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ASIAN JOURNAL OF
SCIENCE AND TECHNOLOGY

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 10, Issue, 01, pp.9251-9257, January, 2019

RESEARCH ARTICLE

BIRD-STRIKE AIRCRAFT ACCIDENTS AND THEIR PREVENTION

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ARTICLE INFO

Article History:
Received 27th October, 2018
Received in revised form
18th November, 2018
Accepted 24th December, 2018
Published online 30th January, 2019

Key words:

Active and Passive control, Engine-Ingestion, Windshield-penetration, Training and Flight-Rules, Personal-Protection Equipment.

ABSTRACT

Introduction: Not less than 210 people have been killed worldwide due to bird-strikes with aircraft, since 1988. Bird-strikes to aircraft result in some $610 million in damage a year. Five jet-airliners have had major accidents involving bird-strikes since 1975. Experts estimate that only about 20 percent of all bird strikes are reported. In recent years, bird-strikes have been reported involving Malaysian aviation. **Method:** Literature in the form of journal-articles, international-committee reports and news-media articles were reviewed with the aim of providing solutions to the problem, besides outlining salient recommendations. **Results:** Birds-strikes in relation to times of year, type of aircraft, phase of flight, altitude, speed, part of aircraft struck, bird-species responsible, climate conditions, bird-weight, are described. Besides the Luftwaffe method, various equipment and techniques in such prevention are described, including habitat-modification, exclusion including removal, pyrotechnics, trapping, and newer novel-methods. Recommendations are made where appropriate. **Conclusion:** Bird-strike aircraft-accidents cost too much morbidity, mortality and financial cost in aviation. Methods that here today solve are identified.

Citation: ***Dr. Meer Ahmad, A.M.*, 2019.** "Bird-strike aircraft accidents and their prevention", *Asian Journal of Science and Technology*, 10, (01), 9251-9257.

INTRODUCTION

On 26th September 2017, an Air Asia Flight from Medan, Indonesia to Penang was forced to return to Medan after a bird was sucked into one of its engines. The airliner was carrying 150 passengers. There were a couple more such incidents reported in Malaysia in 2016 and 2017. On January 15th, 2009, a US Airways jet hit a flock of geese shortly after it took off from LaGuardia Airport in New York and was forced to land in the Hudson River. Reports indicated no deaths, nor serious injuries. The birds were sucked into both engines causing the engines to fail. The 112,815 who reported bird and wildlife strikes in the last 20 years may not have seriously considered the damages that could result. Additionally, the actual number of strikes is probably much larger; experts estimate that about 80 percent of them go unreported. If this estimate is accurate, in 20 years there may have been more than 500,000 strikes. Bird and wildlife strikes can be serious and have resulted in more than 350 fatalities (https://www.aopa.org/training-and-safety/active-pilots/safety-and-technique/bird-and-wildlife-strikes). The first pilot to ever be involved in a bird-strike is believed to have been Orville Wright in 1908. Cal Rogers, who made history when he flew across the United States, was performing a demonstration flight in California in 1912 when his Wright Flyer collided with a seagull causing Cal's death (https://www.aopa.org/training-and-safety/active-pilots/safety-and-technique/ bird-and-wildlife-strikes). The threat of bird-strikes became more serious in the 1950s when the aviation-industry began using gas turbines for power. Then, the FAA began testing the engines for bird ingestion capabilities. The engines are able to ingest about three small birds (one and one-half pounds) or one medium bird (two and one-half pounds) without failing. The FAA currently considers a large bird to weigh more than four pounds. There is no aircraft engine certified to ingest a large bird without shutting down (https://www.aopa.org/training-and-safety/active-pilots/ safety-and-technique/bird-and-wildlife-strikes). With increased air traffic, and rising bird-populations, such threat is becoming more serious. Bird-strikes to aircraft cause damage costing about $610 million a year. Since 1975, five jet-airliners were involved in major-accidents caused by bird-strikes (https:// www.aopa.org/training-and-safety/active-pilots/safety-and-technique/bird-and-wildlife-strikes; Robin Lloyd, 2009). In Civil Aviation alone till 1974, 130 deaths had been reported worldwide to the ICAO (International Civil Aviation Organization). Due to the voluntary nature of civil aviation bird–strike reporting, a great deal of underreporting happens, occurs, especially for minor bird strikes (Thorpe, 2003; Thorpe, 2008). Conservative estimates suggest that more routine damage and delays following bird-strikes cost the industry and its insurers US$1.2-1.5 billion per year (https://www.aopa.org/training-and-safety/active-pilots/safety-and-technique/bird-and-wildlife -strikes; Allan, 2006). Efforts have been made to understand bird-behaviour, and bird-

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migration. Many factors, including climate, airport surroundings, and airport location in relation to migratory pathways, play a part in bird strike rates. Using such data, aviation authorities have developed many ways to keep birds away from aircraft (Thorpe, 2003; Thorpe, 2008). The majority of strikes happen close to airports and most countries have regulations that require airport managers to control the bird-strike risk on their property. Bird-strike prevention has, but, lagged behind various aspects of flight safety in the development and implementation of risk assessment protocols, possibly because of the inherent difficulty in quantifying the variability in the populations and behavior of the various bird species involved (Allan, 2006). In addition, engineers have attempted to introduce aircraft design-changes to decrease damage due to bird-strikes. Research in new material designs for jet-engine compressor-blades, stronger windshield-design, and damage-resistant wings is happening the past few years (Thorpe, 2003; Thorpe, 2008).

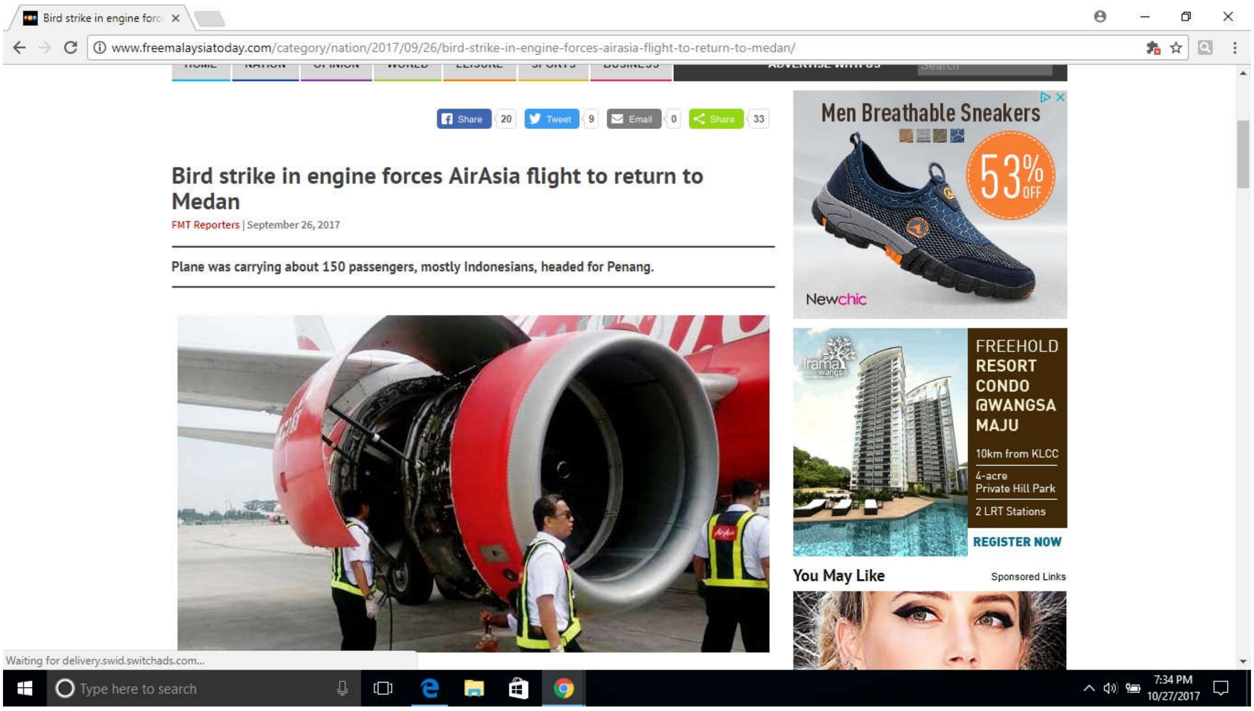
MATERIALS AND METHOD

Literature in the form of journal-articles, international-committee reports and news-media articles were reviewed with the aim of providing solutions to the problem, besides outlining salient recommendations.

RESULTS AND DISCUSSION

Bird-strike accidents in military aviation: In 1987, this author reported two cases of bird-strikes in the Royal Malaysian Air-force involving experienced Majors flying the A4 (F4) Skyhawk on low-level high-speed missions at separate times. Both flew their aircraft back to base without ejecting. In both cases, the bird hit the cockpit-canopy, shattering it, besides hitting them on their heads and necks - shattering their helmet-mounted visors also. One, being hit on his forehead, suffered a mild concussion, and then refused to fly anymore – grounding himself. The next was bleeding badly from cuts due to glass-pieces from the broken canopy and visor - some of which were also embedded in his neck requiring surgical-removal subsequently. Neubauer (1990) analyzed 22, 423 bird-strike data for the years 1974 – 1987. Data revealed a steady increase in reported strikes (Fig 2). When bird strikes were tallied by month, an obvious bimodal pattern appeared with peaks in May and October Fig 3. The bimodal pattern is generally attributable to bird migrations in spring and fall. Similar patterns were noted in the Netherlands, Canada, Russia and the UK – a third peak in the Netherlands, when young birds were learning to fly (Neubauer, 1990). Bird-migration is also observed in Malaysia, such as the Tiger Shrike wintering in the Malay Peninsula and Borneo from Eastern Siberia, Japan and Eastern China. Many different birds also migrate here, such as some storks and egrets – and, they typically follow the coast in their pathway. 71% of the bird-strike accidents happened during the day, and a much smaller 17% took place after dark. Only 5% happened during dusk and dawn, traditionally considered high-risk periods (time of day was unknown for 7%) (Neubauer, 1990). Burger (2001) reported that when a municipality-landfill was located close by, the percentages are 12% happenings at night, and about 20% at dawn, because garbage remaining from night-time land-filling would be an attractant (Richardson, 1994). Yet, these figures remain wanting for lack of total-flying hours (or total flights) broken down by daytime, night, dawn, dusk. Such denominators would allow true accident-rates to be calculated during daytime, dusk, dawn, and night, as a reflection of the actual risk of flying during these hours. Of the commoner aircraft in use, the A-10, an air-to-ground attack aircraft, had the highest strike percentage. The T-38, which is the US Air Force's (advanced) jet-trainer, was second Fig. 4. Tactical fighter-aircraft combined for a total of at least 37%, a sizeable proportion compared to bombers, or cargo aircraft. Besides the T-38, aircraft with missions at lower altitudes, such as the A-10, F-4 had additional strikes than the various different aircraft. Conversely, the traditionally high-altitude aircraft, such as the C-5, C141 have small percentages (Neubauer, 1990). The distribution of bird strikes by altitude revealed that 56% of the collisions happenedbelow 305 m (1,000 ft.) AGL (Above Ground Level) while far fewer strikes at 1% happened above 1219 m (4000 ft) Most military, and civilian, statistics reveal greater than 90% of strikes below 914 (3,000). Military-aircraft involved in air-to-ground attack or low-level mission spend most of the time below 1219 m (4000 ft). Altitude helps explain why over half the bird strikes happen during landing/take-off. In addition, 38.8% of bird-strikes to military aircraft happen at low speed. This fits in with both altitude and phase of flight, as most military aircraft have take-off/landing-speeds below 370 km/h (200 KIAS) (Neubauer 1990). The Wing/Propeller was most often hit, followed by the Fuselage, the Canopy/Wind-shield, and the Engine in such a order. The bird groups responsible for the largest number of accidents were gulls (22 cases), hawks (14), vultures (13), ducks (8), geese (4). These totals are in relation to the 83 accidents caused by collisions with known types of birds (Neubauer, 1990).Thus, very often the bird-type is not identified. Gulls were the most serious reported problem in Europe (Thorpe, 2003; Thorpe, 2008). It is generally accepted that airfields frequently attract birds for both feeding/roosting. This explains the disproportionate number of strikes around airfields. Bird strikes were tabulated by type of weather condition. The vast-majority, 61%, happened in clear weather, while few took place below, or in, cloud-layers (19%). Very few strikes happened while flying in the clouds (1%). Aircraft and birds both are active during good-weather. Both avoid clouds (Thorpe, 2003; Thorpe, 2008).

Serious bird-strike accidents: Richardson (1994) analyzed serious (meaning, incurring fatalities or aircraft written off) bird-strike accidents in ten militaries around the world. Serious bird-strike accidents involving military-aircraft have mostly been 1-engined fighter-, or attack-, aircraft (63%). Twin-engined fighter-, and attack-, aircraft accounted for l7% of the accidents, and 1- and 2-engined trainers accounted for 6% and 11%, respectively. Larger aircraft were rarely lost to bird-strikes. No records of serious-accidents involving cargo or tanker aircraft were found (Richardson, 1994). Impact-site also plays a role in bird strike fatalities/injuries. In this analysis, the windshield/canopy was the only impact-site significantly associated with fatal or disabling outcome. There are several possible ways to be killed/injured with a bird coming through the windshield at 556 –7741 km/h (300 – 400 knots) - there is enough force to hurt or kill the pilot directly. Secondly, a cockpit-strike anywhere can distract the pilot enough to cause fatal-error. Finally, the pilot may have to eject from critically-damaged aircraft and may be injured/killed in the process. By taking measures to protect the pilot from direct/indirect injury, we may be able to save aircraft-passengers from direct/indirect injury, and we may be able to save an aircraft that might if not be lost (Neubauer, 1990).

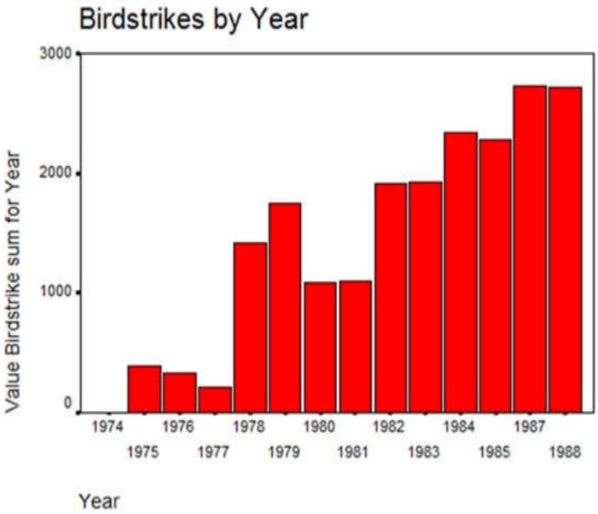


Bird strike in engine forces AirAsia flight to return to Medan

FMT Reporters | September 26, 2017

Plane was carrying about 150 passengers, mostly Indonesians, headed for Penang.

Fig. 1: Air Asia Flight Bird-strike Report in the Medan-sector



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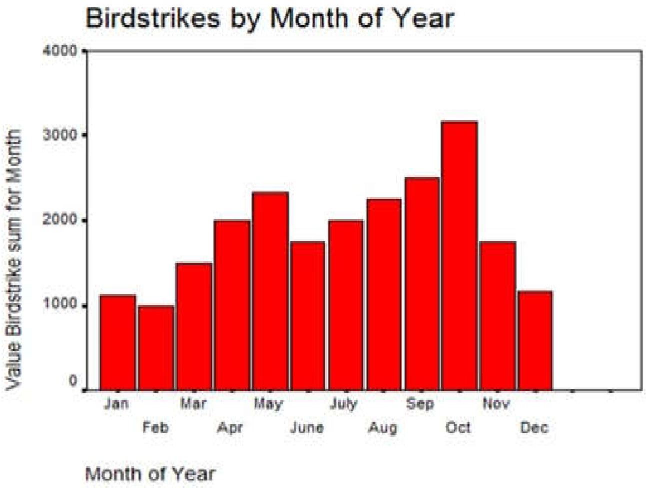

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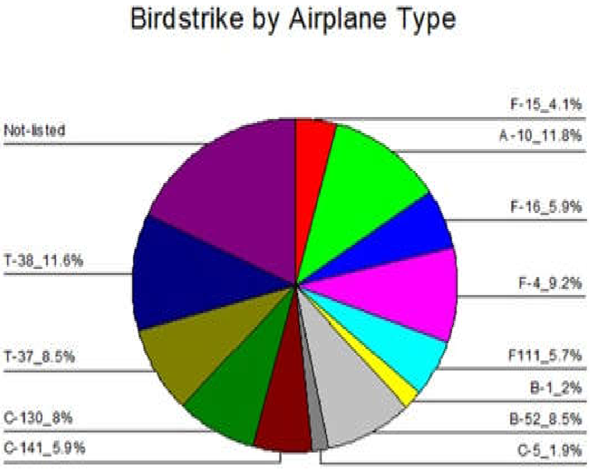

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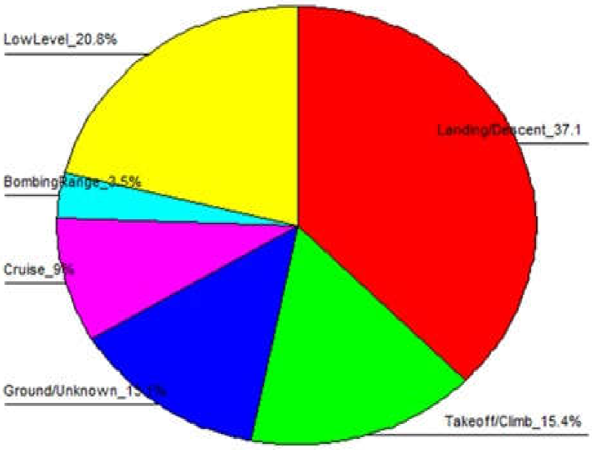

Fig. 5. Bird-strike accident by Speed

Also, as speed increases so does the likelihood of fatal-outcome (Neubauer, 1990).

Bird-strike experience in Civil Aviation: Details of all the fatalities due to bird-strikes and destroyed-aircraft from 1912 to 1995 show that each case of life-lost or destruction of the aircraft, divided into three sections (Thorpe, 2003; Thorpe, 2008):

Section 1: Transport aeroplanes over 5,700 kg (12,000 lbs), including air-liners and all business jets

Section 2: Aeroplanes weighing 5,700 kg and below

Section 3: Helicopters (Thorpe, 2003; Thorpe, 2008). Bird-strikes caused at least 42 fatal accidents and 231 deaths, besides the destruction of 80 civil aircraft (Thorpe, 2003; Thorpe, 2008).

Transport aircraft and executive jets: There were 15 fatal accidents and 188 deaths, besides 41 write-offs. Unexpectedly, only one fatal accident has happened to a jet-powered airliner in over a 1000 million flying-hours. This may partly be due to increased awareness of the problem, airport-measures implemented globally, and tougher air-worthiness requirements. Engine-damage caused 77% of the accidents in this group, followed by windshield-penetration at 10%. Gulls accounted for most of the strikes at 42% of those identified. Engine-ingestion is the major threat (nearly 80% of accidents) to air-liners and executive-jets. There have been many cases of multiple-engine damage – but luckily, enough runway length has allowed take-off to be abandoned, or the airplanes have had sufficient power to return.

Twenty cases per year continue to happen to European air-lines where more than one engine ingests bird – putting the aircraft in an emergency (Thorpe, 2003; Thorpe, 2008). Business-jets comprised 37% of accidents in this section. Such frequently operate out of aerodromes with little, or nothing, in the way of bird-control measures. In many cases, their engines are of an age which pre-dates bird-ingestion testing (Thorpe, 2003; Thorpe, 2008).

Aeroplanes weighing 5,700 kg and less: There were 31 fatal accidents and 61 deaths, besides 53 write-offs. Twenty-seven of the fatal-accidents were in general aviation. These aircraft do not require bird-strike-proof design. Such are thus additionally vulnerable - particularly to windshield-penetration which happens in 52% of bird-strikes. The windshield may be broken by a bird as tiny as a Swift, weighing 40 grams (Thorpe, 2003; Thorpe, 2008). The birds-struck are quite different from those which hit transport-sized aircraft. The main threat is birds-of-prey (Thorpe, 2003; Thorpe, 2008). In six of the general-aviation accidents, the pilot attempted to avoid by taking evasive-action – thus, losing control or colliding with ground objects (Thorpe, 2003; Thorpe, 2008).

Helicopters: There were 6 fatal accidents and 10 deaths, besides 8 helicopters destroyed. This total is quite low, considering most helicopters fly at heights where birds usually fly. Maybe, the relatively slow cruising-speed together with rotor-noise, act as sufficient warning to birds (Thorpe, 2003; Thorpe, 2008). The coming of faster, quieter helicopters could result in future problems.

Methods of Prevention

The German Air Force (Luftwaffe) Method: Prevention in military aviation and civil aviation are quite similar except that the German Air-Force (Luftwaffe) developed for military aviation in Europe a system of long-range and short-range radar surveillance, Notams (Air Traffic Control notification to airmen), and control at air-bases (Wilhem Rulhe, 2008).Such Notams are termed BIRDTAMS which consist of warnings, and flight- restrictions, by area. Bird-strikes dropped dramatically due to the BIRDTAM warning-system, and reduction of low-level operations (Wilhem Rulhe, 2008).In the German Air Force (GAF), the basis for bird-strike prevention is mandatory-reporting, data-collection, analysisand documentation which are scientific (Wilhem Rulhe, 2008; Dekker *et al.,* 2005; Diamond, 2008). Procedures are standardized, and computerized. Feather-remains are identified by comparing with a feather-collection, besides microscopic-analysis (Diamond, 2008).A comprehensive statistical analysis of all the bird-strike incidents is conducted annually for the preceding 12 months (Wilhem Rulhe, 2008).

Measures used to actively manage/control areas on and around airfields: Ecological-strategies prove to be most effective in the long-run. Regular monitoring programs provide management instructions for a specific habitat.The field-work does a synopsis and mapping (supported by aerial-photography) of the different field-observations, e.g. bird-counts, habitat-structures, aquatic-situation, vegetation-cover, nutrients and food-availability (Wilhem Rulhe, 2008).

Basic ecological bird-strike prevention measures include (Wilhem Rulhe, 2008):

- Agriculture not allowed on airfields
- Hydrological mitigation (removal of lakes and ponds, drainage)
- Grazing of sheep or cattle not allowed
- Dumping of organic material (waste) not allowed
- Hunting of predators (foxes, martin, weasel) not allowed
- Long grass management on airfields (max. 2 cuts after migration periods)

Additional to active-surveillance and hazard-control on and around the airfield, there are passive-methods to monitor bird-activity in different spatial-scales to obtain data for use by air-staff and flight-operations units (Wilhem Rulhe, 2008). Within a scale of approximately 5 km., the techniques that are used are based on observations by human-eyes, small mobile-radar (horizontal and vertical), and video/infrared camera-systems, combined with laser distance- and elevation-measurements. The goal is to set up a widely-automated sensor-based local bird-activity observation, and a warning-system, that focuses on problem-areas which passes data online to bird-control personnel, and the airbase control-tower (Wilhem Rulhe, 2008). Bird-concentrations, relevant to flight-safety in the approach- and departure-area, is detected by Airport Surveillance Radar (ASR) systems, up to approximately 15 – 20 km. The effort aims at providing updated bird-status data for each airfield-environment, and at developing clear-regulations for flight-operations such that severe bird-strike risk-situations during approach/landing and take-off/climb are avoided (Wilhem Rulhe, 2008). Country-wide bird-migration intensities is monitored by a network of long-range air-defense radar-systems - each radar-sensor having a 150-km detection-range for large bird-flocks. Although with the primary-task of detecting unfriendly aircraft, there is enough valuable information that can be extracted and interpreted by experts to alert military and civilian air-traffic to bird-migration in dangerous intensities over central Europe. Bird-warnings are communicated directly to the cockpits of aircraft in affected areas on a high priority frequency. Whenever high-intensities of bird-migration is noted a message is formed and transferred to a central processing/server unit to automatically create and immediately transmit a bird-strike warning (WilhemRulhe, 2008). Warning-areas in BIRDTAM are geographically exact. A BIRDTAM is limited in time - up to 4 hours at a maximum but can be up-dated and/or extended whenever there is newer data (WilhemRulhe, 2008).

Control in and around military airfields and civil airports: Airports are large, open areas. Thus, products and techniques that are effective over large areas are best. Birds must be completely kept off the airfield - moving birds to a different part of the airfield is not a solution. Airports may require year-round control-measures – and, sometimes round-the-clock (Harris, 1998). Thus, bird-control at airports requires techniques that achieve long-term results in the airfield and environs - but short-term effectiveness is sometimes required. Sometimes, nocturnal-control is necessary. And where over-flights of birds from outside are a problem, a control-program beyond the airport is required (Harris, 1998). The foundation of any successful airport bird-control program is habitat-control — making the airfield not so attractive to birds (or at least the most problematic species) addresses the basic problem. Trying to clear a whole airfield of birds, primarily with active-control measures is difficult (Harris, 1998). Birds are quite adaptable. These can and do become adapted to any control-method used over the long term.

Thus, the best control-programs employ a variety of products and techniques (Harris, 1998) Management-commitment is ultimately the driving force deciding the success of an airport bird-control program. This is reflected in trained and motivated field-staff together with an adequate supply of appropriate and well-maintained control-products (Harris, 1998). Allan J (2006) presents a technique that uses both national and airport-specific data to evaluate risk by creating a simple probability-times-severity matrix. It uses the frequency of strikes reported for different bird-species at a given airport over the preceding five years as a measure of strike-probability, and the proportion of strikes with each species that result in damage to aircraft, in the national bird-strike database, as a measure of likely severity. Action-thresholds for risk-levels for particular bird-species are then defined, above which the airport should take action to reduce the risk further. The assessment is designed for airports where the reporting and collation of bird-strike events is reasonably consistent over time and where a bird-hazard management-program of some sort presently exists. The protocol allows managers to focus bird-control resources on the species causing the greatest risk, hence maximizing the return-on-investment.

It is now being successfully used at major airports in the United Kingdom and elsewhere in the world (Allan, 2006). Because the incidence of these events is influenced by land-uses in the surroundings of airports, such airports located in the same region might have different trends for bird-strike risk, due to differences in the surrounding habitats. Coccon F et al (2016) developed a quantitative tool that assesses the risk of bird-strike based on the habitats within a 13-km buffer from the airport. Theresearchersdeveloped Generalized Linear Models (GLMs), with binomial distribution, to estimate the contribution of habitats to wildlife use of the study area, depending on season. These GLM-predictions were combined to the flight-altitude of birds within the 13-km buffer, the airport traffic-pattern and the severity-indices associated with impacts (Coccon *et al.,* 2015). The researchers highlighted the key-role of distance of land-uses from the airport on the probability of the presence of birds was highlighted. The reliability of developed risk-index significantly correlate with bird-strike rate. The researchers emphasized the importance of the territory near airports and the wildlife-use of its habitats, as factors in need of consideration for bird-strike risk-assessment procedures. Data and news on the contribution of habitats in attracting birds, depending on season, can be used by airport-managers and local-authorities to plan specific-interventions in the study-area towards lowering the risk (Coccon *et al.,* 2015).

Additional methods

Birds adapt to shots- especially species that are not widely hunted. Brown KM et al. (2001) argue that the Jamaica Bay Wildlife Refuge laughing-gull colonies which had sharply increased in population causing a parallel increase in bird-strikes, should not be managed on-colony at least until all on-airport management possibilities (alternatives) have been properly implemented and demonstrated to be ineffective at reducing bird-strikes, including habitat-modifications and increasing the capability of the bird-control unit to eliminate bird-flocks on-airport using nonlethal bird-dispersal techniques. Given the reasons that the gull-shooting program may be resulting in a non-sustainable regional population of laughing gulls (>30% decline), the authors also recommend that attempts be made to initiate an experimental colony elsewhere on Long Island to determine if colony relocation is a feasible management possibility (option) (Brown *et al.,* 2001). Non-lethal bird-control methods are: habitat-modification (limiting food, water, and shelter), exclusion (with netting, porcupine-wire, sticky-repellents, etc.), pyrotechnics and trapping (Harris, 1998).

Pyrotechnics include a wide variety of noise-making shells fired from shotguns, starter pistols, and flare pistols and are very much used at airports (Harris, 1998).

The results are relatively short-term, because most birds are deterred from returning for a few hours to a few days only (Draulans 1987). Regarding habitat-modification, birds are attracted to airports for food (e.g., earthworms, grasshoppers, and seeds), water, and shelter. Besides, airports provide suitable nesting-habitat for overnight-roosting. Erections (features) that are nearby, or even at some distance from airfields, could cause different bird-hazards to aircraft-safety at each airport (Harris, 1998; Coccon *et al.,* 2015). Habitat-modification is the removal and/or modifications of habitat-features. Certain techniques are used against nesting and resting sites provided by airport-buildings – and, the removal of perching sites on airfields. Airports need to have short-grass immediately adjacent to runways so that signs and lights are visible. But, many airfields also have areas of short-grass away from runways. These grassy areas should be allowed to grow taller to reduce the use of theseby many bird species - especially some particularly hazardous to aircraft-safety (e.g., gulls) (Harris, 1998; Morgenroth, 2005). Tall-vegetation impedes certain birds' access to food-sources (e.g., soil invertebrates). And, it obstructs the birds' lines of sight to approaching predators (Morgenroth, 2005). Most birds spend a substantial proportion of each day resting, preening, and sleeping. This behavior is called loafing. The attractiveness of loafing-habitats can be minimized by removing standing-water and re-vegetating barren-areas. Nesting and roosting on a building, tree, statue or such must be eliminated.

Holes: Closing of holes in buildings can solve many bird-problems in a very simple manner.

Nest-cleanup: Birds can nest deep in dryer-vent airflow-lines, or such openings, up to a depth of 15 feet. The technique is to clean out the nests, and then clean the vent, closing off any openings. There are five different types of bird repellents: (1) tactile (touch), (2) sound, (3) odor (4) behavioural, and (5) visual. The tactile repellents are the most practical/effective. There are two types: Mechanical and chemical**.**

Plastic curtains, or nets, need to be installed on any door that is open all day. Birds can enter a building wherever there is a 1" or greater gap.Vision-based deterrents present a visual-stimulus that is novel, startling, or that birds associate with danger. Lights, scarecrows, dyes, reflecting-tape, predator-decoys, kites, balloons, smoke, and dead or live-birds are visual-stimuli that may disperse birds. Some products incorporate both visual and auditory-stimuli (Harris, 1998). Trained falcons and hawks are used by professional-falconers to chase birds from specific areas by pursuing and occasionally killing them. Most birds have evolved well-developed escape-behaviors that are triggered by the sight of those species of falcons and hawks that could prey on them (Harris, 1998).

Model-aircraft imitating falcons and hawks can be used to chase birds out of specific areas (Harris, 1998). Chemicals which reduce bird-populations at airfields by reducing the population of earthworms can be used (Harris, 1998). Lure areas (sanctuaries) can be established as a means of attracting and holding birds so that they will not move to areas where they are undesirable (Sugden 1976). The most efficient attractant would be food, although here water may also work. The lure-crops are usually the preferred food of the species involved. The lure area should ideally intercept the birds at the lure area, well prior to these approaching the airport.

Wailers, overhead wires and lines, foam and bird-balls, surfactants and water-sprays besides laser can be used (Briot, 2015).

Conclusion

Bird-strike aircraft-accidents cost too much morbidity, mortality and financial cost in aviation. But, bird-strikes can be prevented. Injuries and deaths may be prevented even after such bird-strikes.

Recommendations

- Construction-work digging could churn up invertebrate food that attract birds to the vicinity which needs consideration.Also, the bringing in of earth could make available grass-seeds for birds to feed on.
- Pilots must be made to attend CRM (Cockpit resource-management) training emphasizing emergency-handling of bird-stricken flight. They must be made to accumulate sufficient hours of simulator-training of flight simulating window-penetration.
- Where possible in design, engine air-intake must be screened off. A metal-screen, detachable for inspection/servicing purposes could be suitable.
- Aircraft, particularly in general aviation, must avoid cruising at altitude below 4000 ft AGL. Most part of approach to land must not be less than 5000 ft AGL. In case must, then speed must not be greater than 250 (Knots Indicated Air Speed) KIAS.
- The wearing of helmets containing helmet-mounted visors, placed down, by commercial pilots/general aviation pilots commencing the start of approach, and also till the end of take-off, would offer vital protection of pilots in case of windshield penetration.
- Maintaining flexibility of the windshield, allows for deflection of the striking bird, rather than penetration. Certain aircraft allow for heating of windshields that makes the windshield more flexible. Such heating is advisable during increased risk perceived.
- The German Air Force BIRDTAM method must be applied to Civil Aviation, where it is applicable and not yet in place.

Funding: This Research has not sought or received Funding from any Source whatsoever.

Conflict of Interest: The Author has no Conflict of Interest in writing this Article.

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