTEM to the survey rate of birds/Ha/survey

Discussion

We calculated relative susceptibility to strike (SSS) indices for species commonly found on airports in Eastern Australia by comparing the rate at which those species were struck against the freequency at which they are detected on airport. This index was standardised for survey effort, survey area, and aircraft weight category and aircraft movement numbers. SSS can be used as an input parameter along with species mass, abundance and presence in critical areas to help derive an overall relative species risk index for an airport. In turn this information provides aerodrome operators with a means to accurately prioritise the species they will target in mitigation programs.

The relative susceptibility of different aircraft types to strike was estimated for two crude aircraft weight categories only: RPT and LA. Our limited analysis was consistent with the ATSB finding that RPT aircraft are 16 times more likely to report a strike than light aircraft. However it is likely that this discrepancy in strike rates is not solely due to intrinsic aircraft differences; reporting rates for RPT aircraft are most likely to be significantly higher than those for light aircraft, particularly those operating in the General Aviation sector. Airlines which operate the RPT aircraft tend to have mature reporting systems which are not reflected in General Aviation, where most pilots tend to be reluctant to submit paperwork and are unaware of protocols. We have assumed that this bias will be relatively consistent across airports and thus the relative rankings derived for SSS values using the 16:1 factor should remain unaffected. Although aircraft type is routinely listed in strike databases only broad aircraft weight categories are currently available in Australian aircraft movement databases. Thus movement rate data for aircraft type could not be sourced and susceptibility to strike indices specific for aircraft type could not be derived here. Although not particularly relevant for the management requirements of aerodrome operators RPTE corrected movement rates allow better comparison of strike rates between airports. If in the future more comprehensive movement data becomes available allowing specific aircraft type susceptibility indices to be determined, these will provide aircraft operators and pilots with a means to better assess strike risk to their individual operation.

In this dataset the Spectacled Monarch *Monarcha trivirgatus* has the highest SSS. This species was struck only once but derived a high SSS because it was absent from the survey record. Spectacled Monarchs are unlikely to be found airside: they are partial migrants that when not migrating are almost always confined to protected understorey. This was an unexpected and perhaps anomalous result; it may represent a strike misidentification or alternatively a rare or one-off strike on transiting migrant. It does however highlight the sensitivity of this method to inaccurate data and rare events especially when deriving SSS ratios from small survey and strike numbers. Similarly we query the result for House Sparrow *Passer domesticus* (ranked 3). In this case it is possible that the species is over-represented in the strike record. In our experience "sparrow" is sometimes used as a catchall category for small brown birds that are difficult to identify. The species most commonly struck in this dataset, the Masked Lapwing *Vanellus miles*, scored a mid-range SSS reflecting both its high survey rate and peculiar nesting behaviour. Airports are ideal environments for this species which nest on open grasslands and will aggressively defend that nest even against an oncoming aircraft.

Initially we considered that susceptibility to strike may be a family trait. However, the calculated coefficients of variation for species SSS within families was greater than 100 in almost every case (unpublished data) suggesting that there is large within-family behavioural variation. A few families were relatively consistent across their species, for example the raptor families (Accipitridae and Falconidae) each include many species with high SSS scores and high strike numbers. This probably reflects their decreased requirement for vigilance as top end predators, a tendency to fixate while hunting and in the case of some of the smaller kites and kestrels their tendency to hover. The Anatidae (swan, geese and ducks), Charadriidae (plovers, dotterels and lapwings) and Ardeidae (herons and egrets) were also well populated with species with moderate to high SSS. These are not unexpected given the consistent marine and/or freshwater water association with most of the airports surveyed and the preference of these families to water habitats. Conversely, Threskiornithidae (ibises and spoonbills) appear to have inherent capacity to avoid strike given their relative high populations at many of the airports surveyed yet relatively low strike rates.

We recognise that the value of the SSS as presented here is predicated on the assumption that there is little or no within-species variation in susceptibility to strike. This may well not be the case. We, and others cited above have noted apparent differences in strike rates between age, sex and residency classes within diurnal bird species. In addition there is no guarantee that avoidance behaviour remains consistent within a species across a large geographic range. Local environmental conditions and genetic isolation may both give rise to a spectrum of avoidance abilities. However, at this stage the size and resolution of the available survey and strike datasets is insufficient to test the effect of these factors. Current strike datasets, including those used, here have high proportions of unknown species; this severely limits sub-class and demographic analysis and probably results in an under representation of species that are small and hard to identify.

Developing SSS indices for nocturnal species is problematic. SSS values are heavily dependent on deriving accurate and repeatable species density data. In our experience current nocturnal flying species survey techniques produce, at beast, only coarse approximate data. Nocturnal surveys present a big challenge in strike risk assessment given the global increase in recorded bat strikes (see Patrick *et al* in these proceedings).

Despite these limitations we believe that estimates of aircraft and bird relative susceptibility to strike are useful adjuncts to models that are deployed to determine risk management priorities and resource allocation. As data sets become larger and more accurate we expect that these estimates will be refined and it may eventually be possible to assign different SSS values to a species for different aircraft types. We propose that it will be informative to compare transcontinental SSS values for cosmopolitan species.

References

Australian Transport Safety Bureau (2008) An Analysis of Birdstrike Occurrences 2002-2006. *Aviation Research and Analysis Report AR-2008-027 ATSB.*

Carter, N. B. (2001) All birds are not created equal: risk assessment and prioritisation of wildlife hazards at airfields. *In Bird Strike 2001. Calgary, Canada.*

Kelly, T., Bolger, R. and O'Callaghan M. (1999) The behavioural responses of birds to commercial aircraft. *Proc. Birdstrike '99 Vancouver May 1999.*

Jacobi, V. (1996) Study of bird behaviour to bird strike prevention. *Proc. Bird strike Committee Europe BSCE 23/WP3, London , May 1996.*

van Tets, G.F. (1969) Quantitative and qualitative changes in habitat and avifauna at Sydney airport. *CSIRO Wildlife Research 14:117-28.*