Trends in reporting of wildlife strikes with civil aircraft and in identification of species struck under a primarily voluntary reporting system, 1990-2013

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Trends in reporting of wildlife strikes with civil aircraft and in identification of species struck under a primarily voluntary reporting system, 1990-2013

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Executive Summary

Reporting of wildlife strikes with civil aircraft is voluntary for airports and pilots but strongly encouraged by the FAA via Advisory Circulars and other activities. In 2009, the FAA undertook a review of the trends in strike reporting from 1990-2008 to determine if mandatory reporting was needed, as was recommended by the National Transportation Safety Board in 2009. The review concluded that given the positive trends in reporting rates and species identification coupled with the decline or stabilization in damage strikes, mandatory reporting was not recommended at that time (2009) to achieve the objectives of the database. Recommendations were made to further enhance the reporting of strikes. The objective of this report is to determine if the positive trends in reporting documented in 2009 have been sustained based on the recommended outreach actions and if any changes are needed in FAA policies regarding strike reporting at this time. The primary focus is to examine strike reporting for the past 5 years (2009-2013) compared to the previous 5 years (2004-2008). Although this report covers both commercial and general aviation aircraft at Part 139-certificated and non-certificated airports as was done in the 2009 study, the focus of this report is strike reporting for commercial aircraft at Part 139 airports.

I examined the overall number of strikes and damage strikes reported to the FAA by wildlife type (birds, mammals, reptiles) and by airport type (14 CFR Part 139 certificated airports, non-certificated General Aviation [GA] airports in the National Plan of Integrated Airport System [NPIAS], and other GA airports). To derive estimates of the percentage of strikes being reported to the NWSD by commercial aircraft and by all civil aircraft (commercial and general aviation) at Part 139 airports nationwide, I compared strike reporting rates at 20 selected Part 139 airports that have well established wildlife hazard management programs that emphasize the reporting of all known strikes with strike reporting rates at other Part 139 airports. As another means of gauging the number of known bird strikes that are not being reported to the NWSD, I examined bird strike reports submitted independent of the NWSD through the Air Traffic Organization (ATO) Mandatory Occurrence Reporting (MOR) system. Another objective was to document the number of strike events that are being reported independently by multiple sources to determine if the breadth of reporting by the aviation community is increasing. I also documented trends in the percent of strikes reported to the FAA that provide an identification of the birds struck to species. Finally, I documented actions that the FAA has undertaken since 2009 to promote the reporting of strikes.

The overall number of reported strikes for all aircraft and airport types has increased 6.2 fold from 1,851 in 1990 to a record 11,399 in 2013. In contrast, the number of strikes indicating damage to the aircraft increased from 340 in 1990 to a peak of 764 in 2000 but has subsequently declined by 21% to 605 in 2013. The percent of reported strikes indicating damage ranged from 15% to 19% from 1990-1998 but has subsequently steadily declined to 5% in 2013.

Reported strikes for all aircraft types at Part 139 airports and NPIAS GA airports increased by 43% and 61%, respectively, in 2009-2013 compared to 2004-2008. In contrast, damage strikes declined by 2% at Part 139 airports and increased by only 5% at NPIAS GA airports. In addition to the slight decline in damage strikes reported at Part 139 airports, the mean number of wildlife-induced aborted take-offs and precautionary landings declined by 16% and 9%, respectively.

Commercial aircraft movements (take-off or landing) at Part 139 airports declined by 13% from 2004-2008 to 2009-2013. Thus, whereas, the number of reported strikes for commercial aircraft at Part 139 airports increased by 46% from 2004-2008 to 2009-2013, the strike rate (strikes/100,000 movements) increased by 67%. The number of damage strikes declined by 2% and the damage strike rate increased by 12% (note: these numbers refer to strikes with commercial aircraft only and not to strikes with all aircraft types at Part 139 airports as discussed in previous paragraph).

GA aircraft movements at NPIAS GA airports declined by 8% in 2009-2013 compared to 2004-2008. Thus, whereas the number of reported strikes with GA aircraft increased by 43% from 2004-2008 to 2009-2013, the strike rate increased by 55%. The number of damage strikes to GA aircraft at NPIAS GA airports increased by 13% and the damage strike rate increased 23% (note: these numbers refer to strikes with GA aircraft only and not to strikes with all aircraft at NPIAS GA airports as discussed 2 paragraphs above).

Based on a comparison of strike rates at 20 selected Part 139 airports with strike rates at 484 other Part 139 airports, reporting of known strikes for commercial aircraft increased from an estimated 78% to 91% and damage strike reporting increased from an estimated 76% to 93%, 2004-2008 to 2009-2013. Reporting of known strikes for all civil aviation (commercial and general aviation aircraft) increased from an estimated 42% to 47% and damage strike reporting increased from an estimated 50% to 59%, 2004-2008 to 2009-2013. An analysis of strike data from the ATO MOR system supported the findings on percent of known strikes reported for commercial aviation. The MOR system added only about 7% more strikes and 4% more damage strikes (all minor) to the NWSD.

The number of strike events with multiple reports submitted from independent sources has increased even more dramatically than the number of strike reports. Whereas the number of strike events reported in 2009-2013 increased by 42% compared to 2004-2008, the number of individual strike reports examined increased by 60%. This finding highlights the increased participation by the aviation community as a whole to ensure that strike events are reported to the NWSD.

The mean number of strikes in which the bird was identified to species increased by 103% from 2,619/year in 2004-2008 to 5,324/year in 2009-2013. The percentage of all bird strikes in which the species was identified increased from a mean of 37% in 2004-2008 to 53% in 2009-2013 (a record 60% in 2013).

The various actions undertaken by the FAA, in partnership with other government and aviation industry groups from 2009 to 2013, have enhanced the quantity and quality of reporting of wildlife strikes involving civil aircraft under a voluntary system. Of significant note is the inclusion of statements in revised Advisory Circulars to emphasize a commitment to reporting all known strikes. These statements provide clear guidance that strike reporting is a critical component of every Wildlife Hazard Management Plan (WHMP) which, when approved, is a part of each Part 139 airport's certification manual.

Another significant development was FAA Order JO 7210.632 (effective 30 Jan 2012) which requires ATO personnel to report all bird strikes of which they become aware. These reports are entered in the MOR system and, as of January 2014, are being integrated into the NWSD if they provide new information.

Also, the open accessibility of the NWSD to the aviation industry and general public for information and analysis, the availability of on-line customized "Airport Wildlife Strike Summary and Risk Analysis Reports" for each Part 139 airport, and enhancements in on-line reporting have all contributed to a greater public and industry awareness of the usefulness of the database and to the importance of strike reporting.

Given the strong, positive trends in reporting rates (an estimated 91% of strikes with commercial aircraft at Part 139 airports are now reported) and species identification coupled with the decline or stabilization in damage strikes, mandatory reporting other than what is already required under ATO Order JO 7210.632 is not recommended at this time to achieve the objectives of the database. I conclude the reporting procedures in place are fully compliant with the International Civil Aviation Organization standard regarding the establishment of a national procedure for recording and reporting wildlife strikes. The level of reporting is adequate to track national trends in wildlife strikes, determine the hazard level of wildlife species that are being struck, and to provide a scientific foundation for FAA policies and guidance regarding the mitigation of risk from wildlife strikes with civil aircraft. The NWSD also provides a means for Part 139 airports to monitor and evaluate the effectiveness of their WHMPs through "Airport Wildlife Strike Summary and Risk Analysis Reports" that are generated annually.

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1. INTRODUCTION

Bird and other wildlife strikes have become a serious aviation safety issue as demonstrated by the emergency forced landing of an Airbus 320 with 155 passengers and crew in the Hudson River in January 2009 after Canada geese were ingested in both engines (National Transportation Safety Board 2010, Marra et al. 2009). Two factors that have contributed to this threat in the USA, as documented by Dolbeer et al. (2014*a*), are:

1. Most populations of large bird and mammal species commonly involved in strikes have increased markedly in the last few decades in North America and adapted to living in urban environments, including airports, and
2. Commercial air carriers have replaced their older three or four-engine aircraft fleets with more efficient and quieter, two-engine aircraft which, in the event of a multiple ingestion event (e.g., the Hudson River incident cited above), may have vulnerabilities not shared by their three or four engine-equipped counterparts. In addition, previous research has indicated that birds are less able to detect and avoid modern jet aircraft with quieter turbofan engines.

The Federal Aviation Administration (FAA) has initiated several programs to address this important safety issue. Among the various programs is a national procedure for recording and reporting wildlife strikes in compliance with International Civil Aviation Organization (ICAO) standards for airports (ICAO 2013). The FAA began collecting wildlife strike data nationally in

1965[1]. However, except for cursory examinations of the strike reports to determine general trends, the data were never submitted to rigorous analysis until the 1990s. In 1995, the FAA, through an interagency agreement with the USDA, Wildlife Services (USDA/WS), initiated a project to obtain more objective estimates of the magnitude and nature of the national wildlife strike problem for civil aviation. This project involves having specialists from the USDA/WS: (1) edit all strike reports (FAA Form 5200-7, Bird/Other Wildlife Strike Report) received by the FAA since 1990 to ensure consistent, error-free data; (2) enter all edited strike reports in the FAA National Wildlife Strike Database (NWSD); (3) supplement strikes reported on Form 5200-7 with additional, non-duplicated strike reports from other sources; (4) provide the FAA with an updated computer file each month containing all edited strike reports; and (5) assist the FAA with the production of annual and special reports summarizing the results of analyses of the data from the NWSD. Such analyses are critical to determining the economic cost of wildlife strikes, the magnitude of safety issues, and most important, the nature of the problems (e.g., wildlife species involved, types of damage, height and phase of flight during which strikes occur, and seasonal patterns). The information obtained from these analyses provides the foundation for FAA national policies and guidance and for refinements in the development and implementation of integrated research and management efforts to reduce wildlife strikes. Data on the number of strikes causing damage to aircraft or other adverse effects (e.g., aborted take-off) also provide a benchmark for individual airports to evaluate and improve their Wildlife Hazard Management Plans (WHMP) in the context of a Safety Management System (Dolbeer and Begier 2012).

The first annual report on wildlife strikes to civil aircraft in the USA was completed in 1995 (Dolbeer et al. 1995) and has been followed by 19 annual reports including the latest report covering the years 1990-2013 (Dolbeer et al 2014*a*). Current and historic annual reports are accessible as PDF files at: http://www.faa.gov/airports/airport_safety/wildlife/

2. BACKGROUND AND OBJECTIVES OF THIS REPORT

Reporting of wildlife strikes with civil aircraft is voluntary for airports and pilots[2] but strongly encouraged by the FAA (Advisory Circular 150/5200-32A: Reporting wildlife aircraft strikes [22 December 2004]) updated as AC 150/5200-32B [May 2013]). In 2009, the National Transportation Safety Board (NTSB) issued Safety Recommendation A-09-75 to require all 14 *Code of Federal Regulations* (CFR) Part 139 airports and 14 CFR Part 121, Part 135, and Part 91 Subpart K aircraft operators to report all wildlife strikes, including, if possible, species identification, to the FAA NWSD. NTSB issued this recommendation to the FAA as a result of their investigation of a March 4, 2008, accident in which a Cessna 500 entered a steep descent and crashed after colliding in flight with a flock of large birds (American white pelicans) about 2 minutes after takeoff from Wiley Post Airport, Oklahoma City, Oklahoma.

In 2009, following the forced landing of Flight 1549 in the Hudson, River and the NTSB Safety Recommendation A-09-75, the FAA undertook a review of the trends in strike reporting from 1990-2008 to determine if mandatory reporting was needed (Dolbeer 2009*a*,*b*). The review concluded that given the positive trends in reporting rates and species identification coupled with the decline or stabilization in damage strikes, mandatory reporting was not recommended at that

[1] Advisory Circular 150/5200-2 *Bird Strike Incident Report Form* (27 Nov 1965) provided the first strike reporting form: FAA Form 3830 Bird Strike/Incident Report (10-65).

[2] Under FAA Order JO 7210.632, (effective 30 Jan 2012), Air Traffic Organization personnel are required to report all bird strikes of which they become aware.

time to achieve the objectives of the database. Based on the statistical trends measured in the study, the database appeared to be adequate for defining the overall national problem, identifying the species posing the greatest and least hazards, and measuring national and regional trends in strikes. Thus, the FAA opted to comply with Safety Recommendation A-09-75 by 1) enhanced promotion of the voluntary reporting of strikes via education and awareness programs throughout the aviation community, 2) revised Advisory Circulars to provide clearer guidance on the importance and means for reporting strikes, 3) improved procedures to transfer strike data from various FAA and industry databases to the NWSD, 4) making the database openly accessible to the aviation industry and general public, 5) refinements in the electronic reporting system for Form 5200-7, and 6) continued publication of annual reports and other studies to document the usefulness of the NWSD in providing an objective, scientific foundation for FAA and aviation industry policies and guidance related to bird and other wildlife strikes.

The objective of this report, based on recommendations of Dolbeer (2009*b*), is to conduct a follow up study to document trends in strike reporting in the 5 years since 2008 compared to previous years to determine if any recommended changes are needed in FAA policies regarding strike reporting at this time.

3. PROCEDURES OF ANALYSES

The primary focus of this analysis was to examine strike reporting for the past 5 years (2009-2013) compared to the previous 5 years (2004-2008). In addition, an examination of trends from 1990 to 2013 (24 years) was presented for some strike statistics to provide a longer-term perspective.

First, I examined the overall number of strikes and damage strikes reported to the FAA by wildlife type (bird, terrestrial mammal, bat [flying mammal], and reptile) by year. This included an analysis of the trend in the mean size (based on biomass) of birds reported struck.

Second, I examined overall trends in strike reporting for all aircraft types at airports certificated for passenger service under 14 CFR Part 139 (Part 139 airports, FAA 2014*a*), for non-certificated General Aviation (GA) airports in the National Plan of Integrated Airport System (NPIAS, FAA 2014*b*), and for other (non-NPIAS) GA airports.

Third, I compared reporting rates (strikes per 100,000 aircraft movements) for strikes involving commercial (air carrier/air taxi) and GA aircraft at Part 139 and NPIAS GA airports, respectively.

Fourth, to derive an estimate of the percentage of known strikes being reported to the NWSD by commercial aircraft and all civil aircraft (commercial and GA) at Part 139 airports nationwide, I compared strike reporting rates at 20 selected Part 139 airports (that have well established wildlife hazard management programs that emphasize the reporting of all known strikes) with strike reporting rates at all other Part 139 airports averaging over 1,000 movements/year, 2009-2013 (484 airports)[3]. The assumption for this analysis was that the reported strikes for the 20 selected Part 139 airports is reflective of the actual known strikes for these airports, 2009-2013. Strikes involving aircraft without a 3-letter Operator ID (private, business, and government aircraft) were excluded from the analysis of strikes with commercial aircraft but included for the analysis of strikes with all civil aircraft. "Carcass found" strikes were included with the

[3] 35 Part 139 airports that averaged <1,000 movements/year, 2009-2013 were excluded from the analysis. These airports had <0.1% of the total commercial aircraft movements at Part 139 airports, 2009-2013.

commercial aircraft since the vast majority of these strikes at Part 139 airports would involve commercial aircraft.

As another means of gauging the number of known bird strikes that are not being reported to the NWSD, I examined bird strike reports submitted independent of the NWSD through the Air Traffic Organization (ATO) Mandatory Occurrence Reporting (MOR) system. Under FAA Order JO 7210.632, (effective 30 Jan 2012), ATO personnel are required to report all bird strikes of which they become aware (see Appendix A-8 in the Order). Thus, I examined the strikes reported by ATO through the MOR system from January to September 2014 to determine how many of these strikes were 1) duplicates (with no new information) of strikes reported independently to the NWSD, 2) duplicates (but with additional information) of strikes reported independently to the NWSD, and 3) new strike events that had not been reported to the NWSD by other means.

A fifth objective, related to the MOR reports, was to examine trends in the sources of strike reports from 2004-2008 to 2009-2013. In particular, I documented the number of strike events that are being reported independently by multiple sources to gauge the breadth of reporting within the aviation community.

A sixth objective was to document trends in the percent of strikes reported to the FAA that provide an identification of the birds struck to species level (e.g., ring-billed gull [*Larus delawarensis*] as opposed to the generic "sea gull" or "unknown bird")[4]. There are about 900 species of wild birds that have been observed at least once in North America north of Mexico (Alsop 2001) of which about 650 are nesting species (Robbins et al. 1983). These species range in body mass from about 2 to 12,000 grams (Dunning 2007). Identification of the species responsible for a strike is critical for 3 reasons: 1) aeronautical studies analyzing the impact force of the object striking the aircraft component; 2) developing and evaluating species-focused WHMPs under airport Safety Management Systems (SMS) to mitigate the risk of strikes by hazardous species (Dolbeer and Wright 2009, Dolbeer and Begier 2012); and 3), determining the legal (protective) status of the species involved in the strikes under federal regulations such as the Migratory Bird Treaty Act and Endangered Species Act, as well as under state and local laws (Cleary and Dolbeer 2005). Species identification is critical to 1) obtain necessary federal, state, and local permits for management actions under an airport's SMS, 2) ensure that management actions are directed at the appropriate species that pose a risk to aviation safety, and 3) justify to the public and defend the management actions taken.

A seventh objective was to document actions that the FAA has undertaken since 2009 to further promote the reporting of strikes.

Based on the findings of these seven objectives, a final objective was to assess if 1) the reporting procedures in place are compliant with the ICAO standard regarding the establishment of a national procedure for recording and reporting wildlife strikes (ICAO 2013), and 2) data presently collected under the reporting system in place are adequate for understanding the problem of wildlife strikes in the USA and for monitoring and evaluating WHMPs at airports or if additional measures, such as mandatory reporting beyond what is now required under the ATO

[4] This analysis only examines species identification for bird strikes and not for other wildlife species. Birds comprise 97% of all wildlife strikes (Table 1). Terrestrial mammals, which comprise 2.2% of strikes, are identified to species in 95% of cases.

MOR system, need to be taken to collect sufficient information for regulatory and policy decisions.

4. SOURCES OF DATA

Wildlife strike data for civil aircraft from 1990-2013 were obtained from the NWSD (Dolbeer et al. 2014*a*) using Version 2014.6. Military aircraft strikes at civil airports were excluded from the analyses. A list of Part 139-certificated airports was obtained from FAA (2014*a*). Aircraft movement data for all Part 139-certificated airports and NPIAS GA airports were obtained from the FAA Terminal Area Forecast (TAF) System (FAA 2014*c*). Wildlife strikes in the ATO MOR system were provided by the FAA.

Strike rates and damage strike rates for commercial aircraft at Part 139 airports and GA aircraft at NPIAS GA airports were calculated in terms of number of strikes and number of damage strikes reported per 100,000 aircraft movements (take-off or landing).

5. RESULTS

5.1 Reported strikes and damage strikes for all airport and aircraft types by birds, terrestrial mammals, bats, reptiles

5.1.1 Years 1990-2013

For the 24-year period, 142,675 strikes were reported to the FAA. Birds were involved in 97.0% of the reported strikes, terrestrial mammals in 2.2%, bats in 0.7% and reptiles in 0.1% (Table 1). The overall number of reported strikes increased 6.2 fold from 1,851 in 1990 to 11,399 in 2013. In contrast, the number of strikes indicating damage to the aircraft increased from 340 in 1990 to a peak of 764 in 2000 but has subsequently declined by 21% to 605 in 2013 (Figure 1). The percent of reported strikes indicating damage ranged from 15% to 19% in 1990-1998 but has subsequently steadily declined to 5% in 2013 (Figure 1).

5.1.2 Years 2009-2013 compared to 2004-2008

Overall, reported wildlife strikes increased by a mean of 42% in 2009-2013 compared to 2004-2008 (Table 2). Bird, bat, terrestrial mammals, and reptile strikes each increased by means of 41%, 252%, 43%, and 151%, respectively. Although the overall number of strike reports increased by a mean of 42%, the number of strikes causing damage was stable, changing by only 1% between these two 5-year periods.

5.1.3 Mean size of birds struck, 1990-2013 and 2009-2013 compared to 2004-2008

The mean size (based on biomass) of birds reported struck by civil aircraft has declined by over 50% from about 800 grams in the mid-1990s to less than 400 grams in 2013 (Figure 2). From 2004-2008 to 2009-2013, the mean biomass of birds involved in reported strikes decreased 31% from a mean of 528 grams to 365 grams (Table 3). This decrease in mean biomass is likely related to the increased rate of reporting of all bird strikes, most of which are non-damaging strikes (see Figure 1) involving smaller birds.

5.2 Reported strikes and damage strikes for all aircraft by airport type, 2009-2013 compared to 2004-2008

The number of airports reporting strikes increased substantially for all airport types in 2009-2013 compared to 2004-2008 (Part 139 airports by 17%, NPIAS GA airports by 37%, other GA airports by 114%, and foreign airports by 27%; Table 4, Figure 3). The numbers of strikes

reported for each airport type showed even greater percent increases (Part 139 airports by 43%, NPIAS GA airports by 61%, other GA airports by 123%, and foreign airports by 46%; Table 4, Figure 4). For all airport types, there was an overall 26% increase in the number of airports reporting strikes and a 45% increase in the number of strikes reported.

In contrast to the substantial increase of 43% in reported strikes at Part 139 airports in 2009-2013 compared to 2004-2008, the mean number of damage strikes at Part 139 airports showed a 2% decline (Table 5, Figure 4). In addition to the slight decline in damage strikes reported at Part 139 airports, the mean number of wildlife-induced aborted take-offs and precautionary landings declined by 16% and 9%, respectively, from 2004-2008 to 2009-2013 (Table 6). NPIAS GA airports, which showed a 61% increase in reported strikes in 2009-2013 compared to 2004-2008 (Table 4, Figure 4), showed only a 5% increase in damage strikes (Table 5, Figure 4) and aborted take-offs (Table 6). Precautionary landings declined by 2%.

Tables A1 and A2 and Figures A1, A2, and A3 in Appendix A provide data on the long-term trends (1990-2013) for reported strikes, damage strikes, aborted take-offs, and precautionary landings by airport type.

5.3 Strike rates for commercial and GA aircraft at Part 139 and NPIAS GA airports, 2009-2013 compared to 2004-2008

Commercial aircraft movements at Part 139 airports declined by an average of 13% in 2009-2013 compared to 2004-2008 (Table 7). Thus, whereas the number of reported strikes for commercial aircraft increased by 46% from 2004-2008 to 2009-2013, the strike rate increased by 67% from 21.62 to 36.09. The number of damage strikes to commercial aircraft at Part 139 airports declined by 2% from 2004-2008 to 2009-2013. However, because there was a 12% decline in movements, the damage strike rate increased 12% from 1.11 to 1.25.

GA aircraft movements at NPIAS GA airports declined by an average of 8% in 2009-2013 compared to 2004-2008 (Table 8). Thus, whereas the number of reported strikes increased by 43% from 2004-2008 to 2009-2013, the strike rate increased by 55% from 0.343 to 0.531. The number of damage strikes to GA aircraft at NPIAS GA airports increased by 13% from 2004-2008 to 2009-2013 and the damage strike rate increased 23% from 0.127 to 0.156.

5.4 Estimated percent of strikes reported at Part 139 airports

5.4.1 Strike rates involving commercial aircraft for selected Part 139 airports compared to other Part 139 airports

In this analysis, the mean strike rate and mean damage strike rate were compared for reported strikes involving all commercial aircraft at 20 selected Part 139 airports with the strike rates at 484 other Part 139 airports, 2009-2013 (Table 9). The 20 airports selected as a baseline or control sample have well-established wildlife hazard management programs in place for at least the past 10 years that are overseen by a wildlife biologist, either from USDA/WS (Begier and Dolbeer 2015), the private sector, in-house, or a combination thereof. These airports were selected based on their established programs and known effort to document all wildlife strikes. I made no *a priori* examination of strike rates. The selection of these 20 Part 139 airports as the baseline sample does not imply that the other Part 139 airports have inadequate wildlife hazard management programs.

An estimate of the percentage of strikes involving commercial aircraft reported at Part 139 airports nationwide, 2009-2013, can be obtained if the following assumptions are made:

1. the mean reported strike rate of 45.038 for the 20 selected Part 139 airports (Table 9) is reflective of the actual known strike rates for these airports, 2009-2013, and
2. the mean reported strike rate of 38.916 for the 484 other airports should actually be the same (45.038) as that of the 20 selected airports.

The 20 selected airports and 484 other Part 139 airports had, respectively, 32.7% and 67.3%, of the commercial air carrier movements from 2009-2013 (Table 9). Thus, the proportion of actual strikes reported by each group of airports can be calculated by multiplying the fraction of total aircraft movements by the reported strike rate or 0.327 * 45.038 + 0.673 * 38.916 = 40.917. If both groups of Part 139 airports had reported strikes at the same rate as the 20 selected Part 139 airports (45.038), the respective proportions would have been 0.327 * 45.038 + 0.673 * 45.038 = 45.038. Therefore, based on the two assumptions above, it can be estimated that 91% (100 * 40.917/45.038) of the known strikes involving commercial aircraft were reported at the 504 Part 139 airports from 2009-2013 (Table 9).

Using the same assumptions and procedures, it can be estimated that 93% (100 * 1.373/1.476) of the known damage strikes involving commercial aircraft were reported at the 504 Part 139 airports from 2009-2013 (Table 9).

Furthermore, using the same assumptions and procedures, it can be calculated that 79% (100 * 22.317/28.256) of the known strikes and 78% (100 * 1.196/1.539) of the known damage strikes involving commercial aircraft for the same 504 Part 139 airports were reported in 2004-2008 (Table 10). Thus, strike reporting for commercial aircraft increased from an estimated 79% to 91% and damage strike reporting increased from an estimated 78% to 93%, 2004-2008 to 2009-2013 (Table 13).

5.4.2 Strike rates involving all civil aircraft (commercial and GA) for selected Part 139 airports compared to other Part 139 airports

This analysis was identical to the analysis in Section 5.4.1 above except that aircraft movements and strikes for all civil aircraft at the 504 Part 139 airports were included.

The 20 selected airports and 484 other Part 139 airports had, respectively, 19.5% and 80.5%, of the total civil aircraft movements from 2009-2013 (Table 11). Thus, the proportion of actual strikes reported by each group of airports can be calculated by multiplying the fraction of total aircraft movements by the reported strike rate or 0.195 * 42.312 + 0.805 * 14.494 = 19.906. If both groups of Part 139 airports had reported strikes for all civil aircraft at the same rate as the 20 selected Part 139 airports (42.312), the respective proportions would have been 0.195 * 42.312 + 0.805 * 42.312 = 42.312. Therefore, based on the two assumptions above, it can be estimated that 47% (100 * 19.906/42.312) of the known strikes involving all civil aircraft were reported at the 504 Part 139 airports from 2009-2013 (Tables 11, 13).

Using the same assumptions and procedures, it can be estimated that 59% (100 * 0.853/1.436) of the known damage strikes involving all civil aircraft were reported at the 504 Part 139 airports from 2009-2013 (Tables 11, 13).

Furthermore, using the same assumptions and procedures, it can be calculated that 42% (100 * 10.958/26.333) of the known strikes and 50% (100 * 0.747/1.486) of the known damage strikes involving all civil aircraft for the same 504 Part 139 airports were reported in 2004-2008 (Table 12). Thus, strike reporting for all civil aircraft at Part 139 airports increased from an estimated

42% to 47% and damage strike reporting increased from an estimated 50% to 59%, 2004-2008 to 2009-2013 (Table 13).

5.4.3 Comparison of strikes reported to ATO MOR system with strikes reported to NWSD by other means

From January to September 2014, there were 2,914 reports in the ATO MOR system indicating a bird strike (Table 14). Of these 2,914 strike reports, 765 (26%) had not been reported to the NWSD by other means and thus were new strike reports that may not have been entered in the NWSD otherwise. These 765 new reports represented 7% of the 10,422 strike reports entered in the NWSD from January - September 2014. Of note, only 14 (1.8%) of these 765 new reports indicated damage to the aircraft; thus these new MOR reports indicating damage represented only 3.6% of the 391 reports indicating damage in the NWSD from January-September 2014. None of the new damage reports from MOR indicated substantial damage to the aircraft.

Of the 2,149 MOR reports that covered strike events already entered in the NWSD, 1,423 (66%) provided no new information and 726 reports (34%) provided additional information about the strike event such as the registration number of aircraft, time of day, or distance from airport.

5.5 Strike reporting via multiple sources

Not only has there been a mean increase of 42% in the number of strike events reported from 2004-2008 to 2009-2013 (Table 2), but the number of strike events with multiple reports submitted from independent sources has increased even more dramatically (Table 15). In 2004-2008, 6,833 (19%) of the 36,496 strike events had multiple submissions that had to be processed and reconciled before finalizing the entry into the NWSD. In 2009-2013, the number of strike events with multiple reports submitted from various sources increased 2.4 fold to 16,280; 31% of all strike events had multiple (2 to 9) reports submitted. Overall, an estimated 76,571 separate reports had to be examined in 2009-2013 to finalize the entry of 51,904 strike events compared to 47,757 reports for the 36,496 strike events in 2004-2008. Thus, while the number of reported strike events increased by 42%, the number of strike reports examined increased by 60%.

This analysis (Table 15) also shows the greater reliance in recent years by groups such as airlines and airports to use FAA Form 5200-7 to electronically report strikes as opposed to reporting the strikes by other means. The proportion of strikes reported via Form 5200-7 increased from 70% in 2004-2008 to 87% in 2009-2013 (91% in 2013).

5.6 Trend in number and percent of reported bird strikes that identify the species struck

There has been continued improvement in bird species identification in 2009-2013 compared to 2004-2008 and to previous years back to 1990 (Table 16, Figure 5). The mean number of bird strikes in which the species was identified to species increased by 103% from 2,619/year in 2004-2008 to 5,324/year in 2009-2013. The percentage of all bird strikes in which the species was identified increased from a mean of 37% in 2004-2008 to 53% in 2009-2013 (a record 60% in 2013). Concurrently, the mean number of individual bird species identified as struck increased by 48% from 191 species in 2004-2008 to 283 species in 2009-2013 (a record 312 species in 2013). From 1990-2013, 506 identified species of birds were involved in strikes with civil aircraft of which 483 were species from North America and 23 were species struck by U.S.-registered aircraft in locations outside North America (the 483 species represent about 75% of the 650 bird species found nesting in North America and 54% of the 900 species ever observed in North America). Of the 483 identified bird species struck from North America, 456 (94%) are

species federally protected under the Migratory Bird Treaty Act. In addition, 19 species of bats, 42 species of terrestrial mammals, and 15 species of reptiles involved in strikes were identified from 1990-2013 (Dolbeer et al. 2014*a*).

5.7 Actions by FAA to improve bird strike reporting, 2009-2013

5.7.1 Advisory Circulars (ACs)

AC 150/5200-32B "Reporting Wildlife Aircraft Strikes" was revised in May 2013 to include an important addition:

> "The effectiveness of a Wildlife Hazard Management Plan (WHMP) to reduce wildlife hazards both on and near an airport and the reevaluation of all facets of damage/non-damage strikes from year to year requires accurate and consistent reporting. Therefore, every WHMP should include a commitment to document and report to the NWSD all wildlife strikes that occur within the separation distances described in sections 1-2 and 1-3 of Advisory Circular 150/5200-33, Hazardous Attractants On or Near Airports (current version), to better identify, understand, and reduce threats to safe aviation."

AC 150/5200-38 "Protocol for the conduct and review of Wildlife Hazard Site Visits, Wildlife Hazard Assessments, and Wildlife Hazard Management Plans". This AC, in final draft stage to be published in 2015, contains a statement similar to that quoted above for AC 150/5200-32B that emphasizes a commitment to reporting all known strikes.

AC 150/5200-36A "Qualifications for Wildlife Biologist Conducting Wildlife Hazard Assessments and Training Curriculums for Airport Personnel Involved in Controlling Wildlife Hazards on Airports" was revised in January 2012. The AC requires that the NWSD and strike reporting be a component of 1) the required annual recurrent training for all airport employees involved in implementing an airport's WHMP and 2) the curriculum for people taking the 3-day FAA-approved course to become a "qualified airport biologist." From 2009-2013, approximately 300 people have taken an FAA-approved 3-day course to become a "qualified airport biologist".

5.7.2 FAA Air Traffic Organization (ATO) Mandatory Occurrence Reporting (MOR) System

Under FAA Order JO 7210.632, (effective 30 Jan 2012), ATO personnel are required (Appendix A-8 in the Order) to report all bird strikes of which they become aware. These reports are entered in the MOR system and, as of January 2014, are being integrated into the NWSD if they provide new information (as discussed in Section 5.4.2 above).

5.7.3 Memorandum of Understanding (MOU) between FAA and Bird Strike Committee-USA (May 2012)

The International Civil Aviation Organization recommends (Chapter 2 in ICAO 2012) that each member country establish a national committee to advise the Civil Aviation Authority and aviation industry regarding wildlife risks. Bird Strike Committee-USA is an organization with membership from various federal agencies, the aviation industry and other private-sector entities. Among other activities, BSC-USA holds an annual meeting attended by over 300 people to provide training and information exchange. A MOU between FAA and BSC-USA was initially drafted in 2009 and signed in May 2012 to provide a formal means for FAA to receive assistance from the membership of BSC-USA in the development and promotion of programs to mitigate

the risk of bird strikes. A primary objective of BSC-USA, as stated in the organization's by-laws, is to promote the collection and analysis of accurate wildlife strike data. Thus, BSC-USA is providing active support to FAA in promoting accurate strike reporting by airports, pilots, air carriers, and engine manufacturers. As one example, BSC-USA has distributed over 1,000 strike reporting kits in the past 5 years which provide the supplies needed to collect bird strike remains for submission to the Smithsonian Feather Lab for species identification. BSC-USA has also participated as an exhibitor at numerous aviation industry conferences in the past five years to promote the reporting of strikes.

5.7.4 FAA hired a second Wildlife Biologist

From the 1989 to 2009 the FAA had one Wildlife Biologist staff position at headquarters to oversee the national program for mitigating the risks of wildlife strikes. In 2010, the FAA added a second Wildlife Biologist staff position which has enhanced the various outreach and technical assistance activities for Part 139 and especially NPIAS GA airports, as well as with airport certification inspectors in each FAA region.

5.7.5 Wildlife Hazard Assessments (WHA), Wildlife Hazard Management Plans (WHMP)

Since 2009, the FAA has made a major effort to proactively ensure that all Part 139 airports conduct a WHA and develop a WHMP, regardless if they have had a triggering event as defined in 14 CFR Part 139.337. As of December 2014, all Part 139 airports have completed or are in the process of initiating or conducting a WHA. For those airports that do not already have a WHMP, WHMPs will be developed or modified based on the findings of the WHA. For NPIAS GA airports, the FAA is presently developing a plan, as discussed in Dolbeer et al. 2014*a*, to conduct site visits or WHAs for the over 2,700 NPIAS GA airports.

5.7.6 Accessibility of NWSD to aviation industry and general public for information

The NWSD was not accessible (without FAA permission and a password) from its initial development in 1995 through 2008. Since 2009, the FAA has allowed open access to the database; the contents of the database can now be examined and queried on-line or downloaded for analysis by anyone.

In addition, the FAA has developed an on-line "Airport Wildlife Strike Summary and Risk Analysis Report" for each Part 139 airport that is updated annually http://wildlifecenter.pr.erau.edu/strikeInformation.php). Each custom report provides a summary of strike data for the airport (on airport and off-airport strikes) in relation to regional and national means for other Part 139 airports. The report also provides a simple wildlife species risk analysis to assist in setting risk management priorities at the selected airport.

Finally, the FAA, in cooperation with USDA/WS, has continued to publish detailed annual reports that summarize all the wildlife strike data from 1990 through the latest year. These reports document trends in strikes, wildlife species posing the most and least risk, and estimates of the strike-related economic losses.

5.7.7 Enhancement in on-line reporting

Since 2009, the FAA has made various enhancements to the on-line reporting system (Form 5200-7) including improved drop-down menus, a mobile device application, and the ability to edit/update previously submitted strikes. These enhancements, combined with the open accessibility of the database, the detailed annual reports, and on-line customized airport reports,

have led to a greater use of the on-line system to report strikes and edit/update strike reports as new information becomes available.

6. DISCUSSION

6.1 Reported strikes and damage strikes for all airport and aircraft types by birds, terrestrial mammals, bats, reptiles

This analysis demonstrated a significant increase in reporting in 2009-2013 compared to previous years for strikes involving all four wildlife types. Overall, reported strikes involving all species increased by a mean of 42 percent in 2009-2013 compared to 2004-2008. The fact that during this time period reported strikes with damage increased by only 1% clearly documents that the risk caused by wildlife strikes is not increasing; rather, the increase in reported strikes indicates that airports, pilots and commercial aviation, in general, are doing a better job of documenting wildlife that are struck. The stabilization of strikes with damage in spite of a 42% increase in reported strikes is even more remarkable when one considers that 17 of the 21 species of birds in North America with mean body masses >4 lbs (1.8 kg) and at least 10 strikes with civil aircraft showed population increases from 1990-2012 with a net gain of 17 million birds (Dolbeer and Begier 2013, Dolbeer et al. 2014*b*). This pattern in strike reporting is likely due to the continuing improvement in WHMPs at Part 139 (and some NPIAS GA) airports nationwide that result in 1) a better documentation of all wildlife strikes and 2) mitigation efforts focused on the larger, more hazardous species (Dolbeer et al. 2014*b*). The fact that the mean biomass of bird species involved in reported strikes has declined by 31% from 2004-2009 to 2009-2013 (and by over 50% since the mid-1990s) also supports this hypothesis of an increased rate of reporting of all strikes, most of which involve smaller birds that cause no damage.

6.2 Reported strikes and damage strikes for all aircraft by airport type, 2009-2013 compared to 2004-2008

The pattern of a major increase in reported strikes and the lack of an increase in strikes with damage for wildlife type discussed above were also shown for all airport types. In contrast to the substantial increase of 43% in reported strikes at Part 139 airports in 2009-2013 compared to 2004-2008, the mean number of damage strikes at Part 139 airports showed a 2% decline. NPIAS GA airports, which showed a 61% increase in reported strikes in 2009-2013 compared to 2004-2008, showed only a 5% increase in damage strikes. Incidences of aborted take-offs and precautionary landings after wildlife strikes also showed declines at Part 139 airports and no change at NPIAS GA airports in 2009-2013 compared to 2004-2008. These data also support the hypothesis that the major increases in reported strikes with little or no increase in damage strikes, aborted take-offs and precautionary landings are indicators of improved wildlife mitigation efforts at airports directed at species of higher risk (i.e., more likely to cause damage) and a greater attention to reporting all known wildlife strikes.

6.3 Strike rates for commercial and GA aircraft at Part 139 and NPIAS GA airports, 2009-2013 compared to 2004-2008

Because commercial aircraft movements at Part 139 airports declined by an average of 13% in 2009-2013 compared to 2004-2008 and the number of reported strikes for commercial aircraft increased by 46%, the reported strike rate increased by 67%. In contrast to the 67% increase in the reported strike rate, the damage strike rate increased by only 12%.

The pattern for GA aircraft at NPIAS GA airports was similar. Because GA aircraft movements at NPIAS GA airports declined by an average of 8% in 2009-2013 compared to 2004-2008 and the number of reported strikes for GA aircraft increased by 43%, the strike rate increased by 55%. In contrast to the 55% increase in the reported strike rate, the damage strike rate increased 23%.

6.4 Estimated percent of strikes involving commercial aircraft reported at Part 139 airports

Based on the comparison of reported strike rates at 20 airports known to do a thorough job of documenting all known strikes with the strike rates at 484 other Part 139 airports, strike reporting for commercial aircraft at Part 139 airports increased from 79% to 91% and damage strike reporting increased from 78% to 93%, 2004-2008 to 2009-2013.

It is important to note that these estimates do not include some unknown number of non-damage strikes that are never noticed (e.g., events in which small passerine species [e.g., warblers, sparrows, swallows] are blown through the by-pass of large turbofan engines or bounce off the fuselage or landing gear), even at the airports that work closely with the air carriers to do the most thorough job of documenting strikes. Thus, actual strike numbers may be much higher than what is reported. However, these unknown strikes are not important relative to airport WHMPs and are irrelevant from a risk perspective for civil aircraft.

The estimated 79% and 91% reporting rates of known strikes for commercial aircraft at Part 139 airports in 2004-2008 and 2009-2013, respectively, are higher than the estimated 39% reporting rate derived for 2004-2008 in the previous analysis (Dolbeer (2009*a*). However, this previous estimate of 39% for 2004-2008 used all strikes and all movements for GA and commercial aircraft. When I included GA movements and strikes in the present analysis (Tables 11, 12), I obtained a 42% reporting rate for 2004-2008 which was similar to the 39% rate obtained in the previous (Dolbeer 2009*a*) study. The combination of 1) a 46% increase in strike reporting for commercial aircraft at Part 139 airports in 2009-2013 compared to 2004-2008, and 2) the exclusion of GA aircraft (which have a much lower reporting rate [Dolbeer 2009*a*]) from the analysis resulted in the higher estimates of strike reporting for commercial aircraft in this present analysis.

The analysis of reports involving bird strikes gathered through the mandatory ATO MOR system from January-September 2014 is supportive of the 91% reporting rate for commercial aircraft at Part 139 airports. The MOR system provided 7% more strikes to the NWSD, but added only 3.6% more damage strikes (all minor).

6.5 Reporting via multiple sources

The fact that from 2004-2008 to 2009-2013 there was a 2.4-fold increase in the number of strike events with multiple reports submitted from independent sources documents the increased participation by the aviation community as a whole to ensure that strike events are reported to the FAA NWSD. Multiple submissions of a strike often provide a more complete documentation of the event, but these submissions also often require considerable time to process, resolve conflicting information, and ensure that single strike events are not entered into the NWSD as duplicates. Whereas the number of strike events reported in 2009-2013 increased by 42% compared to 2004-2008, the number of individual strike reports examined increased by 60% because of multiple reporting.

This analysis also showed that the efforts by FAA to improve on-line reporting are working for user groups such as airlines and airports. The proportion of strikes reported electronically via Form 5200-7 increased from 70% in 2004-2008 to 87% in 2009-2013 (91% in 2013).

6.6 Trend in number and percent of reported bird strikes that identify the species struck

The continued improvement in bird species identification in 2009-2013 compared to 2004-2008 and to previous years back to 1990 is significant. Support provided by the FAA to the Smithsonian Feather Lab for identification of bird strike remains using feather remains and DNA analysis (Dove et al, 2008) has been a major factor in this improvement. Species identification, when coupled with data on location, phase of flight, height above ground level, aircraft model and speed, and aircraft parts struck and damaged, provide the foundation for understanding and mitigating the risk of bird and other wildlife strikes. The quality and completeness of information provided with each strike report is more important than the mere quantity of strike reports that are filed. Without accurate and relevant information, strike reports are of limited usefulness as has been shown with other national and military databases.

6.7 Actions by FAA to improve bird strike reporting, 2009-2013

The various actions undertaken by the FAA, in partnership with BSC-USA, USDA/WS, and various private-sector and aviation industry groups as outlined in Section 5.7 above, have all enhanced the quantity and quality of reporting of wildlife strikes involving civil aircraft. Of significant note is the inclusion of statements in revised Advisory Circulars to emphasize a commitment to reporting all known strikes. Although these statements in ACs do not (and cannot) mandate the reporting of strikes, they provide clear guidance that strike reporting is a critical component of every WHMP. WHMPs, once approved by an FAA Airport Certification Inspector, are a part of each Part 139 airport's certification manual.

Another significant development was FAA Order JO 7210.632 (effective 30 Jan 2012) which requires ATO personnel to report all bird strikes of which they become aware. These reports are entered in the MOR system and, as of January 2014, are being integrated into the NWSD if they provide new information (as discussed in Section 5.4.2).

Also, the open accessibility of the NWSD to the aviation industry and general public for information and analysis, the availability of on-line customized "Airport Wildlife Strike Summary and Risk Analysis Reports" for each Part 139 airport, and enhancements in on-line reporting have all contributed to a greater public and industry awareness of the usefulness and importance of the database.

7. CONCLUSIONS AND RECOMMENDATIONS

1) Based on a) the significant positive trend observed in overall strike reporting from 1990 to 2013, and especially since 2008, b) the decline or stabilization in damage strikes since 2000, c) the implementation of professionally run wildlife hazard programs at many Part 139 airports throughout the U.S. that are reporting all known strikes, and d) the significant improvement in species identification, I conclude that the current overall reporting rate, estimated at 91% for all known strikes events involving commercial aircraft at Part 139 airports, is adequate to track national and regional trends in wildlife strikes, determine the hazard level of wildlife species that are being struck, and to provide a scientific foundation for FAA policies and guidance regarding the mitigation of risk from wildlife strikes. The NWSD also provides a means for Part 139 airports to monitor and evaluate

the effectiveness of their WHMPs through "Airport Wildlife Strike Summary and Risk Analysis Reports" that are generated annually. The database is presently (2013) capturing over 11,000 strike events per year involving over 300 species of birds and other wildlife (142,675 strikes involving over 500 species of birds and 76 species of other wildlife from 1990-2013).

2) Given the positive trends and levels in reporting and species identification coupled with the decline or stabilization in damage strikes, I do not recommend mandatory reporting other than what is already required under ATO Order JO 7210.632 at this time to achieve the objectives of the database. I conclude the reporting procedures in place are fully compliant with the ICAO standard regarding the establishment of a national procedure for recording and reporting wildlife strikes (ICAO 2013).

3) If the FAA were to consider mandatory reporting beyond what is now required (which I do not recommend at this time based on the findings in this report), careful thought would be required regarding:

   a) precisely who would be required to report a strike? Would ATO, pilots, airline and airport operations, engine manufacturers, and repair facilities all be required to report a strike of which they become aware and would this include GA pilots and airports?

   b) what details of each strike event would be required and who would be responsible for collecting and sending the information to the NWSD in a coherent format that resolved conflicting information? Would it be required to only report that the strike happened or would all known details be mandatory, including costs and sending remains to Smithsonian Feather Lab for identification?

   c) who would be responsible for enforcement and what actions would be taken for non-compliance? and,

   d) what benefits would be gained over the level of reporting now in place?

4) The FAA needs to sustain the momentum that has been generated in the past 5 years to ensure that strike reporting continues to be a priority at Part 139 airports and for air carriers using those airports. Specific recommendations include:

   a) an emphasis on not just reporting strike events but in providing all known details of each event to enhance the usefulness of each report;

   b) use of the "Airport Wildlife Strike Summary and Risk Analysis Reports" by FAA Airport Certification Inspectors during annual inspections to ensure each Part 139 airport is reporting strikes, getting species identified when possible, and using the information to evaluate and adjust the airport's WHMP under a Safety Management System; and,

   c) continued work with the commercial air transport industry to ensure that strikes recorded by air carriers that may not be noted by operations personnel at airports or ATO are entered into the NWSD. It is in the air carriers' self-interest that all strikes associated with airports (approach, landing, taxi, take-off, and climb) be entered in the NWSD so that mitigation efforts at those airports can be implemented to prevent future strikes.

5) The FAA needs to sustain the momentum that has been generated in the past 5 years to ensure that strike reporting continues to increase at NPIAS GA airports. The planned conduct of site visits and WHAs at these airports, as outlined in section 5.7.5 above, is critical to achieve this objective.

6) The FAA should continue publishing annual wildlife strike reports to document trends and characteristics of strikes to civil aircraft. These detailed analyses provide current information to the aviation industry and public regarding efforts to mitigate the risk of wildlife strikes and publicize the usefulness of the NWSD. As a bonus, these detailed annual analyses provide a means to check the database for errors or inconsistencies in records.

7) A follow-up study should be conducted in 5 years to determine trends in strike reporting and if additional measures, such as mandatory reporting beyond what is now required, need to be reconsidered.

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The findings and conclusions expressed do not necessarily reflect current FAA policy decisions regarding the reporting of wildlife strikes or the control of wildlife on or near airports. Data presented regarding specific airports, air carriers, and other entities does not reflect on the quality or adequacy of programs and policies in place to mitigate the risk of wildlife strikes.

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Tables

Table 1. Number of reported wildlife strikes to civil aircraft by wildlife type, 1990–2013 (see Figures 1 and 2).

Year	Birds	Bats	Terrestrial mammals[a]	Reptiles[a]	Total strikes	Strikes with damage
1990	1,795	4	52	0	1,851	372
1991	2,336	3	54	0	2,393	401
1992	2,499	2	73	1	2,575	368
1993	2,504	6	66	0	2,576	399
1994	2,554	2	82	1	2,639	462
1995	2,675	5	84	8	2,772	498
1996	2,852	1	91	3	2,947	505
1997	3,353	1	95	14	3,463	581
1998	3,688	3	111	7	3,809	587
1999	5,020	7	96	1	5,124	707
2000	5,866	16	123	3	6,008	764
2001	5,676	8	138	8	5,830	649
2002	6,098	19	118	15	6,250	674
2003	5,886	20	127	5	6,038	635
2004	6,409	27	129	6	6,571	628
2005	7,090	27	131	7	7,255	609
2006	7,053	49	140	10	7,252	598
2007	7,536	53	172	7	7,768	571
2008	7,416	46	183	5	7,650	529
2009	9,229	67	230	10	9,536	607
2010	9,557	113	246	11	9,927	599
2011	9,773	139	198	15	10,125	542
2012	10,530	165	203	19	10,917	611
2013	10,937	226	203	33	11,399	605
Total	**138,332**	**1,009**	**3,145**	**189**	**142,675**	**13,501**

[a] For terrestrial mammals and reptiles, species with body masses <1 kilogram (2.2 pounds) are excluded from database (Dolbeer et al. 2005).

Table 2. Mean number of reported strikes and strikes with damage per year involving birds, bats, terrestrial mammals, and reptiles for 2009-2013 compared to 2004-2008, all civil aircraft.

	Reported strikes			Reported strikes with damage		
Type of wildlife	2004-2008	2009-2013	Net change	2004-2008	2009-2013	Net change
Birds	7,101	10,005	2,904 (41%)	547	564	17 (3%)
Bats	40	142	102 (252%)	1	1	0 (0%)
Terrestrial mammals	151	216	65 (43%)	40	28	-12 (-30%)
Reptiles	7	18	11 (151%)	0	0	0 (0%)
Total	7,299	10,381	3,082 (42%)	587	593	6 (+1%)

Table 3. Mean number of bird strikes reported per year in which bird was identified to species or species group and mean biomass of bird species involved in those strikes for 2009-2013 compared to 2004-2008 (see Figure 2).

Years	Bird strikes reported[a]	Mean bird biomass (g)[b]
2009-2013	6,125	365
2004-2008	3,335	528
Net change	2,790 (84%)	-163 (-31%)

[a] Strikes with unknown bird (bird not identified to species or species group) were excluded from this analysis.

[b] For each species, the mean biomass of the heaviest sex was used, or if sex was unknown, the mean biomass of all birds in sample (Dunning 2007). For birds identified only to species group (e.g., gull, duck, goose), the mean biomass of all species in database within that group, weighted by numbers struck, was used.

Table 4. Mean number of airports reporting strikes per year and mean number of strikes reported per year by type of civil airport for 2009-2013 compared to 2004-2008.[a]

	Airports with reported strikes			Strikes reported		
Type of civil airport	2004-2008	2009-2013	Net change	2004-2008	2009-2013	Net change
P139	322	375	58 (17%)	5,971	8,599	2,588 (43%)
NPIAS GA	148	203	55 (37%)	296	476	180 (61%)
Other GA	18	38	20 (114%)	23	51	28 (123%)
All USA	488	615	127 (26%)	6,290	9,086	2,796 (45%)
Foreign	76	97	21 (27%)	167	243	76 (46%)
All airports	564	772	148 (26%)	6,457	9,329	2,872 (45%)
All airports + enroute				7,299	10,381	3,081 (42%)

[a] These numbers include strikes by all aircraft types at each type of airport. Tables 7 and 8, which calculate strikes/100,000 movements, include only strikes by commercial and GA aircraft, respectively.

Table 5. Mean number of airports reporting damage strikes per year and mean number of strikes with damage reported per year by type of civil airport for 2009-2013 compared to 2004-2008[a].

	Airports with reported damage strikes			Damage strikes reported		
Type of civil airport	2004-2008	2009-2013	Net change	2004-2008	2009-2013	Net change
P139	148	147	-1 (-1%)	358	352	-6 (-2%)
NPIAS GA	72	80	8 (11%)	85	89	4 (5%)
Other GA	9	9	0 (0%)	10	10	0 (0%)
All USA	229	236	7 (3%)	453	451	-2 (-<1%)
Foreign	16	17	1 (12%)	17	19	2 (13%)
All airports	245	253	8 (3%)	470	470	0 (0%)
All airports + enroute				587	593	6 (1%)

[a] These numbers include strikes by all aircraft types at each type of airport. Tables 7 and 8, which calculate strikes/100,000 movements, include only strikes by commercial and GA aircraft, respectively.

Table 6. Mean number of wildlife-induced aborted take-offs and precautionary landings per year at Part 139 and NPIAS GA airports for 2009-2013 compared to 2004-2008 (see Figure A3 for trend analysis, 1990-2013).

	Aborted take-offs[a]		Precautionary landings[b]	
Years	Part 139 airports	NPIAS GA airports	Part 139 airports	NPIAS GA airports
2009-2013	57	20	152	41
2004-2008	68	19	167	42
Net change	-11 (-16%)	1 (5%)	-15 (-9%)	-1 (-2%)

[a] Pilot initiated take-off run but then aborted take-off after aircraft struck or encountered wildlife on runway.

[b] Pilot completed take-off but returned to land at departure airport or at an "other-than-destination" airport after strike.

Table 7. Mean number of commercial aircraft movements at Part 139 airports and mean number of strikes and strike rates for commercial aircraft in 2009-2013 compared to 2004-2008.

Years	Commercial aircraft movements (x 1 million)	Number of strikes		Strikes/100,000 movements	
		All strikes	Damage strikes	All strikes	Damage strikes
2009-2013	22.53	8,132	281	36.086	1.245
2004-2008	25.78	5,572	286	21.614	1.109
Net change	-3.25 (-13%)	2,560 (46%)	-5 (-2%)	14.472 (67%)	0.136 (12%)

Table 8. Mean number of General Aviation (GA) aircraft movements at NPIAS GA airports and mean number of strikes and strike rates for GA aircraft in 2009-2013 compared to 2004-2008.

Years	GA aircraft movements (x 1 million)	Number of strikes		Strikes/100,000 movements	
		All strikes	Damage strikes	All strikes	Damage strikes
2009-2013	52.61	279	82	0.531	0.156
2004-2008	57.04	196	73	0.343	0.127
Net change	-4.43 (-8%)	83 (43%)	9 (13%)	0.188 (55%)	0.029 (23%)

Table 9. Comparison of mean wildlife strikes per 100,000 aircraft movements for commercial aircraft in 2009-2013 for 20 Part 139-certificated airports with well-established wildlife hazard management programs compared to the mean strike rates for 484[a] other Part 139 airports.

Part 139 airports	Aircraft movements/year	Mean reported strike rate[b]	Mean reported damage strike rate[b]
ORD	860,108	25.532	0.977
DFW	646,100	52.035	1.052
DEN	614,535	71.957	1.367
LAX	564,582	17.748	1.027
PHX	428,286	15.083	0.467
MSP	417,048	23.690	1.247
JFK	406,056	49.451	2.167
EWR	405,934	32.123	1.281
LGA	361,280	38.087	1.218
BOS	347,590	29.805	1.093
SEA	311,367	26.014	0.963
IAD	309,862	26.205	1.355
MCO	292,919	49.843	3.414
SLC	288,429	52.491	3.467
MEM	284,283	61.910	2.322
BWI	250,280	40.675	1.598
PDX	193,885	41.158	1.135
CLE	181,564	58.381	0.661
MCI	135,577	100.312	2.065
OKC	61,641	88.253	0.649
Totals: above 20 Part 139 airports	7,361,327 (32.7%)	45.038[c]	1.476[c]
Totals: 484 other Part 139 airports	15,151,778 (67.3%)	38.916[c]	1.323[c]
Totals: all 504 Part 139 airports	22,534,437 (100%)	40.917[d]	1.373[d]

[a] 35 Part 139 airports that averaged <1,000 commercial aircraft movements/year, 2009-2013 were excluded from the analysis. These airports had <0.1% of the total commercial aircraft movements at Part 139 airports, 2009-2013.

[b] Strikes per 100,000 aircraft movements = 100,000 * the sum of all strikes (or damage strikes)/total movements, 2009-2013.

[c] Mean strike rate (damage strike rate) for the 20 and 484 airports, respectively.

[d] Fraction of aircraft movements * strike rate (or damage strike rate) for the 20 selected airports + fraction of aircraft movements * strike rate (or damage strike rate) for the 484 other airports (see sections 5.4.1 and 5.4.2 in text).

Table 10. Comparison of mean wildlife strikes per 100,000 aircraft movements for commercial aircraft in 2004-2008 for 20 Part 139-certificated airports with well-established wildlife hazard management programs compared to the mean strike rates for 484[a] other Part 139 airports.

Part 139 airports	Aircraft movements/year	Mean reported strike rate[b]	Mean reported damage strike rate[b]
ORD	933,856	14.585	0.899
DFW	711,836	26.186	1.040
DEN	584,561	44.307	1.369
LAX	638,589	9.051	0.501
PHX	494,197	17.645	0.202
MSP	463,974	15.044	0.905
JFK	384,720	36.130	2.859
EWR	427,788	17.813	1.122
LGA	389,960	21.387	1.744
BOS	383,817	18.029	1.198
SEA	344,027	14.069	0.756
IAD	387,567	21.158	1.497
MCO	327,975	25.551	3.476
SLC	349,827	31.158	2.859
MEM	349,221	50.112	2.234
BWI	266,021	28.344	1.203
PDX	227,638	43.139	2.196
CLE	240,188	32.141	1.166
MCI	168,452	61.145	2.968
OKC	68,705	38.134	0.582
Totals: above 20 Part 139 airports	8,142,920 (31.6%)	28.256[c]	1.539[c]
Totals: 484 other Part 139 airports	17,598,006 (68.4%)	19.569[c]	1.037[c]
Totals: all 504 Part 139 airports	25,740,926 (100%)	22.317[d]	1.196[d]

[a] 35 Part 139 airports that averaged <1,000 commercial aircraft movements/year, 2009-2013 were excluded from the analysis. These airports had <0.1% of the total commercial aircraft movements at Part 139 airports, 2009-2013.

[b] Strikes per 100,000 aircraft movements = 100,000 * the sum of all strikes (or damage strikes)/total movements, 2004-2009.

[c] Mean strike rate (damage strike rate) for the 20 and 484 airports, respectively.

[d] Fraction of aircraft movements * strike rate (or damage strike rate) for the 20 selected airports + fraction of aircraft movements * strike rate (or damage strike rate) for the 484 other airports (see sections 5.4.1 and 5.4.2 in text).

Table 11. Comparison of mean wildlife strikes per 100,000 aircraft movements for all civil aircraft (commercial and general aviation) in 2009-2013 for 20 Part 139-certificated airports with well-established wildlife hazard management programs compared to the mean strike rates for 484[a] other Part 139 airports.

Part 139 airports	Aircraft movements/year	Mean reported strike rate[b]	Mean reported damage strike rate[b]
ORD	867,577	25.335	0.968
DFW	651,754	51.615	1.043
DEN	618,264	71.620	1.391
LAX	582,764	17.263	1.030
PHX	450,029	14.444	0.444
MSP	429,748	23.130	1.210
JFK	413,264	48.589	2.129
EWR	416,306	31.371	1.297
LGA	368,039	37.659	1.196
BOS	364,347	28.544	1.043
SEA	314,774	25.733	0.953
IAD	355,601	23.903	1.294
MCO	309,352	47.325	3.233
SLC	350,700	43.798	3.080
MEM	303,071	58.270	2.178
BWI	269,130	38.346	1.635
PDX	215,496	38.052	1.485
CLE	190,026	55.992	0.631
MCI	140,406	97.432	1.994
OKC	81,388	67.823	0.491
Totals: above 20 Part 139 airports	7,692,036 (19.5%)	42.312[c]	1.436[c]
Totals: 484 other Part 139 airports	31,844,511 (80.5%)	14.494[c]	0.712[c]
Totals: all 504 Part 139 airports	39,536,547 (100%)	19.906[d]	0.853[d]

[a] 35 Part 139 airports that averaged <1,000 commercial movements/year, 2009-2013 were excluded from the analysis. These airports had <0.1% of the total commercial aircraft movements and <2.7% of all civil aircraft movements (commercial and GA) at Part 139 airports, 2009-2013.

[b] Strikes per 100,000 aircraft movements = 100,000 * the sum of all strikes (or damage strikes)/total movements, 2009-2013.

[c] Mean strike rate (damage strike rate) for the 20 and 484 airports, respectively.

[d] Fraction of aircraft movements * strike rate (or damage strike rate) for the 20 selected airports + fraction of aircraft movements * strike rate (or damage strike rate) for the 484 other airports (see sections 5.4.1 and 5.4.2 in text).

Table 12. Comparison of mean wildlife strikes per 100,000 aircraft movements for all civil aircraft (commercial and general aviation) in 2004-2008 for 20 Part 139-certificated airports with well-established wildlife hazard management programs compared to the mean strike rates for 484[a] other Part 139 airports.

Part 139 airports	Aircraft movements/year	Mean reported strike rate[b]	Mean reported damage strike rate[b]
ORD	953,293	14.350	0.902
DFW	723,177	25.858	1.023
DEN	593,258	43.657	1.348
LAX	654,358	8.955	0.520
PHX	552,221	15.863	0.181
MSP	491,622	14.320	0.895
JFK	391,932	35.669	2.909
EWR	442,382	17.361	1.130
LGA	400,624	20.818	1.697
BOS	408,443	17.236	1.224
SEA	347,936	13.911	0.747
IAD	457,555	18.446	1.268
MCO	350,410	24.200	3.310
SLC	419,497	26.508	2.384
MEM	381,675	46.008	2.096
BWI	301,668	25.790	1.260
PDX	256,997	39.144	2.412
CLE	253,253	30.641	1.185
MCI	178,574	58.015	2.800
OKC	91,585	29.918	0.437
Totals: above 20 Part 139 airports	8,650,460 (18.1%)	26.333[c]	1.486[c]
Totals: 484 other Part 139 airports	39,020,887 (81.9%)	7.550[c]	0.582[c]
Totals: all 504 Part 139 airports	47,671,347 (100%)	10.958[d]	0.747[d]

[a] 35 Part 139 airports that averaged <1,000 commercial aircraft movements/year, 2009-2013 were excluded from the analysis. These airports had <0.1% of the total commercial aircraft movements and <2.7% of all civil aircraft movements (commercial and GA) at Part 139 airports, 2009-2013.

[b] Strikes per 100,000 aircraft movements = 100,000 * the sum of all strikes (or damage strikes)/total movements, 2004-2009.

[c] Mean strike rate (damage strike rate) for the 20 and 484 airports, respectively.

[d] Fraction of aircraft movements * strike rate (or damage strike rate) for the 20 selected airports + fraction of aircraft movements * strike rate (or damage strike rate) for the 484 other airports (see sections 5.4.1 and 5.4.2 in text).

Table 13. Summary of estimated percent of strikes at Part 139-certificated airports reported to the FAA National Wildlife Strike Database for 2004-2008 and 2009-2013 derived from comparing mean strikes rates at 20 airports with well-established wildlife hazard management programs with mean strike rates for 484 other Part 139 airports (see Tables 9-12 and sections 5.4.1 and 5.4.2 in text).

	Estimated percent of known strikes reported[a]			
	All strikes		Damaging strikes	
Aircraft classification	2004-2008	2009-2013	2004-2008	2009-2013
Commercial only[b]	79	91	78	93
Commercial and general aviation[c]	42	47	50	59

[a] These estimates do not include some unknown number of non-damage strikes that are never noticed (e.g., events in which small passerine species are blown through the by-pass of large turbofan engines or bounce off the fuselage or landing gear). Thus, actual strike numbers may be much higher than what is reported. However, these unknown strikes are not important relative to airport Wildlife Hazard Management Plans and are irrelevant from a risk perspective for civil aircraft.

[b] Strikes involving aircraft with an FAA 3-letter Operator Identification but excluding private, business, and government aircraft.

[c] Strikes involving all civil aircraft.

Table 14. Bird strike reports submitted independent of the National Wildlife Strike Database (NWSD) through the FAA Air Traffic Organization (ATO) Mandatory Occurrence Reporting (MOR) system[a] compared to strikes reported to the NWSD, January-September 2014.

Type of reporting system	Category of strike report	No. of reports	MOR reports as % of total: MOR reports[b]	MOR reports as % of total: NWSD reports[b]
MOR	Duplicated NWSD report with no new information	1,423	49	14
MOR	Supplemented NWSD report with additional information[c]	726	25	7
MOR	New report not in NWSD	765	26	8
MOR	New report (of the 765) indicating damage	(14)	(<1)	(<1)
MOR	Total reports	2,914[d]	100	28
NWSD	Total reports	10,422		
NWSD	Total reports (of the 10,422) indicating damage	(391)		(4)

[a] Under FAA Order JO 7210.632, Appendix A-8, effective 30 Jan 2012, ATO personnel are required to report all bird strikes of which they become aware.

[b] For example, the 1,423 MOR reports that duplicated reports already in the NWSD represented 49% of the 2,914 total MOR reports and 14% of the 10,422 total NWSD reports, January-September 2014.

[c] Strike event was already entered in NWSD but MOR provided additional information such as aircraft registration number, time of day, or distance from airport.

[d] An additional 340 MOR ”bird strike” reports were examined that either involved military aircraft or were determined not to be a bird strike.

Table 15. Number of wildlife strikes with civil aircraft reported to the FAA in which the information was provided by a single report or was provided by multiple reports submitted by various independent sources, 2009-2013 compared to 2004-2008.

	2004 - 2008			2009 - 2013		
Source of strike report[a]	Strike events reported	Events w/ multiple reports[b]	Total reports examined	Strike events reported	Events w/ multiple reports	Total reports examined
FAA 5200-7[c]	25,666	3,380	30,534	45,314	13,226	63,885
Airline	5,315	503	5,856	1,585	5	1,590
Multiple	2,901	2,901	8,703	3,042	3,042	9,126
Airport	1,527	45	1,573	968	7	975
Daily report	462	2	464	442	0	442
Other[d]	359	1	360	551	0	551
PACIR	266	1	267	2	0	2
Total strike events	36,496	6,833	47,757	51,904	16,280	76,571
% with >1 report		19			31	

[a] See Dolbeer et al (2014*a*) for more detailed explanation of the various sources.

[b] Except for "Source = Multiple", these numbers indicate the number of strike events in which 2 or more (maximum was 9) reports of the same type (e.g., Form 5200-7) were submitted. For "Source = Multiple", more than one type (source) of report was submitted (e.g., Airline, FAA 52007, Airport). Based on an examination of 125 randomly selected records from 2009-2013 with "Source = Multiple", a mean of 3.03 different reports were submitted for each strike event with multiple sources.

[c] The proportion of strikes reported via FAA 5200-7 increased from 70% in 2004-2008 to 87% in 2009-2013 (91% in 2013).

[d] Miscellaneous sources such as ATO/MOR (see Table 14), NTSB, ASRS, ASIAS/AIDS, Engine manufacturers, AAIPN-1, Transport Canada, and News Media.

Table 16. Mean number of bird strikes in which bird was identified to species, mean percentage of bird strikes identified to species and mean number of bird species identified per year for 2009-2013 compared to 2004-2008 (see Figure 5 for trend analysis, 1990-2013).

Years	Bird strikes reported[a]	% of bird strikes identified to species	Bird species identified
2009-2013	5,324	53	283
2004-2008	2,619	37	191
Net change	2,705 (103%)	16 (43%)	92 (48%)

[a] Strikes in which the bird was identified to exact species. Strikes with unknown bird or bird only identified to species group were excluded from this analysis.

Figures

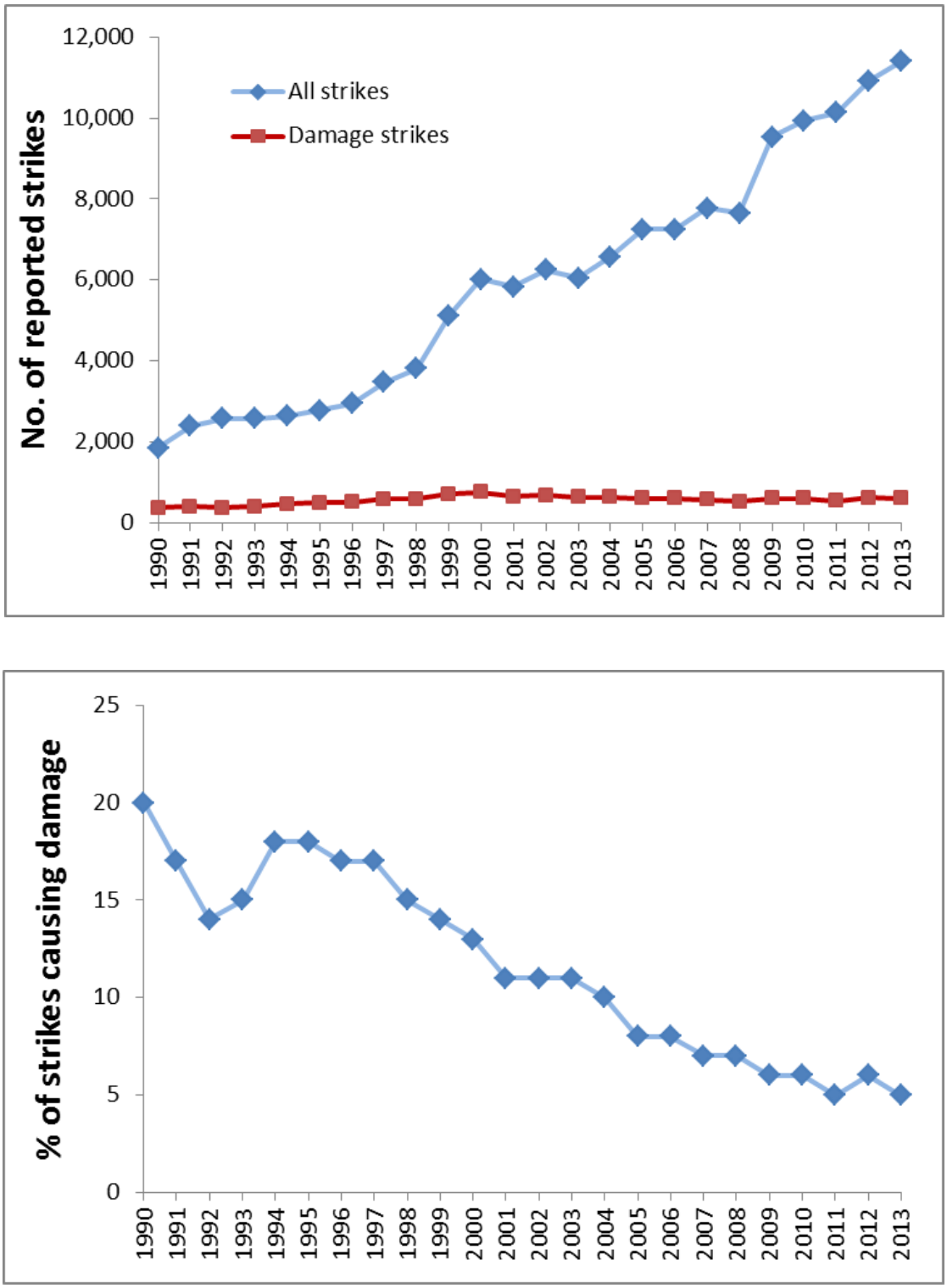


Figure 1. Number of reported wildlife strikes to civil aircraft and number of strikes with reported damage (top) and % of reported strikes indicating damage (bottom), 1990–2013 (see Table 1).

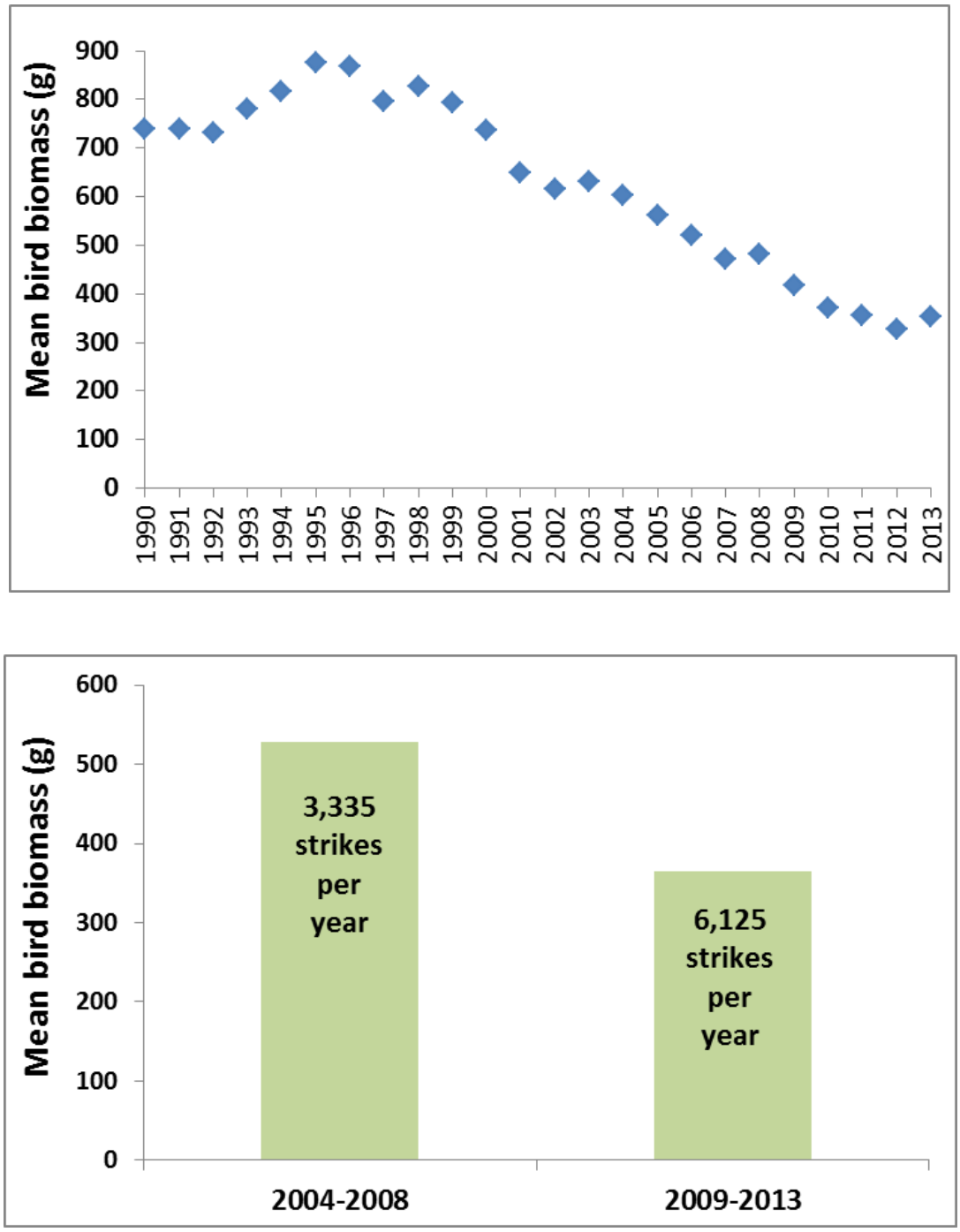


Figure 2. Mean biomass (grams) of birds reported struck by civil aircraft by year, 1990-2013 (top graph) and mean biomass of birds struck in 2004-2008 compared to 2009-2014 (bottom graph, see also Table 3). Strikes involving birds in which the bird was not identified at least to species group were excluded.

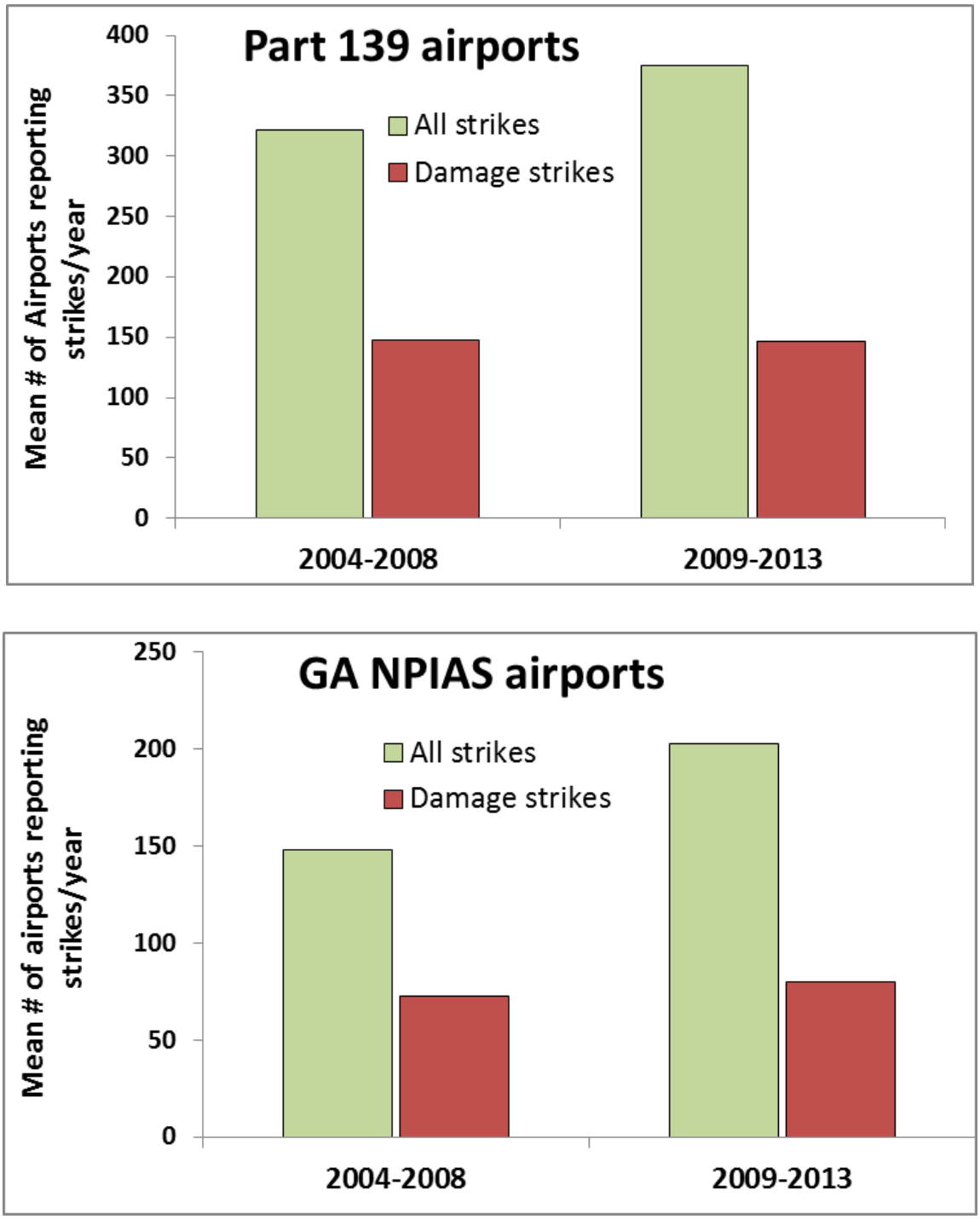


Figure 3. Mean number of airports reporting strikes and strikes with damage per year by type of civil airport for 2009-2013 compared to 2004-2008, USA. Top graph depicts Part 139 certificated airports; bottom graph depicts General Aviation airports in the National Plan of Integrated Airport System (NPIAS).

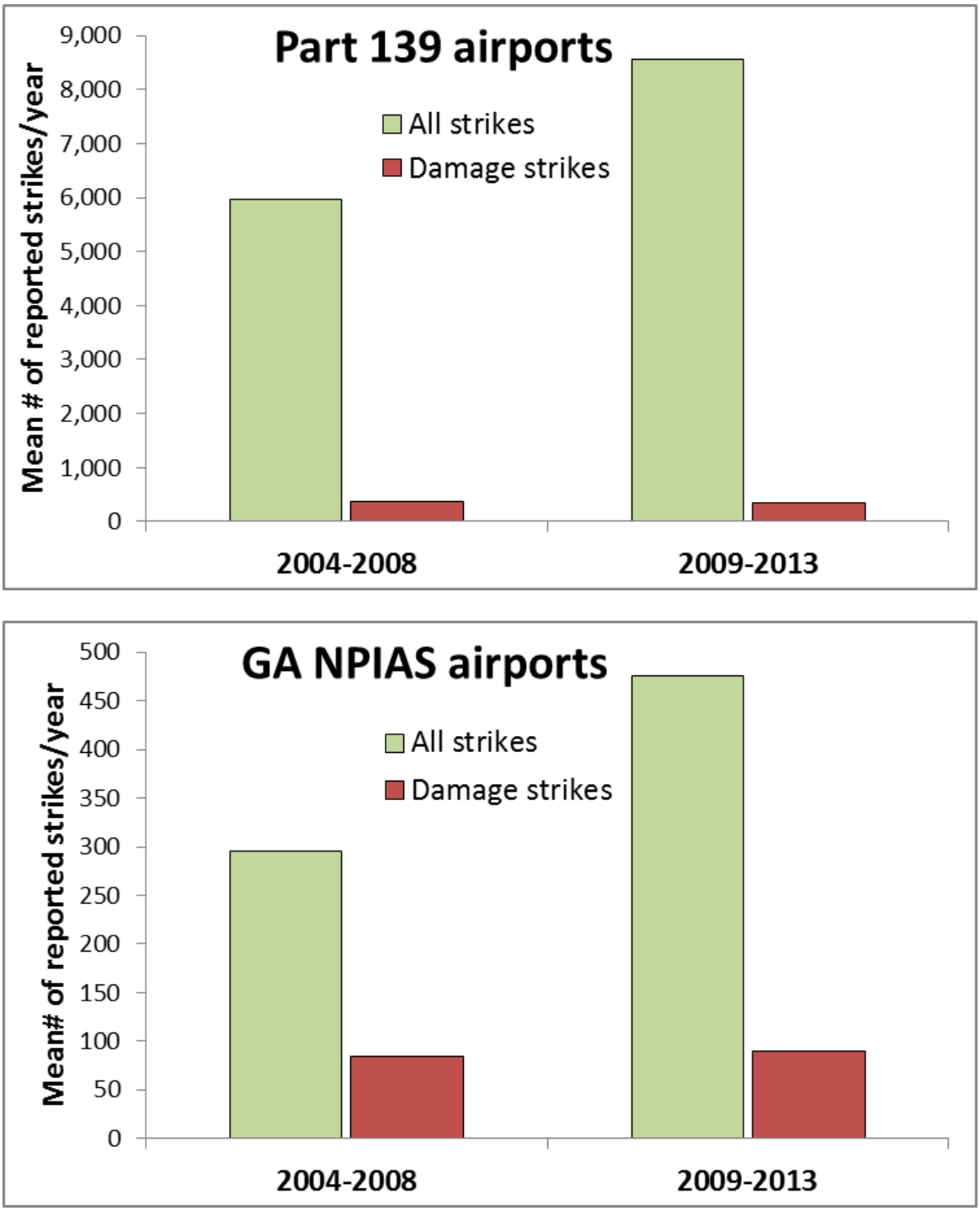


Figure 4. Mean number of reported strikes and reported strikes with damage per year by type of civil airport for 2009-2013 compared to 2004-2008, USA. Top graph depicts Part 139 certificated airports; bottom graph depicts General Aviation airports in the National Plan of Integrated Airport System (NPIAS).

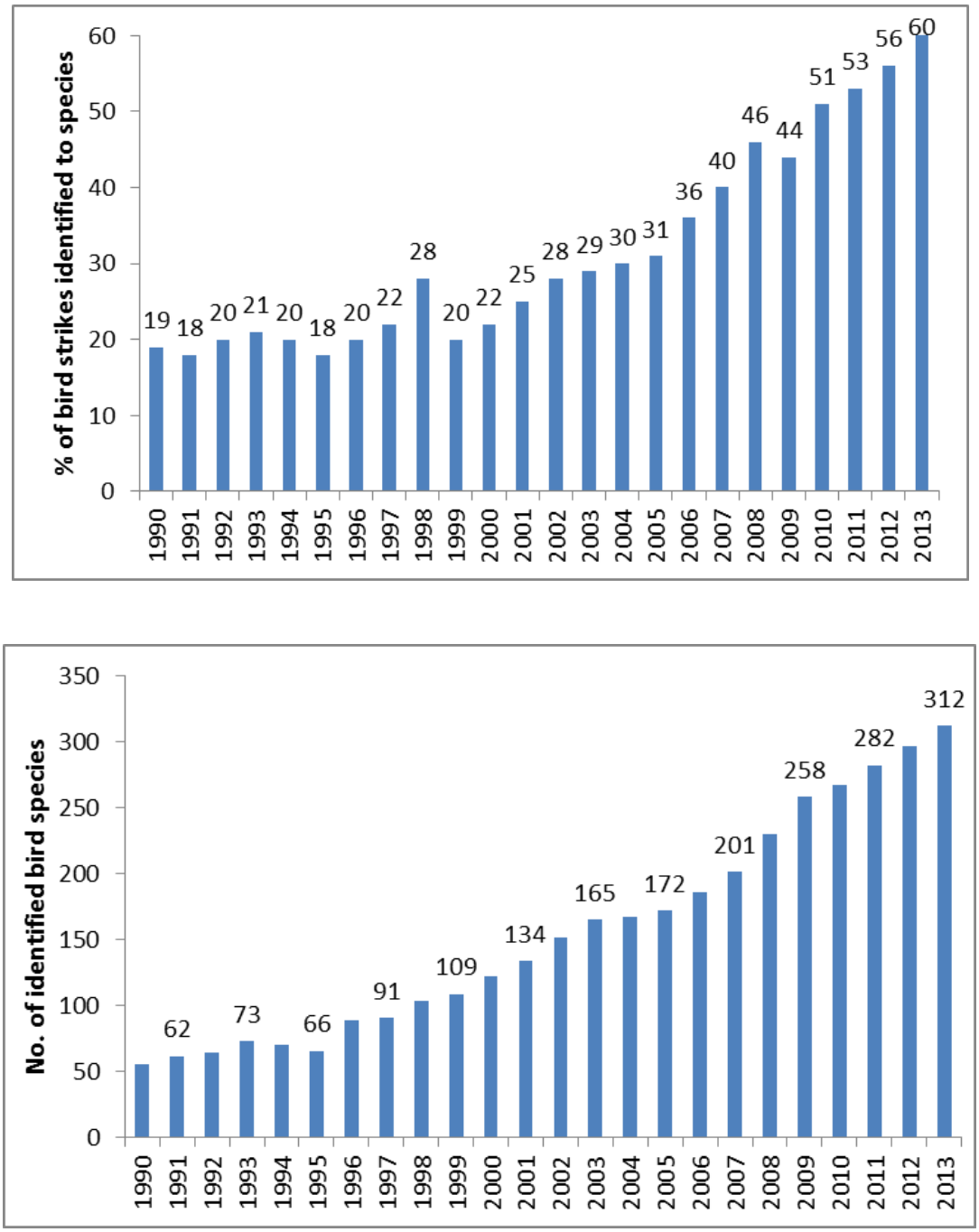


Figure 5. The percentage of reported bird strikes in which the bird was identified to species (top graph) and the number of identified bird species struck by civil aircraft each year (bottom graph), USA, 1990-2013. From 1990-2013, 506 different species of bird have been identified (see Table 16 for analysis of bird species identification in 2009-2013 compared to 2004-2008).

APPENDIX A. Trends in wildlife strikes, 1990 – 2013

Table A1. Number of airports, by classification, with at least 1 reported wildlife strike with civil aircraft in USA, and for foreign airports where USA-based carriers were involved in strike, 1990-2013. See Figures A1 and A2 for trend analyses, 1990-2013, and Tables 4 and 5 for comparison of 2004-2008 versus 2009-2013.

		General Aviation airports					
Year	Part 139-certificated[a]	Airports in NPIAS[a]	Airports not in NPIAS	Total GA airports	All USA airports	Foreign airports	All airports
1990	234	92	8	100	334	27	361
1991	259	86	11	97	356	27	383
1992	255	90	18	108	363	21	384
1993	259	82	16	98	357	18	375
1994	266	96	12	108	374	22	396
1995	261	108	13	121	382	32	414
1996	259	92	17	109	368	33	401
1997	284	103	21	124	408	41	449
1998	292	123	20	143	435	44	479
1999	302	119	28	147	449	58	507
2000	313	129	22	151	464	65	529
2001	317	133	18	151	468	49	517
2002	306	136	18	154	460	67	527
2003	305	131	24	155	460	67	527
2004	309	162	15	177	486	67	553
2005	321	158	19	177	498	80	578
2006	322	131	13	144	466	69	535
2007	328	148	18	166	494	72	566
2008	330	143	23	166	496	92	588
2009	365	196	35	231	596	101	697
2010	377	179	35	214	591	88	679
2011	367	185	40	225	592	103	695
2012	386	219	36	255	641	107	748
2013	380	235	42	277	657	84	741
Total	531	982	318	1300	1831	276	2107

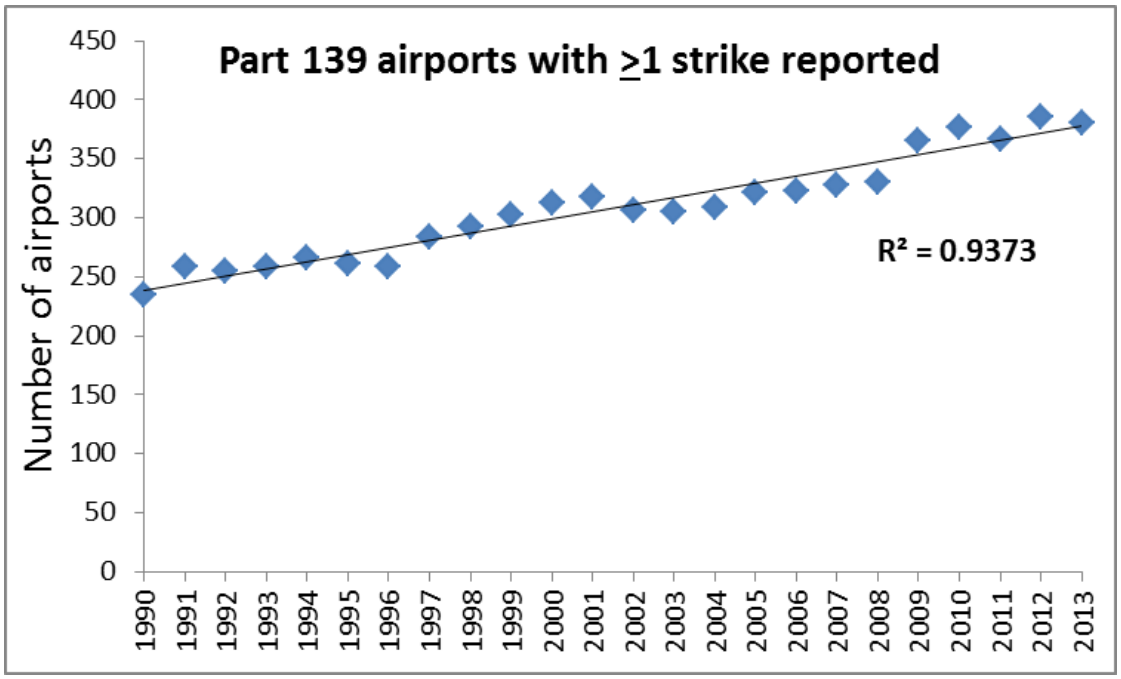
[a] There are about 3,427 airports in the National Plan of Integrated Airport System (NPIAS) (FAA 2014) of which about 540 are certificated under Part 139; thus there are about 2,887 non Part 139-certificated GA airports in the NPIAS.

Table A2. Number of reported wildlife strikes with civil aircraft by airport classification and for foreign airports where USA-based carriers were involved in strike, 1990-2013[a].

		General Aviation airports					
Year	Part 139-certificated[b]	Airports in NPIAS[b]	Airports not in NPIAS	Total GA airports	All USA airports	Foreign airports	All airports
1990	1,505	152	14	166	1,671	34	1,705
1991	1,981	190	17	207	2,188	37	2,225
1992	2,177	210	21	231	2,408	36	2,444
1993	2,219	197	24	221	2,440	33	2,473
1994	2,221	231	17	248	2,469	34	2,503
1995	2,316	208	15	223	2,539	45	2,584
1996	2,496	187	17	204	2,700	50	2,750
1997	2,903	181	32	213	3,116	69	3,185
1998	3,218	236	36	272	3,490	69	3,559
1999	3,804	222	43	265	4,069	98	4,167
2000	4,462	237	49	286	4,748	130	4,878
2001	4,431	271	30	301	4,732	124	4,856
2002	4,781	279	35	314	5,095	145	5,240
2003	4,664	312	35	347	5,011	141	5,152
2004	5,216	299	25	324	5,540	159	5,699
2005	5,510	318	21	339	5,849	183	6,032
2006	5,924	265	15	280	6,204	162	6,366
2007	6,570	313	24	337	6,907	142	7,049
2008	6,637	284	29	313	6,950	189	7,139
2009	8,022	418	40	458	8,480	253	8,733
2010	8,305	419	53	472	8,777	231	9,008
2011	8,448	435	65	500	8,948	265	9,213
2012	8,909	539	42	581	9,490	267	9,757
2013	9,113	568	54	622	9,735	201	9,936
Total	115,832	6,971	753	7,724	123,556	3,097	126,653[a]

[a] In addition, 16,022 strikes were reported in which the aircraft was en-route or the airport where the strike took place could not be determined with certainty.

[b] There are about 3,427 airports in the National Plan of Integrated Airport System (NPIAS) (FAA 2014) of which about 540 are certificated under Part 139; thus there are about 2,887 non Part 139-certificated GA airports in the NPIAS.



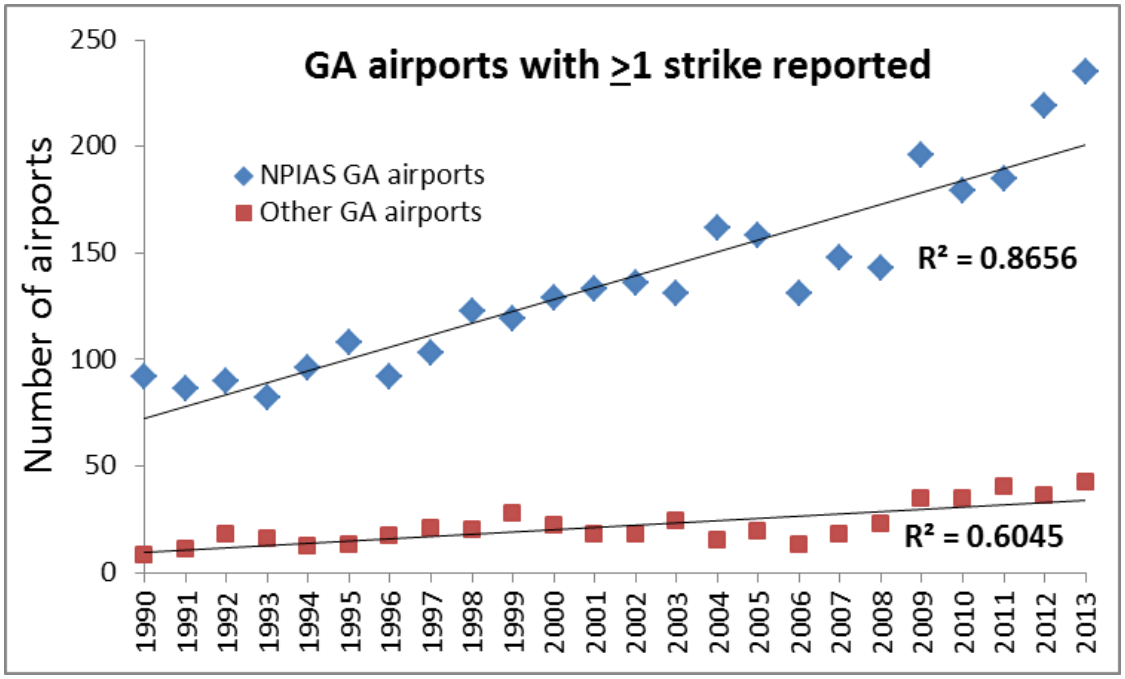
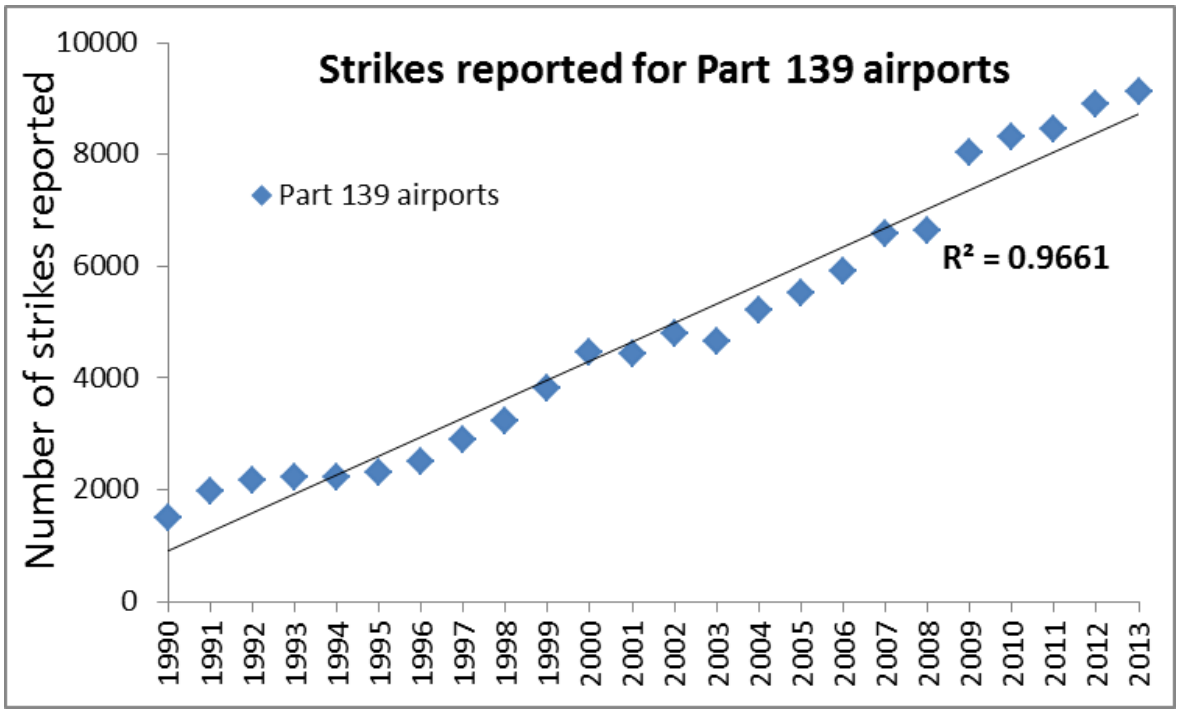


Figure A1. Number of airports with at least 1 reported wildlife strike for Part 139-certificated airports (top graph), and for General Aviation [GA]) airports that are a part of the National Plan of Integrated Airport System (NPIAS) and for other GA airports that are not in NPIAS (bottom graph), 1990-2013 (see Table 4 and Table A1). R^2 values >0.163 (22 df) are significant (Steele and Torre 1960).



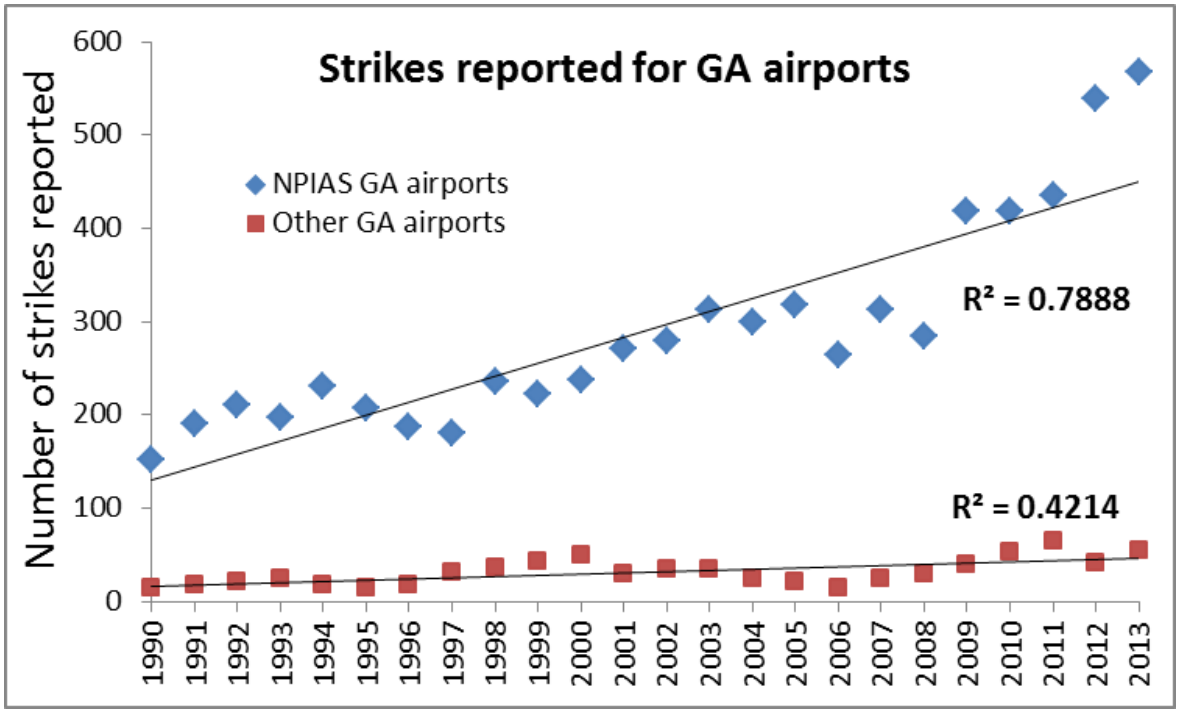


Figure A2. Number of reported wildlife strikes for Part 139-certificated airports (top graph), and for General Aviation [GA]) airports that are a part of the National Plan of Integrated Airport System (NPIAS) and for other GA airports that are not in NPIAS (bottom graph), 1990-2013 (see Table 4 and Table A2). R^2 values > 0.163 (22 df) are significant (Steele and Torre 1960).

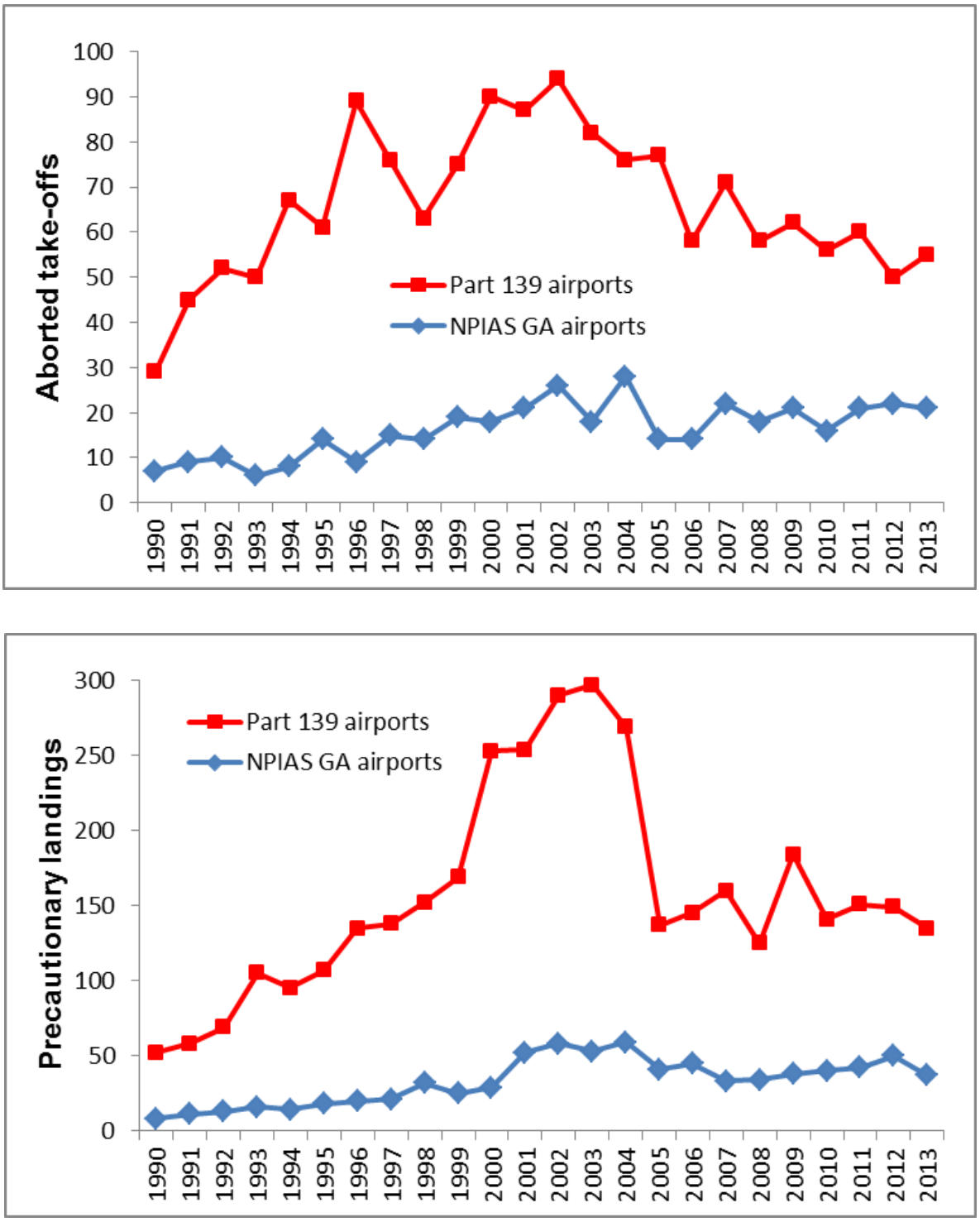


Figure A3. Number of wildlife-induced aborted take-offs (top graph) and precautionary landings (bottom graph) per year at Part 139 and NPIAS GA airports after aircraft struck or encountered wildlife on runway during take-off run, 1990-2013 (see Table 6 for detailed analysis of years 2009-2013 compared to 2004-2008).