

Soaring with Eagles: Birdstrike Analysis in the Design and Operation of New Airplanes

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ABSTRACT

We live in an era of increasing twin-engine commercial airplane operations, with large and very quiet high bypass ratio engines. At the same time, due to several decades of increased attention to the environment, we have large and increasing hazardous species bird populations. These trends, when combined, are not a prescription for continued assurance of a remarkable and enviable safety record for commercial aviation. Therefore, greater diligence must be placed on the evaluation of the current and future aviation wildlife hazard. We have some new weapons in this fight for greater capability to live with this situation. The basic problem is that different databases are populated independently from one another and often contain conflicting, contradictory, and erroneous data.

Databases that were used individually, but not necessarily combined, are being utilized in a conjoined methodology to give us a better picture of the actual risk involved. And new analytical techniques are being applied that will enable us to better visualize and evaluate the nature of the wildlife threat. This paper will attempt to dispel some of the myths and misconceptions about bird behavior and bird strike capability and to shed light on new and improved approaches to maintaining safer skies for the commercial aviation passenger.

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INTRODUCTION

Long before man began to fly, the skies were already occupied by a large population of other creatures plying the skies - birds. What are these creatures and why do we need to understand their presence and behavior? They are important to us because they are a minefield in the sky in the path of our families, friends and fellow travelers who use the commercial aviation system to get from here to there.

There are about 200 to 400 billion birds on earth. They have existed since the age of the dinosaurs. In fact, most scientists think they are the direct descendants of dinosaurs. From an aviation standpoint, they represent a problem because they occupy the portions of the same airspace in which we operate. They mostly exist in the space from 0-5,000 feet, although a few species of birds routinely fly at high altitude, including Bar-headed geese (*Anser indicus*) documented at heights of 21,00 feet (6,400 meters) during their annual spring migration from India to Mongolia over the Himalaya-the world's tallest mountain range [1]. A birdstrike with a vulture, Ruppell's Griffon (*Gyps rueppellii*), has been documented at 37,000 feet [2].

There are many misconceptions about birds. They don't fly at night - they do. They don't fly in the cloud or fog - they do. They are limited to a few hundred feet off the ground - they aren't.

CONSERVATION & THE INCREASED THREAT

Since the advent of the commercial jet age in 1959, there has been an increased awareness of the hazard associated with birdstrike. However, coincident with the advance in aviation there was an increased emphasis on the environment, with the 1962 book *Silent Spring* by Rachel Carson widely credited with helping launch the contemporary American environmental movement. This era spawned significant new and amended federal legislation such as the National Environmental Policy Act (1969), the Clean Air Act (1970), the Clean Water Act (1972), the Endangered Species Act (1973), all supplementing an existing regulation, the Migratory Bird Treaty Act (1918). This led to wildlife conservation and management efforts. Banning of the organochloride insecticide DDT for agricultural use played a

major factor in restoring the Bald eagle (*Haliaeetus leucocephalus*) population from near-extinction as were similar efforts to recover the Canada goose (*Branta canadensis*) population. The populations of these two species have recovered from near extinction and have grown dramatically over the last forty years. Eighty-nine wildlife species with more than 25 reported strikes have been ranked by hazard level [3]. Both the Canada goose and Bald eagle are ranked in the top 10 “extremely hazardous” by percentage of strikes causing damage. Unfortunately, both of these birds weigh significantly more than the 4 pound weight that airplanes are designed to withstand, as required by U.S. Federal Aviation Regulations. Bird population increases have been reported by multiple authors and organizations ([4,5], Eurocontrol SKYbrary portal).

INCREASING POPULATIONS OF HAZARDOUS SPECIES

Due to their large physical size (length 75-110cm, 30-43in and wingspan 127-185cm, 50-73in), mass (3.2-6.5kg, 7.1-14lb), population count and flocking behavior, Canada geese are a particularly hazardous species to aviation. A collision with Canada geese resulted in the well-known “Miracle in the Hudson” ditching of a twin engine transport airplane in 2009, fortunately without fatalities [6]. The Canada goose population in North America for the period 1970-2010 is depicted in Figure 1 [7]. While the population of resident geese had a large increase in the 1980s and 1990s, there is evidence of a stable count for the last ten years resulting from population management efforts.

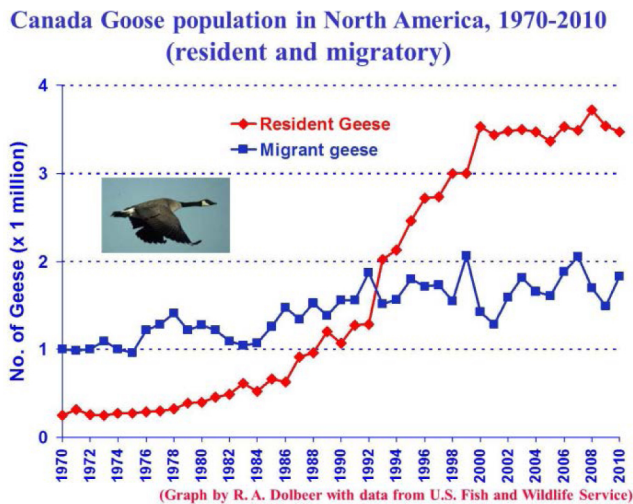


Figure 1. Canada goose population in North America 1970-2010 [7]

Figure 2 depicts the distribution of Canada goose strikes to transport category airplanes by state and airport in the contiguous US. The size of the circles is a measure of the number of strikes at various airports, and the color of the state together with the numerical value represents the number of strikes in the period 1990-2011. Canada goose strikes have been reported in virtually every state of the contiguous US.

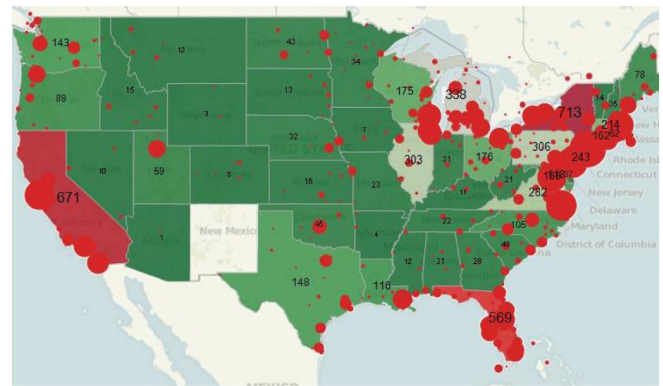


Figure 2. Distribution of Canada goose strikes by state and airport, 1990-2011.

Similarly, the population of Bald eagles has increased, however it is considerably less than the Canada goose population. Nonetheless Bald eagle strikes are spread across the contiguous US states with an increasing trend, Figure 3.

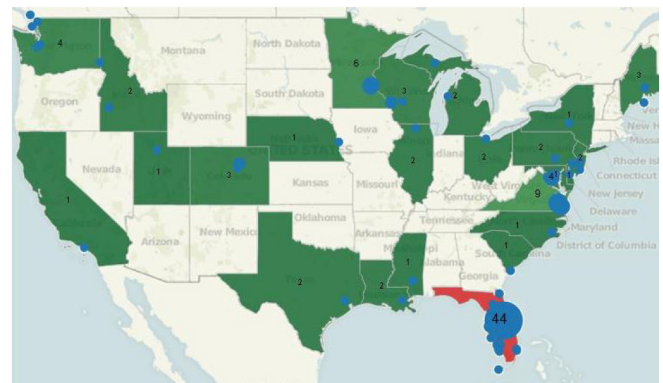


Figure 3. Bald eagle strikes with transport airplanes 1990-2011.

The population of another hazardous bird species, the American white pelican (*Pelecanus erythrorhynchos*), has increased six-fold (Figure 4). A turbine powered airplane encounter with this species resulted in an accident with five fatalities [8]

Breeding population of white pelicans has increased over 6 fold in North America, 1990-2010

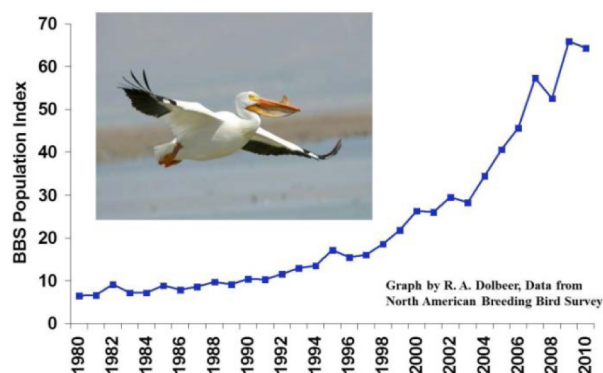


Figure 4. American White Pelican Population 1990-2010 [7].

THE PHYSICS OF A BIRD STRIKE

Birds evolved for flight and consequently do not weigh much. Even large birds seldom exceed 12 pounds in weight. However, impact force is measured as the product of the weight and the square of the velocity. And commercial jet transport aircraft travel very fast. Aircraft are designed to withstand the impact of a 4 pound bird at the cruise speed of the aircraft. The number varies, but we will use 350 kts as a representative value of cruise speed. When you calculate the impact of a 4 pound bird at the cruise speed of the aircraft, the force generated can be 40,000 ft lbs. To understand this value, let us compare it to a bullet. A 30-06 rifle bullet generates a force of 3,000 ft lbs at the muzzle. According to Bird Strike Committee USA, a 12-pound Canada goose striking an aircraft going 150 mph at lift-off generates the force of a 1,000-pound weight dropped from a height of 10 feet. Similar kinetic energy based approaches to bird strikes and aircraft damage have been applied [5,8]. The ICAO Rules of the Air restrict operational indicated airspeed to 250 knots below 10,000 feet above mean sea level, in certain classes of airspace depending on applicable flight rules, which serves to ensure that even a strike by a Canada goose would be only marginally above the certification KE value [8]. Where accidents have occurred, they have usually been associated with high energy impacts - heavy birds (greater than 4 lb/1.8 kg) encountered at relatively high speed, resulting in kinetic energies of impact higher than certification values. The FAA National Wildlife Strike Database (NWSDB) contains fields for indicated air speed (IAS), height above ground level (AGL) and species for many bird strikes. Given IAS and height AGL, and the aircraft geographic location, the true air speed V_{TAS} and pressure altitude H_p can be derived, and bird mass M obtained from a separate species table. This enables calculation of kinetic energy (KE), using the equation:

$$KE = \frac{1}{2} M V_{TAS}^2$$

Kinetic energy may be visualized as a scatterplot of strikes in the flight envelope [9]. Figure 5 shows aircraft true air speed (TAS) plotted along the x-axis and aircraft pressure altitude (H_p) along the y-axis. Each individual point represents a single wildlife strike. By using the calculated kinetic energy field for size, the highest energy strikes become visually apparent. In this representation, larger circles represent more kinetic energy involved in the strike. Additionally, color is used to encode bird species. Figure 5 shows damaging bird strikes to aircraft in North America for the period 1990-2011, with 15 species in the 4-8 lb. weight range, particularly hazardous species include the Black vulture (*Coragyps atratus*), Snow goose (*Chen caerulescens*), and Turkey vulture (*Cathartes aura*). Transport category airplanes are required to withstand a strike by a 4-lb bird at cruise speed, with an additional requirement of 8-lb for a strike to the empennage in the US. Airplane damage is strongly correlated to kinetic energy.

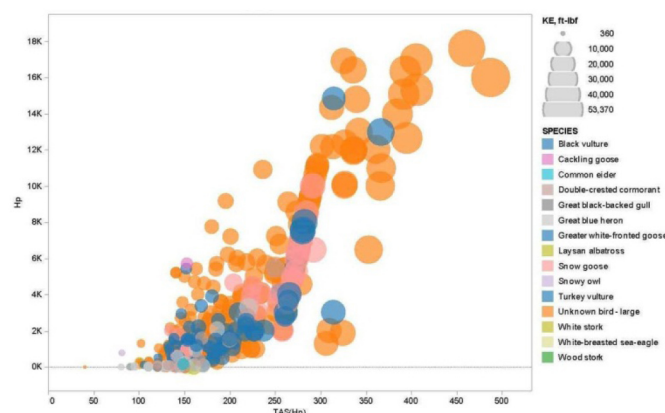


Figure 5. Kinetic energy of bird strikes in the weight range 4-8lb.

Figure 6 depicts damaging strikes for birds with weight range 8-12lb, and shows the four most frequently struck species (Bald eagle, Brown pelican, Canada goose & Sandhill crane), with the Canada goose posing a very hazardous species for North America.

Airplane collisions with Canada geese often result in damage. Figure 7 illustrates Canada goose strikes in the period 2000-2011 for North America, with red indicating damage, and green indicating no damage. The ratio of strikes with damage to all strikes is decreasing, an indicator of effectiveness of goose management in the airport environment over that period.