BIRD STRIKE SYNDROME: TOWARDS DEVELOPING AN INDEX OF BIRD INJURY

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Abstract

The use of trauma scoring techniques is well established in clinical medicine. These techniques allow the semi-quantitative description of injuries in patients with extensive physical trauma. The novel use of analogous methods to describe the injuries sustained by aircraft **-** killed birds is described here. By assigning trauma scores to injuries of aircraft struck birds it is hoped that a signature of injuries associated with bird strike will emerge. In other words this study examines whether or not a 'Bird Strike Syndrome' exists. Such a 'syndrome' could have major implications for post mortem analysis of airfield carcasses, the definition of a bird strike and the assembly of bird strike databases. This paper discusses the methodology used in this study**,** and the suggested application of trauma scoring for improved quality control in the compilation of bird strike statistics.

Keywords: Bird strike, 'Bird Strike Syndrome', index of bird injury, cadavers, trauma scoring, cluster analysis

1. Introduction

Reliable bird strike statistics are vital for evaluating the relative risk posed by bird species to aircraft. Such statistics are essential, to allow airfield management to effectively target hazardous species or groups of birds (SHAMOUN-BARANES, 1998).

One of the simplest techniques used to identity aircraft struck birds is the collection of macroscopic bird remains from the runway (LINNELL et al., 1996). These data, according to the definition of a bird strike, should be included in bird strike statistics if the cadaver is collected from within 61 metres of the runway's centre-line, unless another reason for the bird's death is identified (CLEARY & DOLBEER, 1999). Although cadaver derived data may account for as much as 86.6% of all strikes, it is often ignored when collating bird strike statistics (BARRAS & DOLBEER, 2000).

LYNE et al. (1998) detailed necropsy results of 92 such bird carcases collected at Dublin airport, Ireland. This study provided a preliminary description of a "Bird Strike Syndrome" and revealed that an overwhelming majority of birds in this sample had sustained injuries to the ventral surface. One suggested explanation for such a trend was that birds "slowed down" when in close proximity to aircraft in an attempt to avoid collision (KELLY et al., 1996).

If a "Bird Strike Syndrome" exists, is it possible to use this to reliably identify aircraft struck birds, distinguishing them from birds that have killed by other mortality factors? This paper outlines a method for the classification of bird injuries. A method, which attempts to standardise the quantitative description of such injuries, is also described.

Injuries are identified through detailed necropsy of bird carcasses collected from airport runways, road verges and below overhead lines. Injuries associated with other sources of mortality including window strike, raptor attack and gunshot are also identified and compared to those of aircraft struck birds. Trauma scoring techniques, adapted from clinical medicine, are used to quantify injuries.

2. Materials and Methods

2.1 Study areas/Cadaver sources

This projects uses two main study areas, Dublin and Cork airports (51^{0}50'50" N, 8^{0}29'40"W, and 53^{0}25'40"N, 6^{0}14'27"W respectively), two of the largest and busiest airports in the Republic of Ireland. Over 17 million passengers passed through Dublin airport in 2004 with 2.2 million passengers passed through Cork airport in the same time.

Road-killed bird cadavers are also collected from primary and secondary routes in the Cork region (Ordnance Survey: X075730). Shot birds and fatalities from window strike and raptor attack are collected from a number of locations.

2.2 Specimen collection

Bird patrol units at both Dublin and Cork airport collected cadavers for this study. Cadavers were collected through routine inspections of the airfield as well as from aircraft following collisions. All specimens were labelled with the time and date of collection, as well as the location in which they were found and the prevailing weather conditions. In cases where a strike is reported, or where birds are removed the hull, undercarriage, wings and/or engines, the type of aircraft and the phase of flight is also noted. Cadavers are stored in polythene bags and deep-frozen.

Road killed individuals are collected through daily scanning of both primary and secondary routes. Only freshly killed samples are collected to reduce any confounding effects of individuals that have been struck repeatedly by cars. The location in which the bird was found as well as the date and weather conditions are recorded. Specimens are stored in polythene bags and deep-frozen. Cadavers collected from other locations are labelled and stored in the same manner.

2.3 Necropsy methods

2.3.1 External examination

Specimens are allowed sufficient time to fully defrost. The necropsy follows routine procedure a described in WAINE (1996) with some minor amendments due to the focus on gross injury (see LYNE et al*.,* 1998).

Any identifying marks such as rings, microchips etc are noted. The following measurements are recorded from all cadavers- weight, tarsal length, maximum chordal length, beak length and head length (REDFERN & CLARKE, 2001). The condition of the cadaver is scored based on fat scores (0-8) and/or pectoral muscle scores (0-3) (see BAIRLIEN et al., 1995).

The bones are examined, palpating each joint and long bone for any fractures, dislocations or joint effusions. The integument is also checked for any signs of injury such as puncture wounds or contusions. The feathers are examined and photographed to observe any signs of abnormal wear, fractured veins, discolouration, abnormal development, cysts, stress marks, and/or ectoparasites. The stage of moult is noted.

The uropygial (preen) gland at the base of the tail is examined for any abnormalities. Any discharges from the nares, buccal cavity, eyes, ears, vent and wounds are noted. The presence or absence of the eyes is also noted to indicate if any post mortem scavenging has occurred. The legs, feet and cere are examined for any encrustations. The beak is also checked for any breakages.

2.3.2 Internal examination
Preparation and initial incision

Smaller birds are pinned on a cork board in dorsal recumbence with limbs outstretched and tense. The bird is soaked with a dilute disinfectant detergent and the feathers are parted down the ventral midline in preparation for the initial incision. The skin is incised through the skin along the midline from the gonys to the vent. The skin is eased away from the underlying thorax and *pectoralis* muscles by blunt dissection and the condition on the muscle along with the presence of subcutaneous fat is observed.

Removal of superficial muscles and examination of the buccal cavity
The buccal cavity is opened allowing the lower mandible to be reflected. The buccal cavity and infraorbital sinuses are examined. The pectoral muscles are reflected away from the sternum and ribs. For individuals which have been involved in multiple strikes (two/more individuals struck during the same incident or found together on collection) a sample of the pectoral muscle is taken using a sterile scalpel blade. This is to allow DNA analysis at a later date. The trachea and oesophagus are dissected along their length. The midline of the abdominal muscles is incised and the insertion of the muscles to the rib cage cut. The abdominal contents are examined for any haemorrhaging or other damage. The abdominal tunic is reflected to reveal the underlying post-hepatic septum.

Removal of the sternum and the examination of the viscera *in situ*
The ribs are cleared of the overlying muscle and cut along the line of angulation. The sternum is lifted away from its caudal edge and dissected away from the thoracic air sacs and the pericardium. The sternum is removed by dislocating the joints between the coracoid bones and the edge of the sternum. Any damage to the sternum is noted. The heart, lungs and liver are examined *in situ* for any contusions, haemorrhaging or lesions. The post hepatic septum is removed.

Examination of the thoracic and abdominal organs
The crop and oesophagus are removed using blunt dissection and examined for the presence of any parasites. The trachea is removed and held up to the light to examine for any parasites within.

The liver and gastrointestinal tract are separated out. The gastrointestinal tract is removed and its organs including the duodenum, colon, spleen and pancreas are examined for any signs of damage. A section of the kidney and gonads are taken and examined for any sign of abnormalities.

Examination of the skull, brain and spinal cord

The skin is removed from the skull using blunt dissection. Any staining of the skull is noted before its removal for examination of the brain. The brain is sectioned and any signs of contusions or haematomas are noted.

The skin in removed from around the spinal cord through blunt dissection to observe if any bruising, haemorrhaging or fracture has taken place.

2.4 Injury recording
Each injury is assigned a score based on an anatomical scoring system used in trauma medicine known as the Abbreviated Injury Scale (AIS), COPES et al. (1990). Injuries are ranked on a scale of 1-6 (***Table I***) with 1 being minor and 6 unsurvivable. Organ injury scales have also been developed to provide physicians with a common nomenclature to describe injuries to various organs and their severity (MOORE, 1989; MOORE, 1990; MOORE, 1992; MOORE, 1994; MOORE, 1995). Injuries can be scaled based on mechanism, such as blunt or laceration, or anatomic description, haematoma, laceration, contusion, vascular. Bilateral injuries to organs or extremities increase the AIS score.

***Table I**. Abbreviated Injury Scale (AIS)*

AIS Score	*Injury*
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Unsurvivable

Another tool used is medical trauma research is the Injury Severity Score (ISS), BAKER et al. (1974). This anatomical scoring system uses the AIS to provide an overall score for patients with multiple injuries. Broadly based on the ISS injuries in this study will be allocated to one of the six body regions described in *Table II.*

Each body region receives a single score based on its most severe injury. If for example the abdominal region receives both a minor contusion to the liver (AIS 2) and a complex rupture of the spleen (AIS 5) then the score for the abdominal region is AIS 5; i.e. the maximum score received by the region. The end result of this type of classification is a series of six trauma (AIS) scores for each cadaver examined.

Table II. Description of body regions into which injuries are classified

Region	*Description*
Head & neck	Including the skull, brain and cervical vertebrae excluding frontal area
Frontal skull region	Frontal area of the skull including beak
Thorax	Ventrally the region from the base of the posterior extremity of the pectoral muscles including sternum, ribs,
Abdomen	Ventrally the region directly posterior to the thorax extending to the cloaca
Extremities	Skeletal and muscular structures of the wings, legs including caudal region of the spine and pubic bone
Vertebral column	Vertebral column excluding caudal and cervical vertebrae

2.5 Data analysis

As mentioned, each individual received a series of six trauma scores based on the severity of injuries to each of the six body regions (*Table II*). In order to classify injury by pattern these trauma scores were used as variables. The first step in the analysis was to use these variables to perform a Principal Component Analysis (PCA). In brief, this analysis yielded a set of uncorrelated variables, known as factors, which describe the maximum amount of common variance in the correlation matrix using the minimum number of explanatory concepts. Individuals received a score for each factor based on how much of their variability was explicable by this factor. A cluster analysis was performed using the factor scores as variables. “Quick Cluster” (SPSS version 11.01) based on Ward’s method of sorting was the technique used (WARD, 1963). SPSS’s Quick Cluster uses squared Euclidean distances as its measure, which weights all cluster variables equally.

Once the individuals had been assigned to clusters, chi-squared tests (significance level of 0.05) were applied to test the relationship between the cluster-belonging and whether or not these birds were found on the runway, on the roadside or were recorded as shot. Cadavers found on the runway were classified as aircraft struck, unless they had been recorded as shot. Cadavers found on the roadside were recorded as road killed.

3. Results

Table III lists the species that have been included in the current analysis.

Two main injury patterns emerged from the cluster analysis. The name given to each cluster reflects the most significant descriptors around which the cluster was formed.

Cluster 1 (n=95; %=81.8) *Thoracic injuries*
This group is characterised by major injuries to the thoracic region. Severe injury to the head/ neck and frontal skull region is unlikely.
Cluster 2 (n=21; %=18.2) *Head, neck and vertebral injuries*
This group is characterised by major injuries to the head and neck region and the vertebral region. Bird in this cluster are also likely to have injury to the frontal skull region but highly unlikely to have sustained thoracic injury.

Figure 1 illustrates the results of the PCA with individuals labelled according to cluster. **Figure 2** illustrates the same results but in this graph individuals are labelled according to cause of death. A chi squared analysis revealed no significant correlation between cluster-belonging and whether or not birds were found on the runway, on the roadside or had been shot (χ^2= 2.34 p<=1.0).

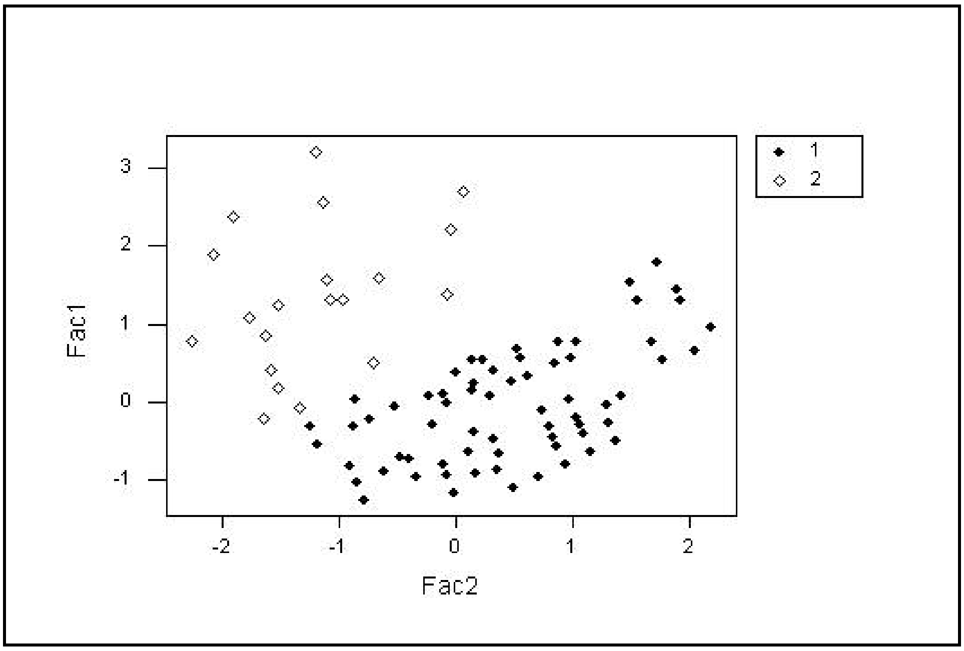

Figure 1 Results of PCA on the 6 injury parameters (see *Table II)*. The injuries of 116 individuals are represented according to the two main functions of the analysis. Each individual is represented by a single point of the graph and labelled according to the cluster to which they have been assigned.

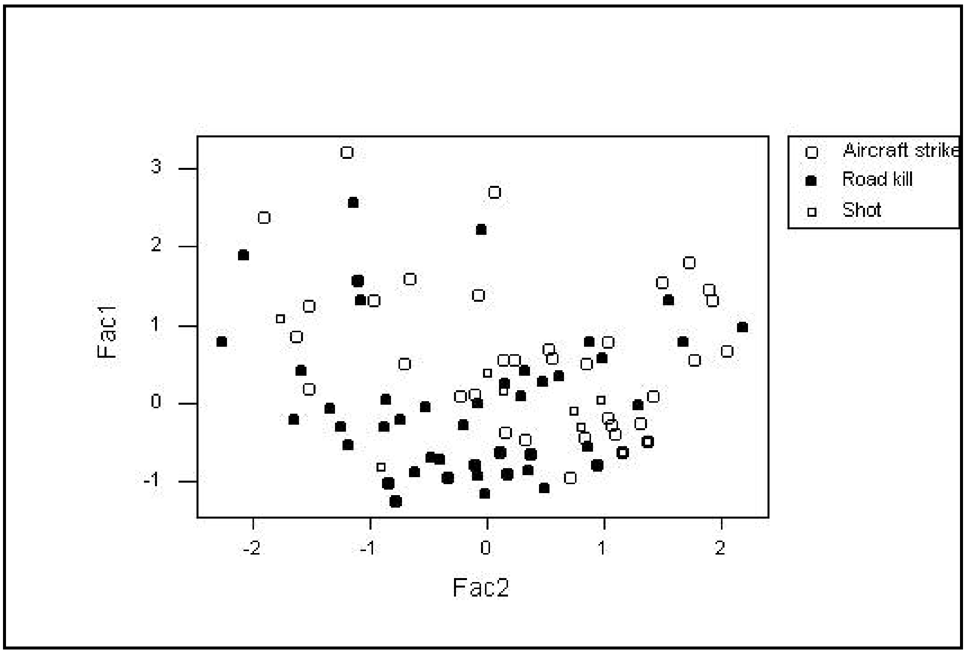

Figure 2 Results of PCA on the 6 injury parameters (see *Table II*). The injuries of 116 individuals are represented according to the two main functions of the analysis. Each individual is represented by a single point of the graph and labelled according to cause of death.

Table III. Species included in the analysis

Common name	**Latin name**
Black Headed Gull	*Larus ridibundus*
Blackbird	*Turdus merula*
Feral Pigeon	*Columba livia*
Golden Plover	*Pluvialis apricaria*
Greenfinch	*Carduelis chloris*
Grey Heron	*Ardea cinerea*
Jackdaw	*Corvus monedula*
Kestrel	*Falco tinnunculus*
Lapwing	*Vanellus vanellus*
Lesser Black Backed Gull	*Larus fuscus*
Magpie	*Pica pica*
Meadow pipit	*Anthus pratensis*
Merlin	*Falco columbarius*
Mistle thrush	*Turdus viscivorus*
Moorhen	*Gallinula chloropus*
Pheasant	*Phasianus colchicus*
Pied wagtail	*Motacilla alba*
Rock pipit	*Anthus petrosis*
Rook	*Corvus frugilegus*
Sandmartin	*Riparia riparia*
Skylark	*Alauda arvensis*
Sparrowhawk	*Accipiter nisus*
Starling	*Sturnus vulgaris*
Swallow	*Hirundo rustica*
Woodpigeon	*Columba palumbus*

4 Discussion

Our analysis reveals that injured birds fall into two distinct categories: those with major injury to the thoracic region and those with major injury to the head or vertebral region. There appears to be no significant difference in the clustering of groups between different mortality factors i.e. aircraft strike, road-killed or shot birds. LYNE et al. (1998) detailed what they believed to be a ‘Bird Strike Syndrome’. The results of this paper would suggest that this ‘syndrome’ is not confined to bird strike but could be better described as a ‘Trauma Syndrome’. The trend of significant ventral injuries seen by LYNE et al. still exists, however these injuries are not unique to aircraft struck birds and are seen throughout road killed and shot birds.

These results indicate an interesting pattern of behaviour immediately prior to fatal trauma. This is the exposure of the ventral surface to the oncoming object, or alternatively, the protection of the cranial region. The fact that this trend is seen across such a broad group of species and sources of mortality may suggest some type of fixed action pattern in the response. In other words, these birds, when faced with imminent death revert to an innate behavioural pattern. Despite the obvious differences that exist between these three sources of mortality, they are likely to share a key stimulus or stimuli which produce this pattern of behaviour in birds. Further study in this area could provide interesting insights into the stimuli that allow birds to successfully avoid aircraft.

Post-mortem analysis of bird cadavers yields large amounts of qualitative data, which is difficult to categorise and summarise. The aim of the current analysis is both to standardise and summarise the data which these post mortems yield, to allow ease of analysis. The downfall of such analysis is that it may mask greater trends in the data, which numerical description of injury location and severity cannot account for. This must be kept in mind when considering the results illustrated in **Figures 1** and **2**.

The nature of our analysis has undoubtedly left unanswered questions about the injury patterns of aircraft struck cadavers. Future analysis of these data will focus on refining the method of injury classification to identify any subtle groups or clusters that may exist. Other recorded variables such as sex, age, condition, season of strike and species may yield distinct groups of injury patterns.

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