Department of Defense
Legacy Resource Management Program

PROJECT NUMBER 11−944

Bird Strike Hazards and Mitigation Strategies for Military Rotary-wing Aircraft

Washburn, Cisar, and DeVault

31 December 2012

FINAL PROJECT REPORT

The efforts of this study report are dedicated to Captain Jeffrey Bland and 1st Lieutenant Thomas Heitmann, United States Marine Corps, Light Attack Helicopter Training Squadron 303. Both Marines perished on 19 September 2011 after their AH-1W (Super Cobra) attack helicopter struck a Red-tailed Hawk during a daytime mission and crashed at Marine Corps Air Station Camp Pendleton. Ideally, the findings of this report will help avoid the future tragic loss of heroic young men and women who take to the air to bravely defend our freedom.

FINAL PROJECT REPORT

Legacy Project Number: 11−944

Project Title

BIRD STRIKE HAZARDS AND MITIGATION STRATEGIES FOR MILITARY ROTARY-WING AIRCRAFT

Service/Sponsor: US Army

MAJCOM: Army Installation Management Command

Report Submitted by:

Brian E. Washburn, Ph.D.
Research Wildlife Biologist
USDA, APHIS, Wildlife Services,
National Wildlife Research Center
Sandusky, OH

Paul J. Cisar
Chief, Training and Operations Support Branch
US Army Environmental Command
Aberdeen, MD

Travis L. DeVault, Ph.D.
Field Station and Project Leader
USDA, APHIS, Wildlife Services,
National Wildlife Research Center
Sandusky, OH

31 December 2012

ACKNOWLEDGMENTS

We thank the United States Department of Defense (DoD) Legacy Resource Management Program for funding and supporting the execution of this project. We appreciate the encouragement, professional advice, and data access provided by the United States Air Force Safety Center Bird/Wildlife Aircraft Strike Hazard (BASH) Team (specifically Daniel Sullivan and Lt. Tiffany Robertson), the U.S. Navy BASH Team and the Naval Safety Center (specifically Matthew Klope and Lt. Vern Jensen), the U.S. Army Combat Readiness/Safety Center (specifically Robert Dickinson and Charisse Lyle), and the U.S. Coast Guard Safety Center (specifically LCDR Brian Potter).

DISCLAIMER

This report was prepared under an interagency agreement with the U.S. Department of Agriculture, Animal Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, with funds awarded by the DoD Legacy Resource Management Program. The content reflects the views of the National Wildlife Research Center and does not necessarily reflect the views of the DoD Legacy Resource Management Program.

EXECUTIVE SUMMARY

Wildlife collisions with civilian and military aircraft pose significant risks and economic losses. Worldwide, wildlife strikes have resulted in the loss of more than 276 human lives and more than 200 military and civil aircraft since 1988. Wildlife strikes with civil aircraft are well documented through the Federal Aviation Administration's (FAA) National Wildlife Strike Database (NWSD) in the United States (U.S.). The Military Services within the U.S. Department of Defense – U.S Army (ARMY), U.S. Air Force (USAF), U.S. Navy and U.S. Marine Corps (NAVY), and the U. S. Coast Guard (USCG) – maintain records regarding wildlife strikes with military aircraft. Military wildlife strikes differ from wildlife strikes with civil aircraft in various aspects. Patterns and characteristics of wildlife strikes might also vary among types of aircraft (i.e., between fixed-wing and rotary-wing aircraft).

Although several examinations of wildlife strikes with fixed-wing aircraft (both civilian and military) have been conducted, there are currently very few available analyses of wildlife strike hazards to civil helicopters. Although rotary-wing aircraft operations comprise important mission components of all Military Services, no assessment of wildlife strikes to military rotary-wing aircraft has been conducted. Thus, a comprehensive analysis of wildlife strikes to rotary-wing aircraft among all Military Services is clearly needed to provide an understanding of the nature and extent of this issue.

The objectives of this project were to (1) acquire wildlife strike data for military rotary-wing aircraft and civil helicopters, (2) conduct a comprehensive analysis of data available from all Military Services regarding wildlife strikes with rotary-wing aircraft, (3) compare military rotary-wing wildlife strikes to those with civil helicopters, and (4) provide recommendations for aircrews, flight and mission planners, aircraft engineers, and airfield managers to reduce the frequency and negative impacts of wildlife strikes to military flight operations.

We acquired all available wildlife strike records and associated information involving rotary-wing aircraft from the Military Services. We acquired all wildlife strike data to civil helicopters from the FAA's NWSD. We created a new inclusive rotary-wing wildlife strike database and conducted a line-by-line review of each wildlife strike record in the database to ensure data integrity and consistency. We parsed our database to include only wildlife strikes to military rotary-wing aircraft and civil helicopters that were reported to have occurred within the contiguous U.S., Alaska, Hawaii, or within near-shore areas along the coasts. In addition, we examined wildlife strikes to ARMY and USAF rotary-wing aircraft engaged in flight operations during overseas deployments associated with U.S. military bases around the world.

Overall, wildlife strikes with ARMY and USCG rotary-wing aircraft remained constant across years. The ARMY and USCG do not have formal BASH programs and thus we suspect that many wildlife strikes, particularly ones not causing damage, are often unreported. An increasing pattern of reported wildlife strikes to USAF and NAVY rotary-wing aircraft over time was likely due to increased awareness and increases in 'in theater' overseas flight operations (e.g., Search and Rescue) for USAF rotary-wing aircraft squadrons during the latter half of the 2000s.

Month (season), time of day, location (on- or off-airfield), and other factors influenced the frequency of wildlife strikes with rotary-wing aircraft and with civil helicopters. For both civil and military aircraft, the frequency of wildlife strikes was highest during fall (September and October) and lowest number during winter (December through February).

Although wildlife strikes to military rotary-wing aircraft and civil helicopters occurred during all phases of (aircraft) flight, wildlife strikes happened most frequently when the aircraft were traveling enroute or were engaged in terrain flight. The highest proportion of impact locations for reported wildlife strikes within the U.S. for all Military Services was the windscreen, although the radome / nose and main rotor system were also frequently struck by wildlife. In regard to wildlife strikes with civil helicopters, the windscreen was the most commonly struck section during flight operations within the U.S.

Wildlife strikes with ARMY and USAF rotary-wing aircraft were reported to have occurred in more than 31 foreign countries. Almost two-thirds of overseas reported wildlife strikes to ARMY rotary-wing aircraft occurred during deployments in the Middle East (e.g., Iraq), whereas wildlife strikes to USAF rotary-wing aircraft outside of the U.S. occurred most frequently in Afghanistan and Iraq. Although ARMY and USAF rotary-wing aircraft collided with a wide variety of bird species during flight operations outside of the U.S., the groups most frequently struck were larks, perching birds, and doves and pigeons.

Wildlife strikes to military rotary-wing aircraft and civil helicopters during flight operations within the U.S. are both costly and deadly. The average cost of a damaging wildlife strike to a military rotary-wing aircraft varied from $12,184 per incident for USCG aircraft to $337,281 per incident for NAVY aircraft. The average cost of a damaging wildlife strike to a civil helicopter within the U.S. was $41,158. Wildlife strikes to military rotary-wing aircraft resulted in a total of 8 human injuries and 2 human fatalities during 1979−2011, whereas wildlife strikes to civil helicopters caused a total of 52 human injuries and 9 human fatalities during 1990−2011. Human injuries were typically cuts, lacerations, and/or bruising to pilots and copilots. Two servicemen were lost when a Red-tailed Hawk (*Buteo jamaicensis*) collided with a USMC AH-1W ‘Super Cobra’ attack helicopter, causing it to crash in California in 2011. Eight people were lost when a Red-tailed Hawk struck a private corporation’s civil helicopter, causing it to crash in Louisiana in 2009.

Our analyses of wildlife strikes to military rotary-wing aircraft, both within the U.S. and during overseas deployments, as well as civil helicopters have shown that there are important patterns within wildlife strike data for flight operations conducted both on airfields and during off-airfield missions. Based on our findings, we provide recommendations to aircrews, flight and mission planners, aircraft engineers, and airfield managers to increase their understanding of wildlife strikes to rotary-wing aircraft and to provide general guidelines for reducing the frequency and severity of such events (Section 5.5 of this report).

TABLE OF CONTENTS

1. INTRODUCTION ……..……..……...1

2. BACKGROUND …….....…….2

3. METHODS …...……..……..……..……2

3.1. Planning Phase ……2

3.2. Execution Phase ……..3

3.3. Statistical Analyses ……6

4. RESULTS .....……..…….……7

4.1. Wildlife Strikes with Military Rotary-wing Aircraft Within the U.S.……....…8

4.1.1. 'On' Airfield Wildlife Strikes …..…….…….....…….19

4.1.2. 'Off' Airfield Wildlife Strikes …….…….....……..…….22

4.2. Wildlife Strikes with ARMY and USAF Rotary-wing Aircraft Deployed Outside the U.S. …….…..……..…….....26

4.2.1. 'On' Airfield Wildlife Strikes …..…….…….....…….35

4.2.2. 'Off' Airfield Wildlife Strikes …….…….....……..…….37

4.3 Wildlife Strikes with Civil Helicopters …….…….....…….40

4.3.1. 'On' Airfield Wildlife Strikes …..…….…….....…….47

4.3.2. 'Off' Airfield Wildlife Strikes …….…….....……..…….50

5. DISCUSSION ……...……..……53

5.1. Wildlife Strikes with Military Rotary-wing Aircraft Within the U.S. ….....53

5.2. Wildlife Strikes with Military Rotary-wing Aircraft Outside of the U.S. ..……55

5.3. Wildlife Strikes with Civil Helicopters …...……..……...…….……..56

5.4. Comparisons of Wildlife Strikes with Military Rotary-wing Aircraft and Civil Helicopters ….…….……58

TABLE OF CONTENTS (CONTINUED)

5.5. Recommendations for Aircrews, Flight and Mission Planners, Aircraft Engineers, and Airfield Managers ……...58

5.6. Limitations of the Study ..…..……...……59

6. BENEFIT TO THE MISSION ..……...……60

7. LITERATURE CITED ..……...……61

LIST OF FIGURES

Figure 1. An ARMY UH-60 'Black Hawk' helicopter conducting an 'in theater' operational mission. Variants of the Sikorsky made H-60 airframe (aircraft model) are used by all Military Services for a variety of mission types. **6**

Figure 2. Total number of reported wildlife strikes with ARMY and USAF rotary-wing aircraft, each year, during 1990−2011. ..... **7**

Figure 3. Total number of reported wildlife strikes with ARMY rotary-wing aircraft, each year, in the U.S. during 1990−2011. ..... **9**

Figure 4. Total number of reported wildlife strikes with USAF rotary-wing aircraft, each year, in the U.S. during 1994−2011. ..... **9**

Figure 5. Total number of reported wildlife strikes with NAVY rotary-wing aircraft, each year, in the U.S. during 2001−2011. ..... **10**

Figure 6. Total number of reported wildlife strikes with USCG rotary-wing aircraft, each year, in the U.S. during 1979−2011. ..... **10**

Figure 7. Proportion (%) of reported wildlife strikes, by month, in the U.S. for rotary-wing aircraft for each Military Service during 1979−2011. ..... **11**

LIST OF FIGURES (CONTINUED)

Figure 8. Proportion (%) of reported wildlife strikes, by time of day, in the U.S. for rotary-wing aircraft for each Military Service during 1990−2011 ..... **12**

Figure 9. Total number of reported wildlife strikes with ARMY rotary-wing aircraft, each year, outside of the U.S. during 1990−2011 ..... **27**

Figure 10. Total number of reported wildlife strikes with USAF rotary-wing aircraft, each year, outside of the U.S. during 1994−2011 ..... **27**

Figure 11. Proportion (%) of reported wildlife strikes, by month, for ARMY and USAF rotary-wing aircraft at locations outside of the U.S. during 1990−2011. ..... **28**

Figure 12. Proportion (%) of reported wildlife strikes, by time of day, with ARMY and USAF rotary-wing aircraft at locations outside of the U.S. during 1990−2011 ..... **28**

Figure 13. Total number of reported wildlife strikes with civil helicopters, each year, in the U.S. during 1990−2011 ..... **41**

Figure 14. Proportion (%) reported wildlife strikes, by month, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1979−2011 ..... **42**

Figure 15. Proportion (%) of reported wildlife strikes, by time of day, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011 ..... **42**

LIST OF TABLES

Table 1. Number of reported wildlife strikes, by wildlife group, in the U.S. for rotary-wing aircraft for each Military Service and for all Services combined during 1990−2011 ..... **14**

Table 2. Number of reported wildlife strikes, by airframe model, in the U.S. for rotary-wing aircraft for each Military Service during 1979−2011 ..... **15**

Table 3. Number of reported wildlife strikes, by aircraft category, in the U.S. for rotary-wing aircraft for each Military Service and for all Services combined during 1979−2011 ..... **16**

Table 4. Proportion (%) of reported wildlife strikes, by phase of flight, in the U.S. for rotary-wing aircraft for each Military Service during 1979−2011 ..... **16**

Table 5. Proportion (%) of reported wildlife strikes, by impact location on the aircraft, in the U.S. for rotary-wing aircraft for each Military Service during 1979−2011 ..... **18**

Table 6. Number of reported wildlife strikes, without or with damage where the strike occurred 'on' or 'off' an airfield, in the U.S. for rotary-wing aircraft for each Military Service during 1990−2011 ..... **18**

Table 7. Number of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'on' or over an airfield, by wildlife group, in the U.S. for rotary-wing aircraft for each Military Service during 1990−2011 ..... **20**

Table 8. Proportion (%) of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'on' or over an airfield, by impact location on the aircraft, in the U.S. for rotary-wing aircraft for each Military Service during 1990−2011 ..... **21**

Table 9. Number of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'off' an airfield, by wildlife group, in the U.S. for rotary-wing aircraft for each Military Service during 1990−2011 ..... **24**

Table 10. Proportion (%) of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'off' an airfield, by impact location on the aircraft, in the U.S. for rotary-wing aircraft for each Military Service during 1990−2011 ..... **24**

LIST OF TABLES (CONTINUED)

Table 11. Number of reported wildlife strikes, by foreign country, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011 ..... **30**

Table 12. Number of reported wildlife strikes, by wildlife group, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011 ..... **31**

Table 13. Number of reported wildlife strikes, by airframe model, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011 ..... **32**

Table 14. Number of reported wildlife strikes, by aircraft category, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011 ..... **32**

Table 15. Proportion (%) of reported wildlife strikes, by phase of flight, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011 ..... **33**

Table 16. Proportion (%) of reported wildlife strikes, by impact location on the aircraft, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011 ..... **34**

Table 17. Number of reported wildlife strikes, without or with damage where the strike occurred 'on' or 'off' an airfield, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011 ..... **34**

Table 18. Number of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'on' or over an airfield, by wildlife group, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011 ..... **36**

Table 19. Proportion (%) of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'on' or over an airfield, by impact location on the aircraft, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011 ..... **37**

Table 20. Number of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'off' an airport, by wildlife group, for USAF rotary-wing aircraft outside of the U.S. during 1990−2011 ..... **38**

Table 21. Proportion (%) of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'off' an airfield, by impact location on the aircraft, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011 ..... **40**

LIST OF TABLES (CONTINUED)

Table 22. Proportion (%) of reported wildlife strikes, by wildlife group, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011 ..... **44**

Table 23. Number of reported wildlife strikes, by airframe model, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1979−2011 ..... **45**

Table 24. Proportion (%) of reported wildlife strikes, by phase of flight, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1979−2011 ..... **45**

Table 25. Proportion (%) of reported wildlife strikes, by impact location on the aircraft, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1979−2011 ..... **46**

Table 26. Number of reported wildlife strikes, without or with damage where the strike occurred 'on' or 'off' an airfield, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011 ..... **46**

Table 27. Number of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'on' or over an airfield, by wildlife species group, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011 ..... **48**

Table 28. Proportion (%) of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'on' or over an airfield, by impact location on the aircraft, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011 ..... **49**

Table 29. Number of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'off' an airport, by wildlife species group, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011 ..... **51**

Table 30. Proportion (%) of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'off' an airfield, by impact location on the aircraft, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011 ..... **52**

LIST OF ACRONYMS

AAF	Army Air Field
AFB	Air Force Base
AGL	Above Ground Level
AHAS	Avian Hazard Advisory System
ARMY	United States Army
BASH	Bird/Animal Aircraft Strike Hazard
FAA	Federal Aviation Administration
MCAS	Marine Corps Air Station
MOA	Military Operations Area
MTR	Military Training Route
NAS	Naval Air Station
NAVY	United States Navy
NOLF	Naval Outlying Landing Field
NWSD	National Wildlife Strike Database
SAR	Search and Rescue
SE	Standard Error of the Mean
USAF	United States Air Force
USCG	United States Coast Guard
USMC	United States Marine Corps
VIP	Very Important Person

1. INTRODUCTION

Wildlife collisions with aircraft (of which 97% involve birds) pose increasing risks and economic losses to aviation worldwide. Annual economic losses from such strikes with civil aircraft are conservatively estimated to exceed $1.2 billion worldwide and $718 million in the United States (U.S.) alone (Allan 2002, Dolbeer et al. 2012). The U.S. military also incurs substantial losses from wildlife strikes. From 1985 to 1998, bird strikes cost the U.S. Air Force (USAF) alone an average of $35 million annually (Zakrajsek and Bissonette 2005). Worldwide, wildlife strikes have resulted in the loss of more than 276 human lives and more than 200 military and civil aircraft since 1988 (Thorpe 2010, Dolbeer et al. 2012).

Wildlife strikes with civil aircraft are well documented. The Federal Aviation Administration (FAA) maintains the FAA National Wildlife Strike Database (NWSD) for civil aviation in the U.S. and produces annual summary reports (Dolbeer et al. 2012). Wildlife strikes with military aircraft are less well characterized, although it is clear that military wildlife strikes differ from wildlife strikes with civil aircraft in various aspects. For example, Zakrajsek and Bissonette (2005) ranked bird strike hazards for USAF aircraft and noted several differences from similar rankings for civil aircraft as reported by Dolbeer et al. 2000 (also see DeVault et al. 2011). In particular, some smaller-sized birds [e.g., blackbirds (Icteridae), Horned Lark (*Eremophila alpestris*), thrushes (Turdidae), meadowlarks (*Sturnus* spp.)] were considered to be more hazardous to military aircraft than to civil aircraft. This disparity is likely due to differences in flight characteristics and procedures between military and civilian aircraft. Patterns and characteristics of wildlife strikes might also vary among types of aircraft (i.e., between fixed-wing and rotary-wing aircraft). A fixed-wing aircraft is a vehicle capable of flight using wings that generate vertical lift due to forward airspeed, typically produced by an engine, and the shape of the wings (Montgomery and Foster 2006). An airplane is the most common class of fixed-wing aircraft; airplanes come in a variety of shapes, sizes, and wing configurations. A rotary-wing aircraft is supported in flight using lift generated by wings, called rotor blades, which revolve around and are typically mounted on a single mast (e.g., rotor; Montgomery and Foster 2006). Helicopters are the most common class of rotary-wing aircraft, both in the military and civilian applications. A tilt-wing aircraft, such as the Bell-Boeing V-22 Osprey, is an aircraft that uses a pair of powered rotors mounted on rotating shafts for lift and propulsion (Eden 2004, Montgomery and Foster 2006). For the purposes of this report, we classified tilt-wing aircraft as rotary-wing aircraft.

The objectives of this project are to (1) acquire wildlife strike data for military rotary-wing aircraft and civil helicopters, (2) conduct a comprehensive analysis of data available from all Military Services regarding wildlife strikes with rotary-wing aircraft, (3) compare military rotary-wing wildlife strikes to those with civil helicopters, and (4) provide recommendations for aircrews, flight and mission planners, aircraft engineers, and airfield managers to reduce the frequency and negative impacts of wildlife strikes to military flight operations.

2. BACKGROUND

Although several examinations of wildlife strikes with fixed-wing aircraft (both civilian and military) have been conducted (examples include Dolbeer et al. 2000, Zakrajsek and Bissonette 2005, DeVault et al. 2011, Dolbeer et al. 2012), there are currently no available analyses of wildlife strike hazards for military rotary-wing aircraft.

An initial review of U.S. Army (ARMY) Safety Center Bird/Wildlife Aircraft Strike Hazard (BASH) data for the period of 1990−2010 indicated that ARMY rotary-wing aircraft reported wildlife strikes were an important issue and resulted in more than $2.6 million in damage to aircraft during that time period. Notably, it appeared that ARMY data on wildlife strikes is generally limited to strikes that cause significant monetary (i.e., reportable) damage to the aircraft. Although rotary-wing aircraft operations comprise important mission components of all Military Services, no assessment of wildlife strikes to rotary-wing aircraft has been conducted. Thus, a comprehensive analysis of wildlife strikes to rotary-wing aircraft among all Military Services is clearly needed to provide an understanding of the nature and extent of this issue.

In addition to general differences in bird strike hazards between civil and military aircraft, there are notable differences with respect to aircraft type. In 2006, the U.S. Department of Agriculture and the FAA conducted a cursory investigation into reported bird strikes to civil helicopters during 1990−2005 (Cleary et al. 2006). Their analysis indicated that 50% of bird strikes to civilian helicopters resulted in damage to the aircraft, and 18% of the bird strikes resulted in substantial damage. In comparison, during the same time period only 15% of strikes to other aircraft types resulted in damage and only 4% incurred substantial damage. Furthermore, helicopters accounted for 13% of destroyed aircraft (i.e., total airframe loss) and 24% of the human injuries caused by bird strikes, even though helicopters comprised only 0.6% of all reported bird strikes to civil aircraft during that period. Helicopters also encountered a much higher rate of strikes during the enroute phase of flight (63% of strikes), whereas only 2% of bird strikes with civilian fixed-wing aircraft occurred enroute. These differences in patterns of bird strikes among aircraft types warrant further study.

3. METHODS

3.1 Planning Phase

Service representatives from the ARMY, USAF, U.S. Navy and U.S. Marine Corps (hereafter combined as NAVY), and the U.S. Coast Guard (USCG) Safety Centers and BASH programs endorsed this research effort and offered access to the military wildlife strike data needed to conduct the analyses. We identified the appropriate individual from the Safety Center of each Military Service that served as a point of contact. Working with each point of contact, we requested all wildlife strike records and associated information from their respective wildlife strike databases for all available years.

3.2 Execution Phase

We acquired all available wildlife strike records to rotary-wing aircraft from the Military Services (i.e., ARMY, USAF, NAVY, and USCG). In addition, we acquired narrative records and other information (e.g., USMC flash reports) regarding wildlife strikes with military rotary-wing aircraft.

Wildlife strike data to civilian rotary-wing aircraft (i.e., civil helicopters) for the U.S. are readily available from the FAA's NWSD. We searched the NWSD and extracted all records that involved rotary-wing aircraft during 1990−2011. The wildlife strike information in the NWSD is obtained through a voluntary reporting system; the information is primarily reported to the FAA by pilots and airports (Dolbeer et al. 2012).

Using all available records from each of the 5 wildlife strike databases, we created a new inclusive rotary-wing wildlife strike database. We conducted a line-by-line review of each wildlife strike record in the inclusive database to ensure data integrity and consistency. Due to the diverse nature of the data fields contained within the different databases, it was necessary to extract data from narrative records, accident reports, and incident information (e.g., pilot commentary). We removed duplicate records (e.g., when the same wildlife strike incident found in the USAF and FAA civil databases, USCG and FAA civil databases) and parsed out wildlife strike records that were associated with fixed-wing aircraft.

We examined all available information (i.e., strike databases, incident reports) for each wildlife strike record and (when possible or necessary) recoded or classified wildlife strike information to allow for consistency in terminology / categories among Military Services and civil helicopter strike records for variable (e.g., the phase of flight the aircraft was in when the wildlife strike was reported to have occurred).

To ensure data consistency among summaries and analyses, we parsed our database to include only wildlife strikes to military rotary-wing aircraft and civil helicopters that were reported to have occurred with the contiguous United States (CONUS), Alaska, Hawaii, or within near-shore areas along the coasts (i.e., < 10 miles from the U.S. coastline).

In addition, we were able to extract pertinent wildlife strike records and thus developed a separate database of wildlife strikes to ARMY and USAF rotary-wing aircraft engaged in flight operations during overseas deployments (i.e., outside of the U.S.) associated with U.S. military bases around the world. Notably, these flight operations were conducted during training exercises, peacekeeping operations, and 'in theater' combat operations (e.g., within Iraq and Afghanistan).

Based on the reported local time, the time of day each wildlife strike event was reported to have occurred was determined. Strike events reported to have occurred between 08:00 to 18:00 local time were categorized as 'day', whereas strike events between 20:00−06:00 were categorized as 'night'. 'Dawn' strike events occurred during 06:00−08:00 and 'dusk' during 18:00−20:00.

For each individual wildlife strike event, if information was available, the animal(s) involved was assigned to one of 28 wildlife groups. Wildlife groups were based on guilds and taxonomic groupings of related wildlife species and families (DeGraff et al. 1985). In cases where the wildlife involved was identified to the species level, we assigned that wildlife strike to the appropriate wildlife group based on the species involved [e.g., Canada Goose (*Branta canadensis*) would be assigned to the 'Waterfowl' wildlife group]. Wildlife strike events to rotary-wing aircraft involving more than one individual animal (e.g., a flock of birds) were enumerated the same as wildlife strike events that involved only one animal, because the number of individuals involved was not available from the majority of reported wildlife strikes from the various databases.

The airframe model for each rotary-wing aircraft reported to be involved in a wildlife strike event was determined from the designation provided for that aircraft within the strike event record and associated reports. Several civil and military variants of a given airframe model might exist, all which were placed into the same airframe model category. For example, the Sikorsky manufactured H-60 airframe is used by the ARMY (as the 'Black Hawk'), by the USAF (as the 'Pave Hawk'), by the NAVY (as the 'Seahawk'), and by the USCG (as the 'Jayhawk). Variants of the Bell manufactured H-57 airframe is used by the military (e.g., NAVY TH-57) and by civilian entities and private companies (e.g., Bell Ranger series).

The aircraft category for each rotary-wing aircraft was determined from the designation provided for that aircraft (Eden 2004). For example, an AH-64 would be designated into the 'attack' category, whereas a CH-47 would be designated into the 'cargo' aircraft category. The aircraft category relates the variant for the airframe and the specific configuration of that aircraft (e.g., weapons systems, equipment).

When the proper information was available within the wildlife strike records, we categorized the mission type for each reported wildlife strike event into 1 of 4 categories: (1) Search and rescue (SAR) operations involved efforts to find and retrieve personnel from hazardous situations (e.g., lifesaving efforts associated with capsized watercraft), (2) Service operations involved a variety of missions to provide support or service (e.g., law enforcement, moving personnel and/or equipment), (3) Training operations involved flight operations associated with pilot and/or aircrew training, and (4) Combat operations involved flight operations by rotary-wing aircraft in hostile environments (e.g., in support of ground personnel).

Phase of flight was defined as the phase of flight the aircraft was in at the time the wildlife strike occurred (FAA 2000, U.S. Army 2012). Aircraft in the 'enroute' phase of flight were flying at an altitude of 1,000 feet Above Ground Level (AGL) or higher. Rotary-wing aircraft that were flying (moving forward) at an altitude of less than 1,000 feet AGL were classified as being in 'terrain flight'. 'Hovering' rotary-wing aircraft were off the ground (but less than 1,000 feet AGL) and stationary (i.e., no horizontal movement). Aircraft on 'approach' were in early stages of the landing process of landing (at more than 100 feet AGL and moving forward), typically on or over an airfield. 'Landing' rotary-wing aircraft were in the final stages of landing and were less than 100 feet AGL. Rotary-wing aircraft that were 'taxiing' were moving along the ground or just above the ground (less than 10 feet AGL) in a transition for one part of the airfield to another (e.g., traversing from the hanger to an active helopad). Aircraft in the 'take-off' phase were in the process of leaving the ground and were ascending upward (at or below 100 feet AGL). Rotary-wing aircraft in the 'climbout' phase were in the later stages of 'taking off' (at more than 100 feet AGL and moving forward), typically on or over the airfield.

The impact location was defined as the area(s) of the airframe that the wildlife 'struck' during a reported wildlife strike event. For example, if a bird hit the nose, chin bubble, or other part of the very front of an aircraft, the impact location was categorized as 'radome / nose'. If wildlife strike more than one location on the aircraft (e.g., windscreen and main rotor system), the impact location was categorized as 'multiple impact'.

We defined a wildlife strike event with a rotary-wing aircraft as a damaging strike if there was any amount of damage to the aircraft reported. Damaging wildlife strikes varied greatly in the amount of actual damage incurred to the aircraft during the event, and ranged from minor abrasions found on the airframe or an aircraft component to the complete destruction of the aircraft.

For each wildlife strike, the reported location of the strike event (if known) was determined to be 'on' an airfield if the aircraft was within the horizontal delineation of an airfield when the strike occurred. 'Off' airfield strikes were defined as wildlife strike events that were reported to have occurred when the aircraft was not 'on' or flying over an airfield (e.g., an aircraft traveling enroute to a specified destination).

Many wildlife strike reports for military rotary-wing aircraft and civil helicopters were incomplete and specific fields of information were missing, unknown, or we were unable to effectively obtain the information for report narratives; thus sample sizes varied among individual variables and among specific analyses.

Figure 1. An ARMY UH-60 'Black Hawk' helicopter conducting an 'in theater' operational mission. Variants of the Sikorsky manufactured H-60 airframe (aircraft model) are used by all Military Services for a variety of mission types. Photo Credit: U.S. Army.

3.3 Statistical Analyses

Our investigation included identification of trends in wildlife strikes with military rotary-wing aircraft with respect to a variety of factors (e.g., impact location on the aircraft, phase of flight, wildlife species involved in strikes). We summarized wildlife strike data for each Military Service and civil helicopters for flight operations within the U.S., as well as for ARMY and USAF overseas flight operations (i.e., outside of the U.S.). We summarized wildlife strikes that were reported to have occurred within airport environments (i.e., on or over an airfield) and those that were reported to have occurred during flight operations 'off' airfield.

We compared patterns of wildlife strikes with military rotary-wing aircraft to wildlife strikes with civil helicopters using appropriate statistical techniques. Linear regression analyses (Zar 1996) were used to determine if significant trends were occurring in the number of reported wildlife strikes to military rotary-wing aircraft and civil helicopters by year (Zar 1996). We used chi-squared analysis (Zar 1996) to compare the number of wildlife strikes with military rotary-wing aircraft of each of the Military Services and civil helicopters among several variables (e.g., month, time of day, wildlife groups, aircraft model, and others). We compared the proportion of damaging wildlife strikes relative to all wildlife strikes among the Military Services and civil helicopters using comparison of proportion tests (Zar 1996).

4. RESULTS

A total of 2,090 reported wildlife strikes with ARMY (n = 554) and USAF (n = 1,536) rotary-wing aircraft during flight operations worldwide that occurred from 1990 to 2011 was found within the wildlife strike databases for these 2 Military Services. Although there were some NAVY and USCG wildlife strikes with rotary-wing aircraft occurred outside of the U.S., we did not have sufficient information to effectively evaluate those wildlife strikes.

An average of 25.2 (± 2.6 SE) wildlife strikes to ARMY rotary-wing aircraft during flight operations were reported annually during 1990−2011 (Figure 2). During this 22-year time period, the annual number of reported wildlife strikes to ARMY rotary-wing aircraft during flight operations remained constant ($y = -0.20x + 420.5$; $R^2 = 0.01$, $F_{1,21} = 0.1$, $P = 0.93$). During 1994−2011, an average of 85.3 (± 8.7 SE) reported wildlife strikes to USAF rotary-wing aircraft occurred annually during flight operations (Figure 2). The annual number of wildlife strikes to USAF rotary-wing aircraft increased ($y = 6.23x - 12{,}388$; $R^2 = 0.82$, $F_{1,17} = 49.7$, $P < 0.0001$) by 630% during 1994−2011.

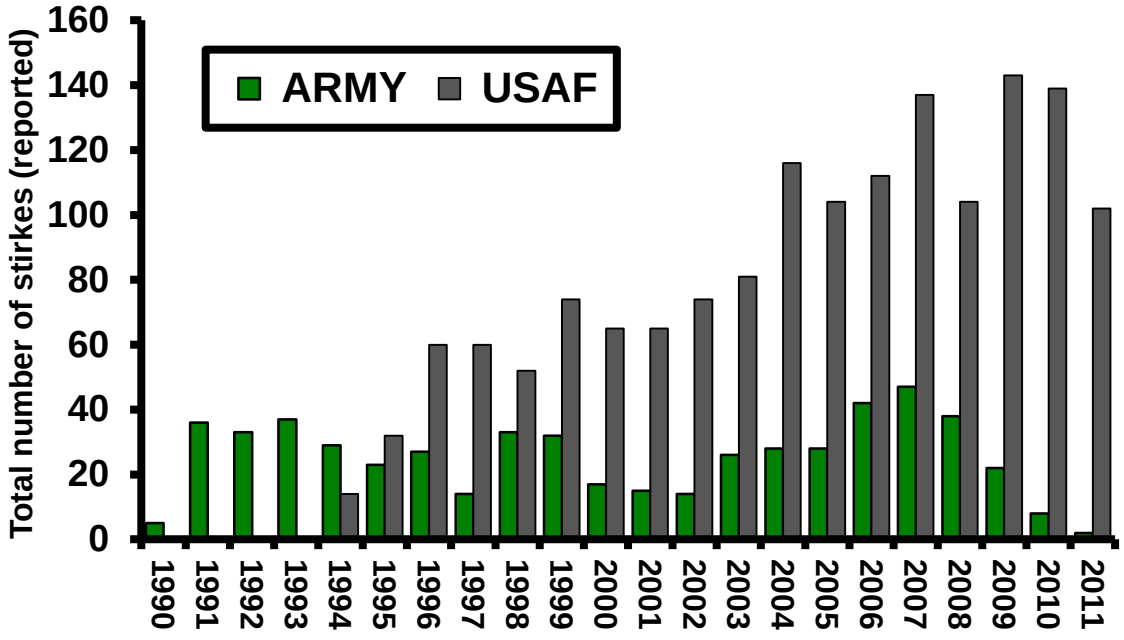

Figure 2. Total number of reported worldwide wildlife strikes with ARMY and USAF rotary-wing aircraft, each year, during 1990−2011.

4.1 Wildlife Strikes with Military Rotary-wing Aircraft Within the U.S.

Military Service wildlife strike databases contained 2,511 records with military rotary-wing aircraft during flight operations within the U.S. for the ARMY (n = 318), NAVY (n = 845), USAF (n = 1,071), and USCG (n = 277).

An average of 14.5 (± 1.6 SE) wildlife strikes to ARMY rotary-wing aircraft during flight operations within the U.S. were reported annually during 1990−2011 (Figure 3). During this 22-year time period, the annual number of reported wildlife strikes to ARMY rotary-wing aircraft during flight operations within the U.S. decreased ($y = -0.65x + 1{,}320.3$; $R^2 = 0.33$, $F_{1,21} = 10.0$, $P = 0.005$) by 85%.

During 1994−2011, an average of 59.5 (± 5.5 SE) reported wildlife strikes with USAF rotary-wing aircraft occurred annually during flight operations within the U.S. (Figure 4). From 1994 to 2004, the annual number of reported wildlife strikes to USAF rotary-wing aircraft increased ($y = 6.99x - 13{,}924.5$; $R^2 = 0.85$, $F_{1,10} = 52.6$, $P < 0.0001$) by 1,030%. However, the average number of reported wildlife strikes per year to USAF rotary-wing aircraft within the U.S. decreased ($y = -6.0x - 12{,}119.1$; $R^2 = 0.77$, $F_{1,18} = 16.4$, $P = 0.01$) by 22% during 2004−2010.

An average of 76.8 (± 9.3 SE) wildlife strikes to NAVY rotary-wing aircraft during flight operations within the U.S. were reported annually during 2001−2011 (Figure 5). During this 11-year time period, the annual number of reported wildlife strikes to NAVY rotary-wing aircraft during flight operations within the U.S. increased ($y = 7.63x - 15{,}223.5$; $R^2 = 0.67$, $F_{1,10} = 18.4$, $P = 0.002$) by 367%.

During 1979−2011, an average of 8.5 (± 1.0 SE) reported wildlife strikes with USCG rotary-wing aircraft occurred annually during flight operations within the U.S. (Figure 6). The annual number of reported wildlife strikes with USCG rotary-wing aircraft remained similar ($y = 0.14x - 272.3$; $R^2 = 0.06$, $F_{1,32} = 2.0$, $P = 0.18$) during this 33-year time period.

The number of reported wildlife strikes with rotary-wing aircraft varied among months (season) for ARMY ($\chi^2 = 32.2$, df = 11, $P = 0.0007$), USAF ($\chi^2 = 204.3$, df = 11, $P < 0.0001$), NAVY ($\chi^2 = 120.9$, df = 11, $P < 0.0001$), and USCG ($\chi^2 = 21.3$, df = 11, $P = 0.03$) flight operations within the U.S. For all Military Services, the highest number of wildlife strikes occurred during fall (September and October) whereas the lowest number per month was found in winter (December and January; Figure 7).

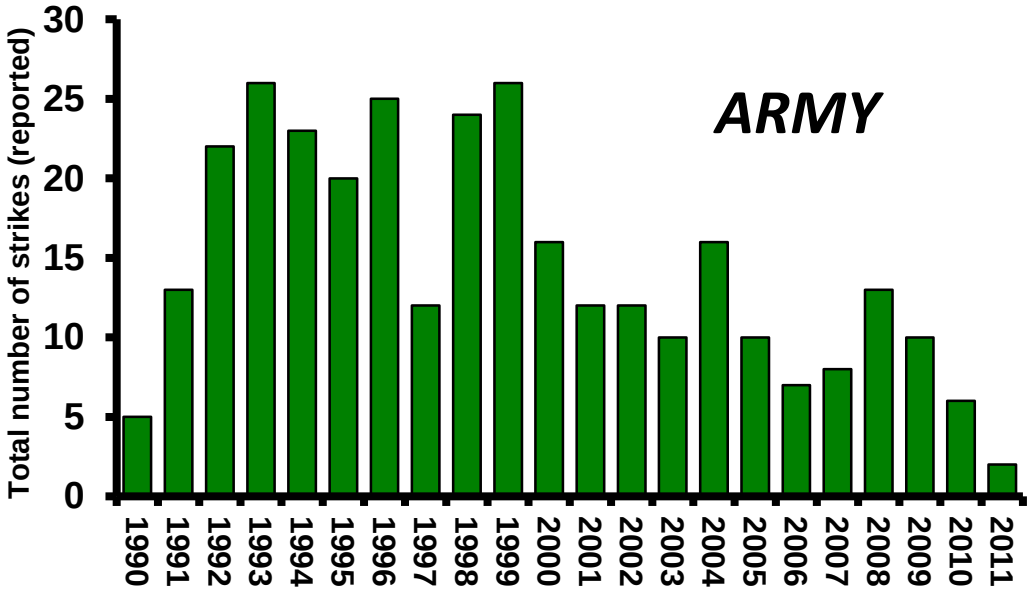

Figure 3. Total number of reported wildlife strikes with ARMY rotary-wing aircraft in the U.S. during 1990−2011.

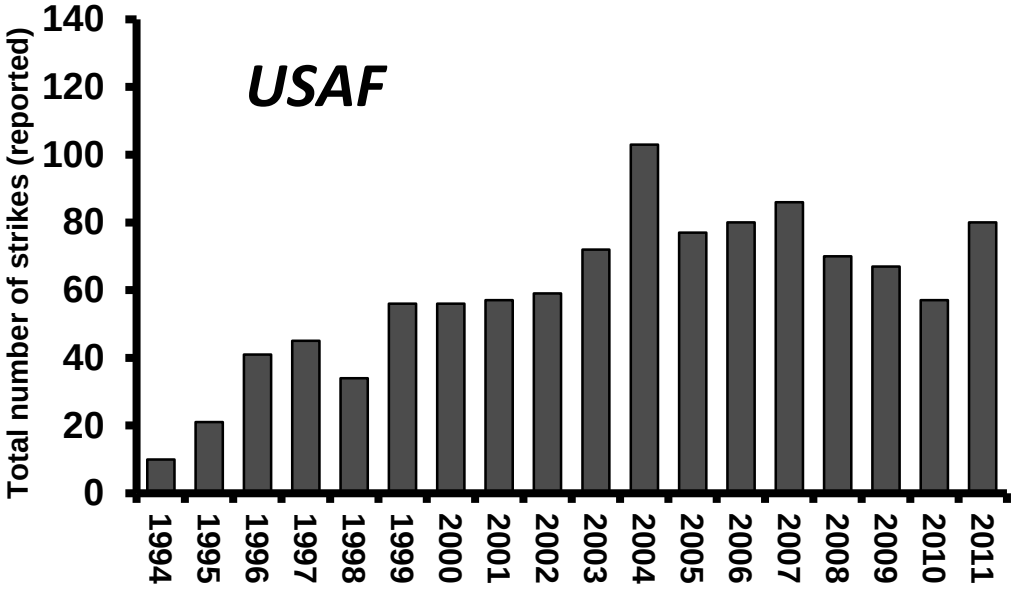

Figure 4. Total number of reported wildlife strikes with USAF rotary-wing aircraft in the U.S. during 1994−2011.

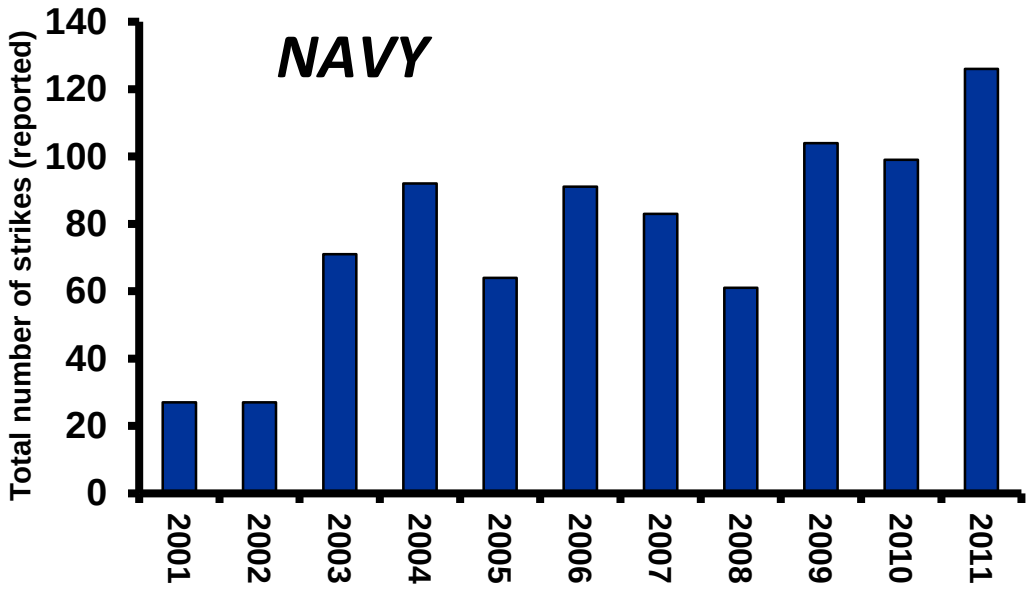

Figure 5. Total number of reported wildlife strikes with NAVY rotary-wing aircraft in the U.S. during 2001−2011.

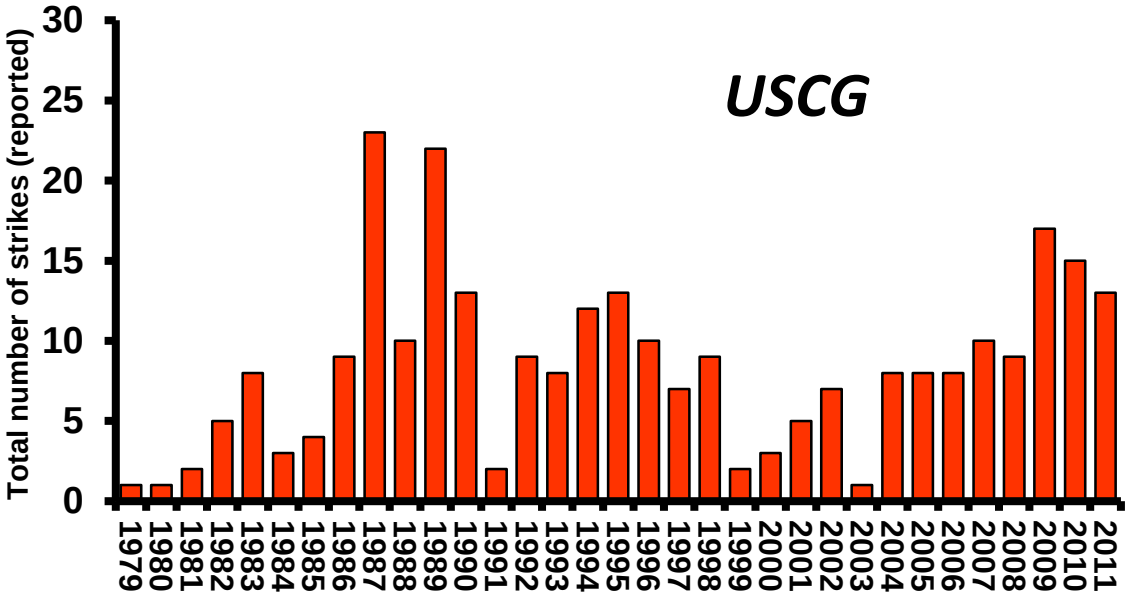

Figure 6. Total number of reported wildlife strikes with USCG rotary-wing aircraft in the U.S. during 1979−2011.

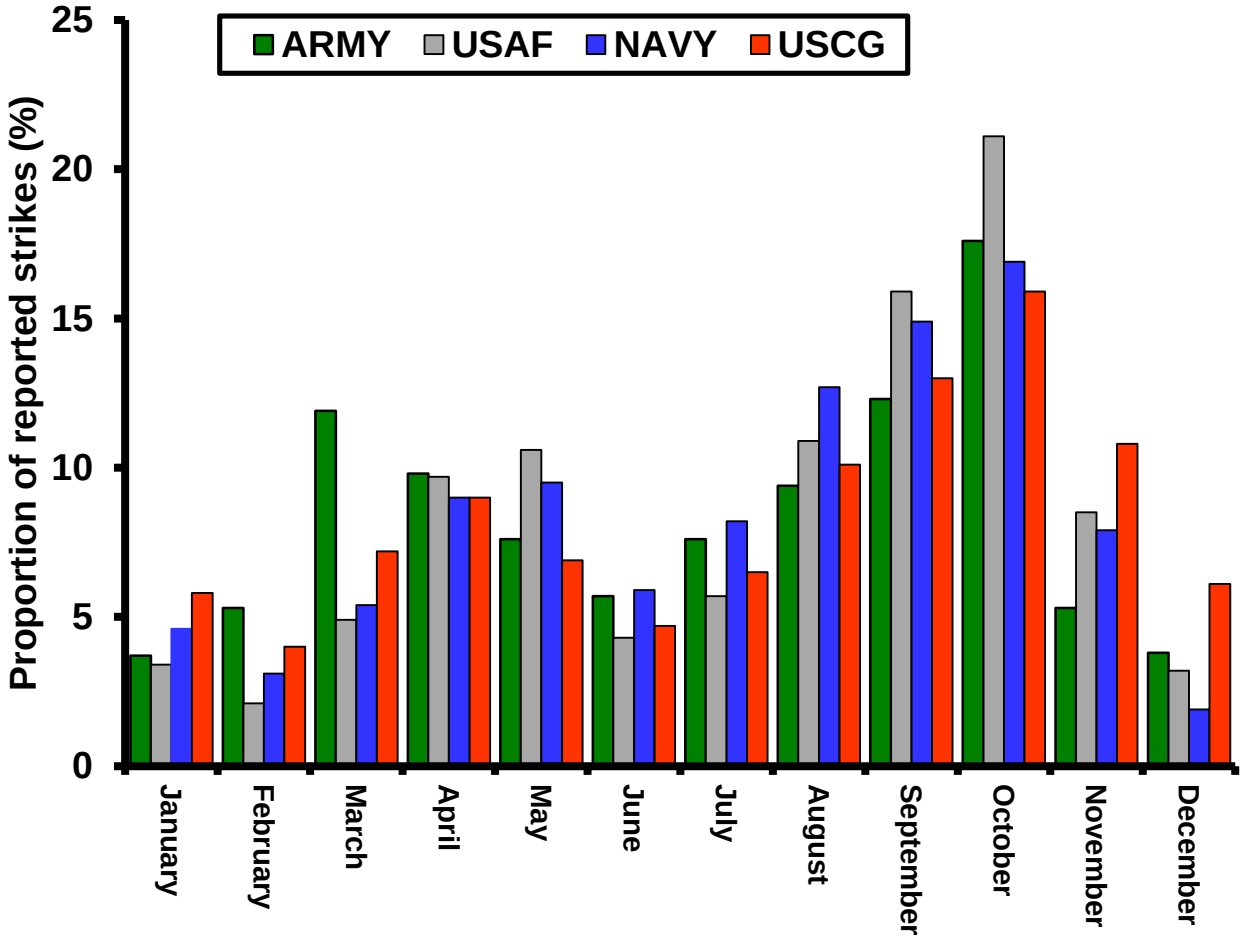

Figure 7. Proportion (%) of reported wildlife strikes, by month, in the U.S. for rotary-wing aircraft for each Military Service during 1979−2011.

The number of reported wildlife strikes with rotary-wing aircraft varied among time of day for ARMY (χ^2 = 38.3, df = 3, P < 0.0001), USAF (χ^2 = 123.5, df = 3, P < 0.0001), and NAVY (χ^2 = 68.4 df = 3, P < 0.0001) aircraft operations in the U.S. For all 3 Military Services, most wildlife strikes occurred during day and night time periods and relatively few during dawn or dusk (Figure 8). Although the occurrence of wildlife strikes during day and night time periods was similar for ARMY (χ^2 = 2.8, df = 1, P = 0.10) and NAVY (χ^2 = 0.03, df = 1, P = 0.87) aircraft, more (χ^2 = 312.4, df = 1, P < 0.0001) wildlife strikes were reported for USAF rotary-wing aircraft operations during the night compared to day time period (Figure 8).

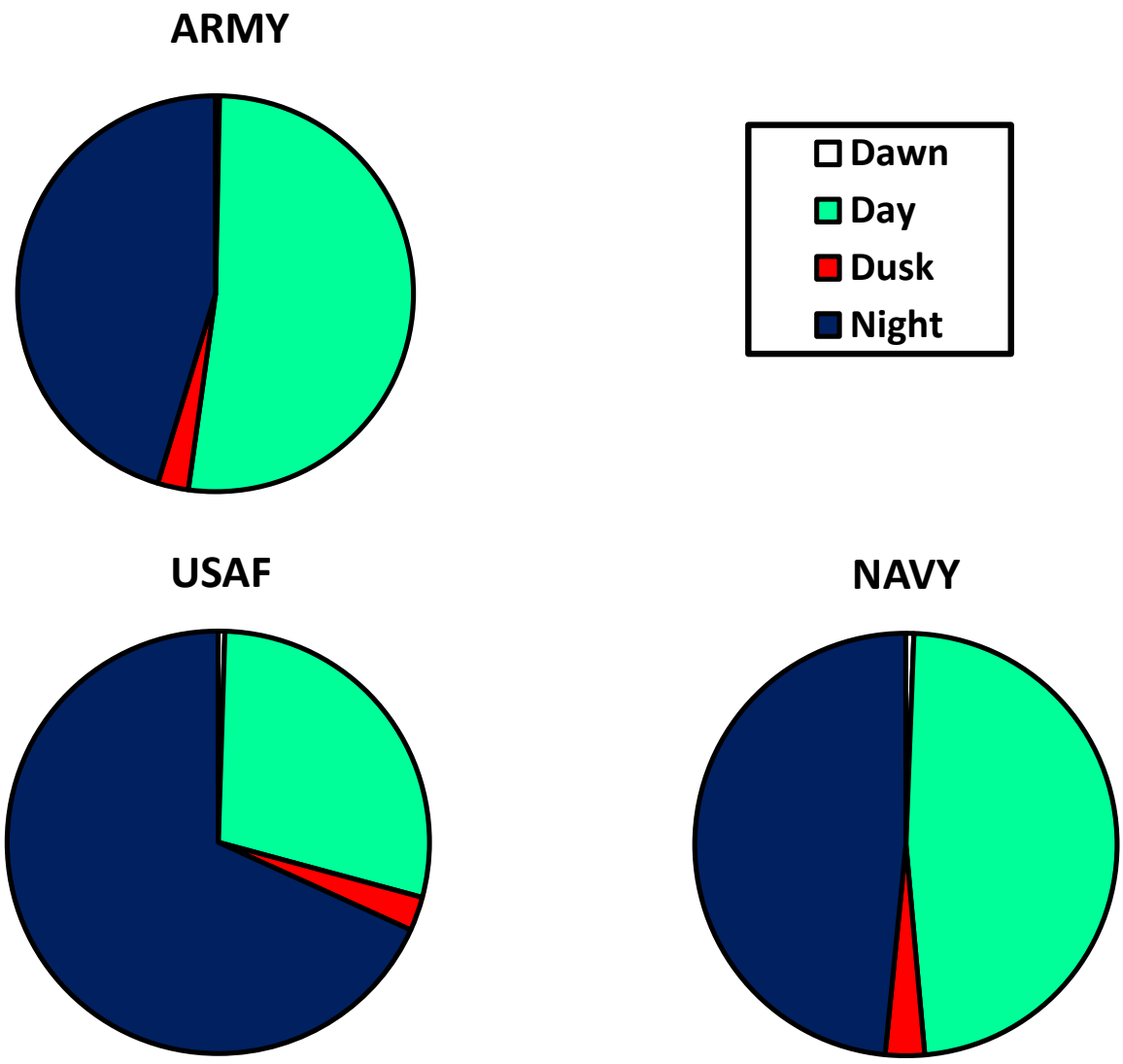

Figure 8. Proportion (%) of reported wildlife strikes, by time of day, in the U.S. for rotary-wing aircraft for each Military Service during 1990−2011.

Among the military rotary-wing strike records reported to have occurred within the U.S., 32.3% (812 of 2,511) contained information regarding the identity of the animal struck to the 'wildlife group' level (Table 1). Birds accounted for 91.0% of the wildlife strikes, whereas mammals (i.e., bats) accounted for the remaining 9.0% of the strikes. The wildlife groups most frequently colliding with rotary-wing aircraft varied among the Military Services. Warblers, bats, and perching birds were the most commonly struck wildlife groups by USAF rotary-wing aircraft, whereas gulls, shorebirds, seabirds, and raptors were most frequently struck by rotary-wing aircraft from the NAVY (Table 1).

Among the 2,283 wildlife strikes with military rotary-wing aircraft that the specific geographic location (i.e., state) could be determined, the majority were reported from Florida (n = 617), New Mexico (n = 204), Georgia (n = 192), California (n = 183), Virginia (n = 171), Alabama (n = 151), and Maryland (n = 107). Wildlife strikes to military aircraft were reported in all U.S. states and the District of Columbia, with one exception: no strikes were reported within Vermont.

Among the military rotary-wing strike records within the U.S., all 2,511 contained information regarding the airframe model of the aircraft struck (Table 2). The H-60 airframe accounted for the highest number of wildlife strikes to rotary-wing aircraft; specifically 27.7%, 50.0%, and 46.2% of the ARMY, USAF, and NAVY wildlife strikes, respectively. In contrast, 67.5% of the reported wildlife strikes to USCG rotary-wing aircraft were to H-65 airframes. Tilt wing aircraft (i.e., V-22) accounted for only 3.6% of all reported wildlife strikes to aircraft within the U.S. (Table 2).

Among the military rotary-wing strikes within the U.S., all 2,511 contained information regarding the aircraft category of the aircraft struck (Table 3). Across all Military Services, 30.4% of the aircraft categories were SAR, 19.8% were multi-mission, 18.9% were utility, and 13.0% were training. Although SAR was the aircraft category of 49.3% and 71.8% of USAF and USCG rotary-wing aircraft, respectively, training accounted for 33.4% of NAVY strikes within the U.S. Aircraft categories for ARMY rotary-wing aircraft were more diverse than the other Military Services, and included the only observation and electronic aircraft categories as well as the majority of attack category aircraft, that were reported to have been struck by wildlife in the U.S. (Table 3).

Wildlife strikes to military aircraft were reported to have occurred during all phases of (aircraft) flight. When the phase of flight during which wildlife strikes occurred was reported (n = 1,596), wildlife strikes occurred most frequently when the aircraft were traveling enroute or were engaged in terrain flight (Table 4). The proportion of wildlife strikes that occurred among the phases of flight varied for ARMY (χ^2 = 226.0, df = 9, P < 0.0001), NAVY (χ^2 = 150.7, df = 9, P < 0.0001), USAF (χ^2 = 422.1, df = 9, P < 0.0001), and USCG (χ^2 = 146.6, df = 9, P < 0.0001) aircraft. Notably, approximately one-half of wildlife strikes to ARMY rotary-wing aircraft and about three-quarters of strikes to USCG rotary-wing aircraft occurred during the enroute phase of flight.

Table 1. Number of reported wildlife strikes, by wildlife group, in the U.S. for rotary-wing aircraft for each Military Service[a] and for all Services combined during 1990−2011.

Wildlife Group	ARMY[b]	USAF	NAVY	All Services
Bats[c]		60	13	73
Blackbirds & starlings		11	1	12
Corvids		1	2	3
Cuckoos		7	2	9
Doves & pigeons	1	25	10	36
Finches		17	3	20
Flycatchers		6	3	9
Gulls	7	4	45	56
Herons, egrets & ibises	1	5	6	12
Larks		37		37
Nightjars		6	5	11
Owls		2	1	3
Perching birds		63	22	85
Raptors & vultures	17	9	31	57
Seabirds			37	37
Shorebirds		9	33	42
Sparrows		45	3	48
Swallows		22	4	26
Swifts & hummingbirds		21	3	24
Terns		1	5	6
Thrashers & thrushes		46	1	47
Vireos		13	2	15
Warblers		88	3	91
Waterbirds	1	10	2	13
Waterfowl	14	13	10	37
Woodpeckers		2	1	3
Unidentified spp.	277	548	597	1,699

[a] *Wildlife species or group information is not identified within the USCG wildlife strike database.*

[b] *Wildlife species or group information is not identified within the ARMY wildlife strike database. However, for a few records the species or group involved in the strike event was identified from pilot or aircrew comments.*

Table 1. (CONTINUED).

[c] *Bats was comprised of big brown bats (Eptesicus fuscus), Brazilian free-tailed bats (Tadarida brasiliensis), Eastern pipistrelles (Perimyotis subflavus), evening bats (Nycticeius humeralis), hairy-tailed bats (Lasiurus ebenus), hoary bats (L. cinereus), pocketed free-tailed bats (Nyctinomops femorosaccus), red bats (L. borealis), Seminole bats (L. seminolis), silver-haired bats (Lasionycteris noctivagans), Western pipistrelles (Pipistrellus hesperus), and bats of 'unidentified' species.*

Table 2. Number of reported wildlife strikes, by airframe model, in the U.S. for rotary-wing aircraft for each Military Service during 1979−2011.

Airframe Model	ARMY	USAF	NAVY	USCG
H-1	65	321	34	
H-3			18	47
H-6	11			
H-46			31	
H-47	22			
H-53		189	25	
H-57			282	
H-58	59			
H-60	88	536	390	41
H-64	55			
H-65				187
H-67	18			
H-68				2
V-22		25	65	

Table 3. Number of reported wildlife strikes, by aircraft category, in the U.S. for rotary-wing aircraft for each Military Service and for all Services combined during 1979−2011.

Aircraft Category	ARMY	USAF	NAVY	USCG	All Services
Attack	76	1	19		96
Cargo	19	29	44		92
Electronic	7				7
Multi-mission	9	199	259	31	498
Observation	68				68
SAR[a]		528	37	199	764
Submarine			184		184
Training	18	25	283		326
Utility	121	289	17	47	474
VIP[b]			2		2

[a] *Search and rescue missions.*
[b] *Very important person missions.*

Table 4. Proportion (%) of reported wildlife strikes, by phase of flight, in the U.S. for rotary-wing aircraft for each Military Service during 1979−2011.

Phase of Flight	ARMY	USAF	NAVY	USCG
Enroute	52.3	31.3	28.6	73.6
Terrain flight	22.2	41.4	25.0	0.6
Hovering	1.8	4.2	4.2	1.9
Approach	14.7	7.2	12.7	8.8
Pattern		5.3	7.1	3.8
Landing	1.1	3.3	4.0	3.1
Taxiing	1.1	2.3	5.1	
‘Touch and go’		0.2	2.2	1.9
Take-off	3.2	2.7	5.5	1.9
Climbout	3.6	2.1	5.6	4.4

Wildlife strikes were reported to have impacted all sections of military rotary-wing aircraft; however, specific areas were impacted by wildlife with a much higher frequency compared to others. The number of reported wildlife strikes to various impact locations on rotary-wing aircraft varied for ARMY ($\chi^2 = 139.6$, df = 9, $P < 0.0001$), USAF ($\chi^2 = 301.7$, df = 9, $P < 0.0001$), NAVY ($\chi^2 = 269.6$, df = 9, $P < 0.0001$), and USCG ($\chi^2 = 107.4$, df = 9, $P < 0.0001$) during flight operations within the U.S. The highest proportion of impact locations for reported wildlife strikes within the U.S. for across the Military Services was the windscreen (25.3% to 28.6% of all reported strikes for each Military Service), although the radome / nose and main rotor system were also areas of rotary-wing aircraft struck by wildlife with a high frequency (Table 5).

The proportion of reported wildlife strikes in the U.S. that were damaging to rotary aircraft were 42.4%, 3.8%, and 12.7% for ARMY, USAF, and NAVY flight operations, respectively (Table 6). The proportion of wildlife strikes that were damaging was higher when the strikes occurred off the airfield compared to on the airfield for ARMY ($z = 4.86$, $P = 0.03$) and USAF ($z = 4.21$, $P = 0.04$) aircraft. In contrast, the proportion of damaging wildlife strikes was similar ($z = 1.20$, $P = 0.27$) for NAVY rotary-wing aircraft for reported wildlife strikes that occurred on- and off-airfield. The USCG wildlife strike database did not contain information to allow for a determination as to whether individual wildlife strikes occurred on- or off-airfield.

The average cost of a damaging wildlife strike (i.e., $ estimate of damaged parts and repair costs) to a rotary-wing aircraft operating within the U.S. varied among the Military Services. The average cost of a wildlife strike to ARMY aircraft was $25,926 per incident (highest reported = $553,763), to USAF aircraft was $14,852 per incident (highest reported = $150,000), to NAVY aircraft was $337,281 per incident (highest reported = $24,800,000), and to USCG aircraft was $12,184 (highest reported was $331,734).

Wildlife strikes to military rotary-wing aircraft operating in the U.S. resulted in a total of 8 human injuries and 2 human fatalities. In each of the 8 wildlife strike events that resulted in human injuries or fatalities during flight operations within the U.S., the aircraft was damaged or destroyed. Human injuries occurred during 6 wildlife strike incidents with ARMY aircraft and 1 incident with an USCG aircraft. All human injuries were comprised of cuts, lacerations, and/or bruising to pilots and copilots when a bird (or birds) impacted the windscreen of the aircraft, shattering the windscreen of the aircraft and sending glass and bird remains into the aircraft cabin and impacting the aircrew. During one wildlife strike incident a pilot was incapacitated from the impact of the bird remains to his face.

The only known human fatalities that involved wildlife strikes to military rotary-wing aircraft within the U.S. occurred when a Red-tailed Hawk (*Buteo jamaicensis*) collided with a USMC AH-1W ‘Super Cobra’ attack helicopter in California during 2011. The hawk impacted the main rotor system and damaged it to the point that the main rotor separated from the airframe while the aircraft was in flight. Two servicemen (the pilot and co-pilot) were lost in this strike event, which also involved the total destruction of the aircraft (monetary loss of $24.8 million) when it crashed.

Table 5. Proportion (%) of reported wildlife strikes, by impact location on the aircraft, in the U.S. for rotary-wing aircraft for each Military Service during 1979−2011.

Impact Location	ARMY	USAF	NAVY	USCG
Radome / nose	16.5	15.8	15.6	20.1
Windscreen	28.7	25.3	26.1	28.6
Fuselage	9.4	23.4	8.9	14.3
Main rotor system	25.5	11.8	18.4	20.6
Engine	8.8	20.0	7.5	12.2
Landing gear		1.0	1.4	2.1
Weapons system	0.7	1.0	0.3	
External fuel tank		0.4	0.2	0.5
Tail section	5.9	1.3	2.6	1.6
Multiple locations	4.5		19.0	

Table 6. Number of reported wildlife strikes, without or with damage where the strike occurred 'on' or 'off' an airfield, in the U.S. for rotary-wing aircraft for each Military Service[a] during 1990−2011.

Location	ARMY	USAF	NAVY
On-Airfield			
Non-damaging	66	416	185
Damaging	33	10	22
% Damaging[b]	*33 %*	*2 %*	*11 %*
Off-Airfield			
Non-damaging	116	614	332
Damaging	101	31	53
% Damaging	*47 %*	*5 %*	*14 %*

[a] *The location (e.g., 'on' or 'off' an airfield) was not reported for wildlife strikes in the USCG database.*

[b] *The proportion of wildlife strikes where damage to the rotary-wing aircraft was reported among all reported wildlife strikes to rotary-wing aircraft (within the specified categories).*

4.1.1 'On' Airfield Wildlife Strikes (Within the U.S.)

Among the military rotary-wing strike records reported to have occurred on or over airfields (i.e., on-airfield) within the U.S., 40.4% (296 of 733) contained information regarding the identity of the animal struck down to the 'wildlife group' level. Birds accounted for 93.9% of the wildlife strikes the occurred on-airfield, whereas mammals (i.e., bats) accounted for the remaining 6.1% of the strikes. The wildlife groups most frequently colliding with rotary-wing aircraft within airfield environments varied among the Military Services. Warblers (n = 26), thrashers & thrushes (n = 20), larks (n = 19), doves & pigeons (n = 19), bats (n = 17), and sparrows (n = 17) were the most commonly struck wildlife groups by USAF rotary-wing aircraft operating on-airfield within the U.S. (Table 7). In contrast, gulls (n = 21), raptors (n = 16), shorebirds
(n = 12), and seabirds (n = 10) were most frequently struck by NAVY rotary-wing aircraft (Table 7). Although limited information is available regarding wildlife strikes with ARMY rotary-wing aircraft (90% of wildlife strikes had no wildlife species/group information), raptors and waterfowl appear to be the most frequently struck wildlife groups within airfield environments. The USCG wildlife strike database did not contain information regarding wildlife species/group information or location information to allow us to determination as to whether individual wildlife strike occurred on- or off-airfield.

When only damaging wildlife strikes to military rotary-wing aircraft on or over airfields within the U.S. are considered, 35.4% (23 of 65) of those reported strike records contained information regarding the identity of the animal struck. The wildlife groups most frequently colliding with rotary-wing aircraft and causing damage within airfield environments was somewhat similar among the Military Services. Doves & pigeons (n = 3) and raptors & vultures (n = 2) were the most commonly struck wildlife groups by USAF rotary-wing aircraft (Table 7). Strikes with raptors & vultures (n = 4), gulls (n = 2), and perching birds (n = 2) caused damage to NAVY rotary-wing aircraft (Table 7). Although limited information is available regarding wildlife strikes with ARMY rotary-wing aircraft (85% of damaging wildlife strikes had no wildlife species/group information), raptors & vultures (n = 2) and waterfowl (n = 2) caused damage to ARMY rotary-wing aircraft.

Wildlife strikes were reported to have impacted all sections of military rotary-wing aircraft operating on or over airfields in the U.S.; however, specific areas were impacted by wildlife with a much higher frequency compared to others. The number of reported wildlife strikes to various impact locations on rotary-wing aircraft varied for ARMY (χ^2 = 49.60, df = 9, P < 0.0001), USAF (χ^2 = 106.02, df = 9, P < 0.0001), and NAVY (χ^2 = 97.06, df = 9, P < 0.0001) during on-airfield flight operations within the U.S. The highest proportion of impact locations for on-airfield wildlife strikes within the U.S. was the main rotor system and windscreen for ARMY rotary-wing aircraft, the engine, windscreen, and fuselage for USAF aircraft, and the windscreen and main rotor system for NAVY rotary-wing aircraft (Table 8).

When only damaging wildlife strikes to military rotary-wing aircraft on or over airfields within the U.S. are considered, the number of reported wildlife strikes to various sections of aircraft varied for ARMY (χ^2 = 18.06, df = 9, P = 0.03) and NAVY (χ^2 = 17.07, df = 9, P < 0.0001),

Table 7. Number of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'on' or over an airfield, by wildlife group, in the U.S. for rotary-wing aircraft for each Military Service[a] during 1990−2011.

Wildlife Group	ARMY[b]		USAF		NAVY	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Bats[c]			17		1	
Blackbirds & starlings			7		1	
Corvids			1		1	
Cuckoos			5			
Doves & pigeons	1		19	3	8	
Finches			6			
Gulls	1	1	2		21	2
Herons, egrets & ibises			1		3	
Larks			19			
Nightjars			4		2	
Owls					1	
Perching birds			17	1	6	2
Raptors & vultures	5	2	3	2	16	4
Seabirds					10	
Shorebirds			6	1	12	1
Sparrows			17		2	
Swallows			9	1	1	1
Swifts & hummingbirds			4		1	
Terns					1	
Thrashers & thrushes			20		1	
Vireos			2			
Warblers			26		1	
Waterbirds			2		1	
Waterfowl	3	2	4		3	
Woodpeckers			1			
Unidentified spp.	89	28	234	2	114	12

[a] *Wildlife species or group information is not identified within the USCG wildlife strike database.*

Table 7. (CONTINUED).

[b] *Wildlife species or group information is not identified within the ARMY wildlife strike database. However, for a few records the species or group involved in the strike event was identified from pilot or aircrew comments.*

[c] *Bats was comprised of Brazilian free-tailed bats (Tadarida brasiliensis), Eastern pipistrelles (Perimyotis subflavus), evening bats (Nycticeius humeralis), hoary bats (Lasiurus cinereus), red bats (L. borealis), Seminole bats (L. seminolis), silver-haired bats (Lasionycteris noctivagans), and bats of 'unidentified' species.*

Table 8. Proportion (%) of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'on' or over an airfield, by impact location on the aircraft, in the U.S. for rotary-wing aircraft for each Military Service[a] during 1990−2011.

Impact Location	ARMY		USAF		NAVY	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Radome / nose	15.1	9.1	13.5		12.8	5.6
Windscreen	25.6	27.3	21.1	16.7	22.8	38.9
Fuselage	5.8	3.0	20.5		5.3	11.1
Main rotor system	36.2	27.3	15.1	16.7	29.6	33.3
Engine	8.1	15.2	26.0	33.3	4.2	
Landing gear			0.5		2.1	
Weapons system	1.1				0.5	
External fuel tank			1.1			
Tail section	5.8	12.1	2.2	33.3	2.1	
Multiple locations	2.3	6.0			20.6	11.1

[a] *The specific location (i.e., 'on' or 'off' an airfield) of wildlife strikes to rotary-wing aircraft was not reported / identified within the USCG wildlife strike database.*

but not USAF (χ^2 = 6.04, df = 9, P = 0.74) aircraft, during on-airfield flight operations within the U.S. However, the sections of aircraft that were most frequently struck and damaged by wildlife varied among the Military Services. Windscreens and main rotor systems were the most frequently impacted sections of ARMY rotary-wing aircraft (Table 8). The engine and the tail section were the most frequently struck and damaged parts of USAF rotary-wing aircraft, whereas the windscreen and main rotor system were the most commonly struck and damaged sections of NAVY rotary-wing aircraft (Table 8).

The average cost of an on-airfield damaging wildlife strike to ARMY aircraft was $28,872 per incident (highest reported = $248,709), to USAF aircraft was $16,873 per incident (highest reported = $128,960), and to NAVY aircraft was $1,156 per incident (highest reported = $10,000).

Within the wildlife strike records for military rotary-wing aircraft (including ARMY, USAF, NAVY, and USCG) conducting flight operations on or over airfields within the U.S., there we no reports of human injuries or fatalities due to a wildlife strike.

4.1.2 'Off' Airfield Wildlife Strikes (Within the U.S.)

Among the military rotary-wing strike records reported to have occurred away from military airfields (i.e., off-airfield) within the U.S., 38.5% (478 of 1,241) contained information regarding the identity of the animal struck to the 'wildlife group' level. Birds accounted for 96.1% of the wildlife strikes the occurred on-airfield, whereas mammals (i.e., bats) accounted for the remaining 3.9% of the strikes when the animal was identified to a 'wildlife group'. The wildlife groups most frequently colliding with rotary-wing aircraft outside of airfield environments varied among the Military Services. Warblers, perching birds, bats, sparrows, and thrushes & thrashers were the most commonly struck wildlife groups by USAF rotary-wing aircraft operating off-airfield within the U.S. (Table 9). In contrast, seabirds, shorebirds, gulls, perching birds, and raptors & vultures were most frequently struck by NAVY rotary-wing aircraft (Table 9). Although limited information is available regarding wildlife strikes with ARMY rotary-wing aircraft (86% of wildlife strikes had no wildlife species/group information), raptors & vultures, waterfowl, and gulls appear to be the most frequently struck wildlife groups away from military airfields. The USCG wildlife strike database did not contain information regarding wildlife species/group information or location information to allow us to determine whether individual wildlife strikes occurred on- or off-airfield.

When only damaging wildlife strikes to military rotary-wing aircraft away from airfields within the U.S. are considered, 27.6% (51 of 185) of those reported strike records contained information regarding the identity of the animal struck. The wildlife groups most frequently colliding with rotary-wing aircraft and causing damage during off-airfield flight operations were somewhat similar among the Military Services. Bats (n = 4) and waterbirds (n = 3) were the most commonly struck wildlife groups that resulted in damage to the aircraft for USAF aircraft

(Table 9). Strikes with raptors & vultures (n = 6), shorebirds (n = 3), and finches (n = 3) caused damage to NAVY aircraft most frequently (Table 9). Although limited information is available regarding wildlife strikes with ARMY rotary-wing aircraft (82% of damaging wildlife strikes had no wildlife species/group information), raptors & vultures (n = 7), waterfowl (n = 7), and gulls (n = 3) caused damage when they collided with ARMY aircraft.

Wildlife strikes impacted all sections of military rotary-wing aircraft that operated away from airfields in the U.S.; however, specific areas were impacted by wildlife with a much higher frequency compared to others. The number of reported wildlife strikes to various sections of rotary-wing aircraft varied for ARMY (χ^2 = 93.50, df = 9, P < 0.0001), USAF (χ^2 = 201.28, df = 9, P < 0.0001), and NAVY (χ^2 = 157.39, df = 9, P < 0.0001) during off-airfield flight operations within the U.S. The highest proportion of impact locations for off-airfield wildlife strikes within the U.S. was the windscreen (27.5% to 30.3% of all reported strikes for each Military Service), although the radome / nose and main rotor system were also sections of rotary-wing aircraft that were frequently struck by wildlife (Table 10).

When only damaging wildlife strikes to military rotary-wing aircraft away from airfields within the U.S. are considered, the number of reported wildlife strikes to various sections of aircraft varied for ARMY (χ^2 = 44.61, df = 9, P < 0.0001) and NAVY (χ^2 = 24.30, df = 9, P = 0.004), but not USAF (χ^2 = 7.74, df = 9, P = 0.56) aircraft. However, the impacted location of the aircraft that was most frequently struck by wildlife varied among the Military Services. Windscreens, radomes / noses, and main rotor systems were the locations on ARMY rotary-wing aircraft most frequently struck (Table 10). The fuselage was the most frequently struck and damaged part of USAF rotary-wing aircraft, whereas the windscreen was impacted in almost half of the reported wildlife strikes to NAVY rotary-wing aircraft (Table 10).

Within the wildlife strikes to military rotary-wing aircraft operating away from airfields within the U.S., there was a total of 8 human injuries and 2 human fatalities. In all 8 wildlife strike events, the rotary-wing aircraft was damaged or destroyed. The human injuries occurred during 6 wildlife strike incidents with ARMY aircraft and 1 incident with an USCG aircraft.

The average cost of an off-airfield damaging wildlife strike to ARMY aircraft was $24,944 per incident (highest reported = $553,763), to USAF aircraft was $14,245 per incident (highest reported = $150,000), and to NAVY aircraft was $476,805 per incident (highest reported = $24,800,000).

Table 9. Number of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'off' an airfield, by wildlife group, in the U.S. for rotary-wing aircraft for each Military Service[a] during 1990−2011.

Wildlife Group	ARMY[b]		USAF		NAVY	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Bats[c]			43	4	5	
Blackbirds & starlings			4			
Cuckoos			2		2	2
Doves & pigeons			6		1	
Finches			11		3	3
Gulls	6	3	2		19	2
Herons, egrets & ibises	1	1	4	1	3	1
Larks			18			
Nightjars			2		2	
Owls			2			
Perching birds			52		14	2
Raptors & vultures	12	7	6	1	13	6
Seabirds					24	1
Shorebirds			7	1	19	3
Sparrows			28	1	1	
Swallows			13		1	
Swifts & hummingbirds			17		1	
Terns			1		3	
Thrashers & thrushes			26			
Vireos			11		2	1
Warblers			62		1	
Waterbirds	1		4	3	1	
Waterfowl	11	7	9	1	6	
Woodpeckers			1		1	
Unidentified spp.	186	83	314	19	263	32

[a] *Wildlife species or group information is not identified within the USCG wildlife strike database.*

Table 9. (CONTINUED).

[b] *Wildlife species or group information is not identified within the ARMY wildlife strike database. However, for a few records the species or group involved in the strike event was identified from pilot or aircrew comments.*

[c] *Bats was comprised of big brown bats (Eptesicus fuscus), Brazilian free-tailed bats (Tadarida brasiliensis), Eastern pipistrelles (Perimyotis subflavus), hairy-tailed bats (Lasiurus ebenus), hoary bats (L. cinereus), pocketed free-tailed bats (Nyctinomops femorosaccus), red bats (L. borealis), Seminole bats (L. seminolis), silver-haired bats (Lasionycteris noctivagans), Western pipistrelles (Pipistrellus hesperus), and bats of 'unidentified' species.*

Table 10. Proportion (%) of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'off' an airfield, by impact location on the aircraft, in the U.S. for rotary-wing aircraft for each Military Service [a] during 1990−2011.

Impact Location	ARMY		USAF		NAVY	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Radome / nose	17.2	20.8	17.1	23.1	19.1	10.9
Windscreen	30.3	26.7	27.5	7.7	28.4	47.7
Fuselage	10.6	8.9	25.0	38.5	10.2	6.5
Main rotor system	21.2	20.8	10.0	7.7	13.9	8.7
Engine	8.6	8.9	16.8	15.3	7.5	10.9
Landing gear			1.2		0.9	2.2
Weapons system	0.5	1.1	1.5			
External fuel tank					0.3	2.2
Tail section	6.1	6.9	0.9	7.7	1.2	2.2
Multiple locations	5.5	5.9			18.5	8.7

[a] *The specific location (i.e., 'on' or 'off' an airfield) of wildlife strikes to rotary-wing aircraft was not reported / identified within the USCG wildlife strike database.*

4.2 Wildlife Strikes with ARMY and USAF Rotary-wing Aircraft Deployed Outside of the U.S.

A total of 701 wildlife strike records with military rotary-wing aircraft during deployments outside of the U.S. was found within the wildlife strike databases for 2 of the Military Services. Of these events, 238 wildlife strikes involved ARMY aircraft and 463 involved USAF aircraft.

During 1990−2011, an average of 10.8 (± 2.7 SE) reported wildlife strikes to ARMY rotary-wing aircraft occurred annually during flight operations outside of the U.S. (Figure 9). The annual number of reported wildlife strikes to ARMY rotary-wing aircraft during 2003−2009 (22.4 ± 4.1 SE) was higher ($F_{3,21} = 8.9$, $P = 0.0008$) than during 1999−1994 (10.2 ± 3.8 SE), 1995−2002 (3.5 ± 0.9 SE), and 2010−2011 (1.0 ± 1.0 SE).

During 1994−2011, an average of 25.7 (± 5.3 SE) reported wildlife strikes to USAF rotary-wing aircraft occurred annually during flight operations outside of the U.S. (Figure 10). The annual number of wildlife strikes to USAF remained constant ($y = 0.02x - 23.7$; $R^2 < 0.01$, $F_{1,10} < 0.01$, $P = 0.97$) during 1994−2004 but increased ($y = 11.0x - 21{,}960.3$; $R^2 = 0.84$, $F_{1,6} = 26.4$, $P = 0.004$) during 2004−2010. The average number of reported wildlife strikes to USAF rotary-wing aircraft during 2005−2010 (46.3 ± 9.1 SE) was over 3.5 times higher ($t_{16} = -4.6$, $P = 0.0003$) than the average number of reported wildlife strikes during 1994−2004 (12.6 ± 1.5 SE).

The number of reported wildlife strikes with rotary-wing aircraft operating outside the U.S. was similar ($\chi^2 = 15.5$, df = 11, $P = 0.16$) across months for ARMY aircraft. In contrast, for USAF aircraft, the number of reported wildlife strikes varied ($\chi^2 = 204.3$, df = 11, $P < 0.0001$) across months of the year. The highest number of wildlife strikes for USAF aircraft occurred during spring (April and May) and fall (September), whereas the lowest number was found in winter (January and February; Figure 11). For ARMY aircraft, the highest number of strikes occurred in March and November, with the lowest number was found in summer (June and July; Figure 11).

The proportion of reported wildlife strikes with ARMY ($\chi^2 = 30.4$, df = 3, $P < 0.0001$) and USAF ($\chi^2 = 247.9$, df = 3, $P < 0.0001$) rotary-wing aircraft varied among the time of day for aircraft operations outside of the U.S. For both ARMY and USAF aircraft, most wildlife strikes occurred during day or night time periods and relatively few during dawn or dusk (Figure 12). Although the occurrence of wildlife strikes during day and night time periods was similar for USAF rotary-wing aircraft ($\chi^2 = 2.7$, df = 1, $P = 0.10$), approximately 3 times more wildlife strikes were reported for ARMY aircraft ($\chi^2 = 125.2$, df = 1, $P = 0.0001$) during the day compared to during the night (Figure 12).

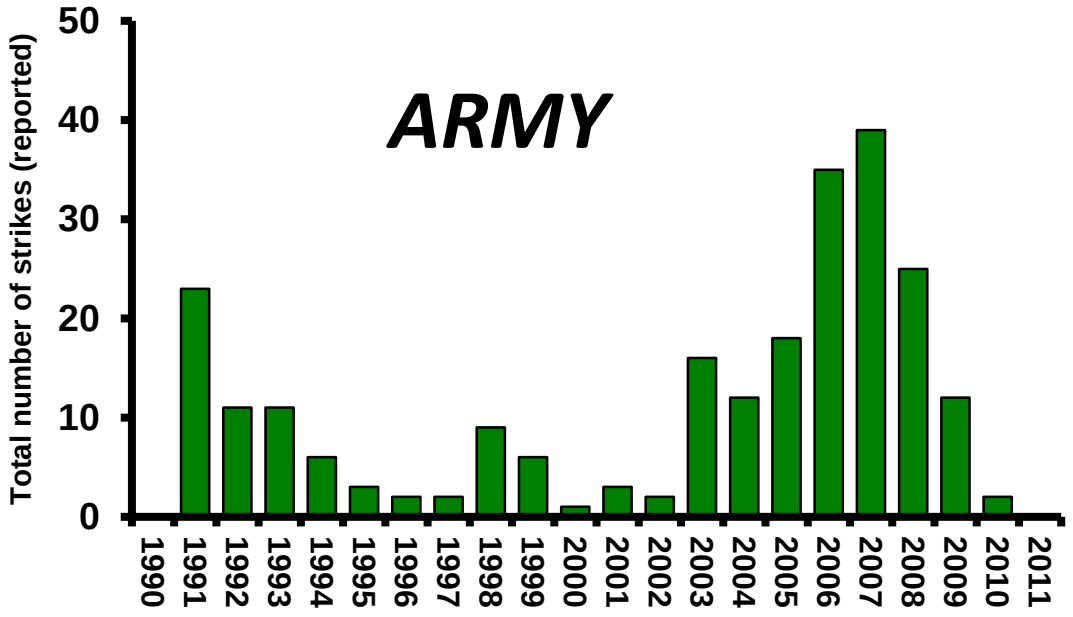

Figure 9. Total number of reported wildlife strikes with ARMY rotary-wing aircraft, each year, at locations outside of the U.S. during 1990−2011.

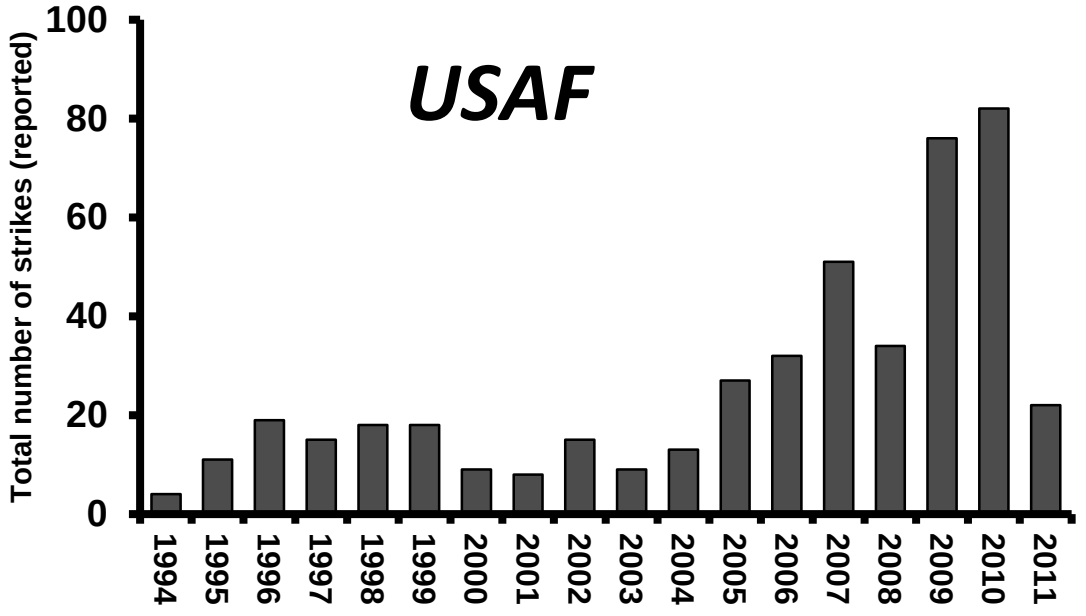

Figure 10. Total number of reported wildlife strikes with USAF rotary-wing aircraft, each year, at locations outside in the U.S. during 1990−2011.

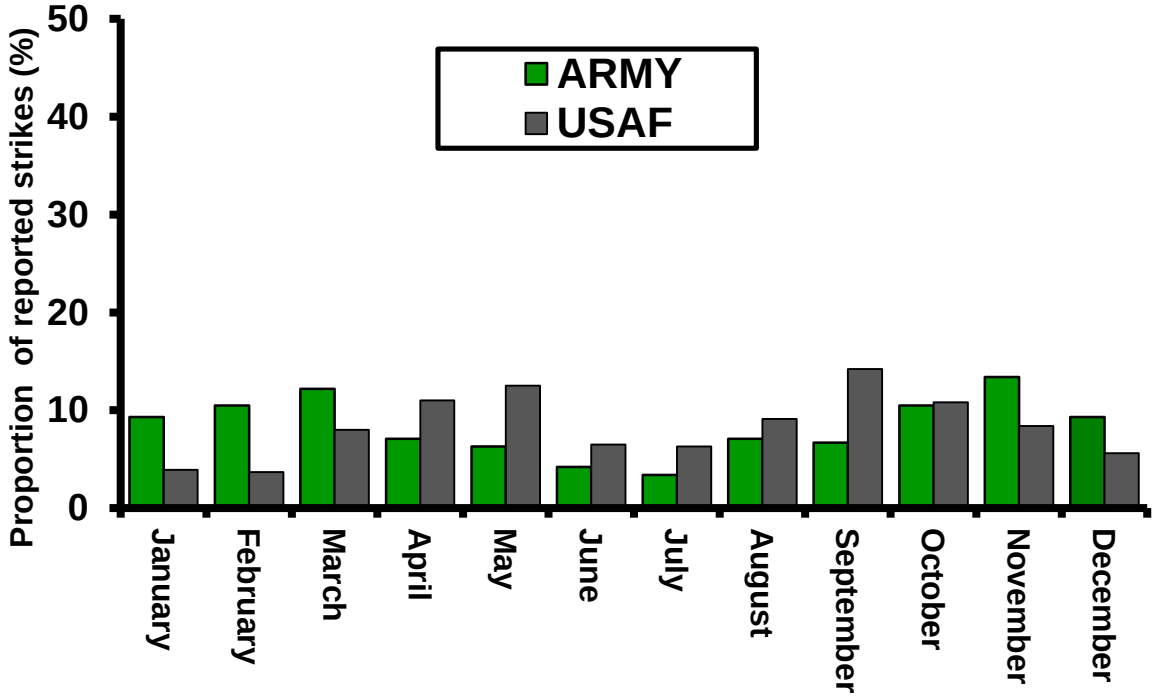

Figure 11. Proportion (%) of reported wildlife strikes, by month, for ARMY and USAF rotary-wing aircraft at locations outside of the U.S. during 1990−2011.

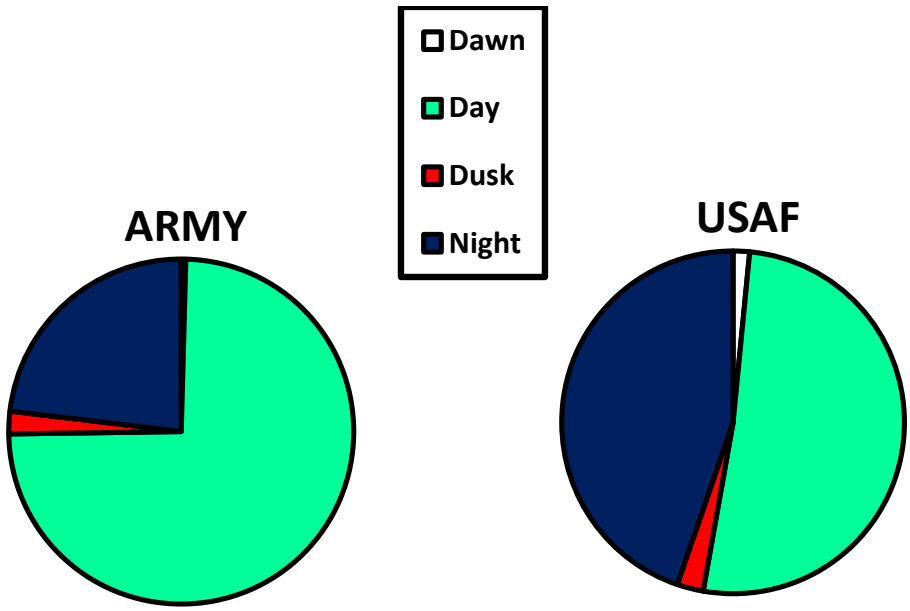

Figure 12. Proportion (%) of reported wildlife strikes, by time of day, with ARMY and USAF rotary-wing aircraft at locations outside of the U.S. during 1990−2011.

Wildlife strikes with ARMY and USAF rotary-wing aircraft were recorded in more than 31 foreign countries (Table 11). Almost two-thirds (60.9%) of reported wildlife strikes to ARMY rotary-wing aircraft during deployments occurred in the Middle East (n = 139; 136 in Iraq), whereas 12.6% and 11.8% occurred in Southeast Asia (n = 30; 28 in South Korea) and Central America (n = 28; 13 in Panama), respectively. Wildlife strikes to USAF rotary-wing aircraft outside of the U.S. occurred most frequently in Afghanistan (n = 177; 38.2%), the Middle East (n = 121; 26.1%), Europe (n = 83; 17.9%), and Southeast Asia (n = 61; 13.2%).

Among the military rotary-wing strike records for incidents outside of the U.S., 34.5% (242 of 701) identified the animal struck down to the 'wildlife group' level (Table 12). Birds accounted for 92.1% of the wildlife strikes, whereas bats comprised the remaining 7.9% of ARMY and USAF strikes. Although rotary-wing aircraft collided with a wide variety of wildlife (bird) groups, the wildlife groups most frequently struck were larks (n = 40), perching birds (n = 36), and doves & pigeons (n = 29; Table 12).

When considering only damaging wildlife strikes for ARMY and USAF incidents outside of the U.S., only 10.8% (23 of 212) of the time the animal struck down was identified to at least the 'wildlife group' level (Table 12). Doves & pigeons were involved in over half (n = 12; 52.2%) of these damaging strike events where the wildlife was identified, whereas raptors, bats, gulls, and thrushes & thrashers (n = 2 for each group) were identified in 8.7% of the damaging strikes (Table 12).

Among the strike records for ARMY and USAF rotary-wing aircraft during overseas deployments outside of the U.S., all 701 contained information regarding the airframe model of the aircraft struck (Table 13). Seventy percent of the rotary-wing aircraft (across both Military Services) reported to have been struck by wildlife were H-60 airframes, 14.6% were H-53 airframes, and all other airframes accounted for less than 10% each. The H-60 airframe accounted for 57.6% and 76.0% of ARMY and USAF wildlife strikes, respectively.

All 701 of the ARMY and USAF rotary-wing wildlife strikes that occurred outside the U.S. contained information regarding the aircraft category of the aircraft struck (Table 14). Across both Military Services, almost half (48.1%) of the aircraft categories were SAR, 28.9% were attack, 23.1% were utility, and 15.8% were multi-mission. Although SAR was the aircraft category of 72.7% of USAF rotary-wing aircraft, utility (61.8%) and attack (24.4%) accounted for the majority of ARMY rotary-wing aircraft categories (Table 14).

Wildlife strikes to ARMY and USAF aircraft operating outside of the U.S. experienced wildlife strikes during all phases of flight. For wildlife strikes when the phase of flight was reported (n = 344), the proportion of wildlife strikes varied among the phases of flight for both ARMY (χ^2 = 201.9, df = 9, P < 0.0001) and USAF (χ^2 = 297.8, df = 9, P < 0.0001) rotary-wing aircraft. Wildlife strikes to rotary-wing aircraft occurred most frequently (> 60%) when the aircraft were engaged in terrain flight (Table 15).

Table 11. Number of reported wildlife strikes, by foreign country, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011.

Country	ARMY	USAF
Afghanistan	12	177
Turkey	3	5
Iraq	136	117
Kuwait	3	3
Saudi Arabia	6	1
South Korea	28	35
Thailand	1	6
Japan		15
Philippines		2
Indonesia		2
Malaysia		1
Kwajalein Island	1	
United Kingdom		61
Germany	13	1
Italy		5
Belgium	1	
Greece		1
Spain		1
Albania		2
Iceland		10
Latvia		1
Lithuania		1
Serbia	1	
Yugoslavia	1	
Panama	13	3
Honduras	10	
Guatemala	3	
Ecuador	1	
San Salvador	1	
Nigeria	1	
Somalia	3	
Other countries		13

Table 12. Number of all wildlife strikes and damaging wildlife strikes, by wildlife group, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011.

Wildlife Group	ARMY[a]		USAF	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Bats[b]	2	1	17	1
Blackbirds & starlings			2	
Corvids			1	1
Doves & pigeons	5	3	24	9
Finches			2	
Gulls			6	2
Herons, egrets & ibises			2	
Larks			40	1
Nightjars			1	
Perching birds			36	
Pheasants & quails			9	
Raptors & vultures	3	2	4	
Shorebirds			8	
Sparrows			18	
Swallows			6	
Swifts & hummingbirds			16	
Terns			1	
Thrashers & thrushes			10	2
Warblers			20	
Waterbirds			1	
Waterfowl	1	1	7	
Unidentified spp.	227	175	232	14

[a] *Wildlife species or group information is not identified within the ARMY wildlife strike database. However, records for species or groups involved in the strike event identified from pilot or aircrew comments are included in the table.*

[b] *Bats was comprised of common pipistrelles (Pipistrellus pipistrellus), European free-tailed bats (Tadarida teniotis), greater mouse-tailed bats (Rhinopoma microphyllum), Kuhl's pipistrelles (P. kuhlii), and bats of 'unidentified' species.*

Table 13. Number of reported wildlife strikes, by airframe model, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011.

Airframe Model	ARMY	USAF
H-1	13	7
H-6	3	
H-47	16	
H-53		103
H-58	15	
H-60	137	352
H-64	52	
Other	2	1

Table 14. Number of reported wildlife strikes, by aircraft category, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011.

Aircraft Category	ARMY	USAF
Attack	58	
Cargo	16	
Electronic	1	
Multi-mission	1	110
Observation	15	
SAR[a]		337
Utility	147	15

[a] *Search and rescue missions.*

Table 15. Proportion (%) of reported wildlife strikes, by phase of flight, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011.

Phase of Flight	ARMY	USAF
Enroute	24.9	16.6
Terrain flight	60.6	67.5
Hovering	1.4	1.5
Approach	7.0	4.2
Pattern		3.3
Landing	0.9	2.7
Taxiing	0.5	0.9
Take-off	2.8	0.9
Climbout	1.9	2.4

During deployments outside of the U.S., the number of reported wildlife strikes to various sections of rotary-wing aircraft varied for ARMY (χ^2 = 114.8, df = 9, P < 0.0001) and USAF (χ^2 = 81.4, df = 9, P < 0.0001) aircraft during flight operations. The highest proportion of impact locations for reported wildlife strikes to ARMY aircraft was the windscreen and the main rotor system (Table 16). For USAF rotary-wing aircraft, the fuselage and windscreen were the most frequently struck sections of the aircraft as a result of wildlife strikes (Table 16).

The proportion of reported wildlife strikes during deployments outside of the U.S. that were damaging to rotary aircraft were 73.5% and 6.5% for ARMY and USAF flight operations, respectively (Table 17). The proportion of wildlife strikes that were damaging was similar between wildlife strikes that occurred on-airfield and off-airfield for ARMY (z = 2.23, P = 0.14) and USAF (z = 2.35, P = 0.13) aircraft.

Wildlife strikes to military rotary-wing aircraft operating outside of the U.S. resulted in a total of 1 human injury and no human fatalities. The minor injury (i.e., cuts to the face of a pilot) occurred in 2004 when a bird crashed through the windscreen of an ARMY OH-58D Kiowa aircraft that was enroute during a combat mission in Iraq.

The average cost of a damaging wildlife strike (i.e., $ estimate of damaged parts and repair costs) to a rotary-wing aircraft operating outside of the U.S. was $31,913 per incident (highest reported = $694,668) for ARMY aircraft and $41,219 per incident (highest reported = $329,897) for USAF aircraft.

Table 16. Proportion (%) of reported wildlife strikes, by impact location on the aircraft, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011.

Impact Location	ARMY	USAF
Radome / nose	14.1	14.2
Windscreen	31.3	21.2
Fuselage	7.5	22.0
Main rotor system	22.5	11.5
Engine	10.1	17.4
Landing gear		3.7
Weapons system	1.8	6.4
External fuel tank		0.5
Tail section	0.9	3.2
Multiple locations	11.8	

Table 17. Number of reported wildlife strikes, without or with damage where the strike occurred 'on' or 'off' an airfield, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011.

Location	ARMY	USAF
On-Airfield		
Non-damaging	11	192
Damaging	18	9
% Damaging[a]	*62 %*	*4 %*
Off-Airfield		
Non-damaging	52	241
Damaging	157	21
% Damaging	*75 %*	*8 %*

[a] *The proportion of wildlife strikes where damage to the rotary-wing aircraft was reported among all reported wildlife strikes to rotary-wing aircraft (within the specified categories).*

4.2.1 'On' Airfield Wildlife Strikes (Outside of the U.S.)

Among the military rotary-wing strike records reported to have occurred on or over airfields (i.e., on-airfield) outside of the U.S., 30.4% (70 of 230) contained information regarding the identity of the animal struck down to the 'wildlife group' level. Birds accounted for 98.3% of the wildlife strikes that occurred on-airfield, whereas bats accounted for the remaining 1.7% of the strikes. The wildlife groups most frequently colliding with rotary-wing aircraft within airfield environments varied among the Military Services. Larks (n = 9), thrashers & thrushes (n = 7), gulls (n = 6), and waterfowl (n = 6) were the most commonly struck wildlife groups by USAF rotary-wing aircraft (Table 18). Although limited information is available regarding wildlife strikes with ARMY rotary-wing aircraft (97% of wildlife strikes had no wildlife species/group information), one dove & pigeon strike was reported for an ARMY rotary-wing aircraft.

When only damaging wildlife strikes to military rotary-wing aircraft on or over airfields outside of the U.S. are considered, 18.5% (5 of 27) of those reported strike records contained information regarding the identity of the animal struck. Gulls (n = 2), corvids (n = 1), and thrashers & thrushes (n = 1) were involved in strikes that resulted in damage to the aircraft for USAF rotary-wing aircraft (Table 18). Although limited information is available regarding wildlife strikes with ARMY rotary-wing aircraft (94% of damaging wildlife strikes had no wildlife species/group information), one damaging dove & pigeon strike was reported for an ARMY rotary-wing aircraft.

Wildlife strikes were reported to have impacted all sections of military rotary-wing aircraft operating on or over airfields outside of the U.S.; however, specific sections were impacted by wildlife with a much higher frequency compared to others. The number of reported wildlife strikes to various impact locations on rotary-wing aircraft varied for USAF (χ^2 = 20.69, df = 9, P < 0.0001) but not ARMY (χ^2 = 12.82, df = 9, P = 0.17) aircraft. The highest proportion of impact locations for on-airfield wildlife strikes during overseas deployments was the main rotor system, radome / nose, and windscreen for ARMY rotary-wing aircraft, and the fuselage, windscreen, and main rotor system for USAF rotary-wing aircraft (Table 19).

When only damaging wildlife strikes to rotary-wing aircraft on or over airfields outside of the U.S. are considered, the number of reported wildlife strikes to various sections of aircraft was similar ARMY (χ^2 = 8.74, df = 9, P = 0.46) and USAF (χ^2 = 6.43, df = 9, P = 0.70) aircraft. Windscreens, radomes / noses, and main rotor systems were the most frequently impacted sections of ARMY rotary-wing aircraft during on-airfield wildlife strike events outside of the U.S. (Table 19). The fuselage and radome / nose were the most frequently struck and damaged parts of USAF rotary-wing aircraft (Table 19).

The average cost of an on-airfield damaging wildlife strike to a rotary-wing aircraft operating on or over an airfield during deployments outside of the U.S. was $20,868 per incident (highest reported = $259,046) for ARMY aircraft and $6,435 per incident (highest reported = $36,000) for USAF aircraft.

There were no reports of human injuries or fatalities due to a wildlife strike for military rotary-wing aircraft (including ARMY and USAF) conducting flight operations on or over airfields during deployments outside of the U.S.

Table 18. Number of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'on' or over an airfield, by wildlife group, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011.

Wildlife Group	ARMY[a]		USAF	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Bats[b]			4	
Blackbirds & starlings			2	
Corvids			1	1
Doves & pigeons	1	1	5	
Finches			1	
Gulls			6	2
Herons, egrets & ibises			2	
Larks			9	
Perching Birds			9	
Pheasants & quails			3	
Raptors & vultures			3	
Shorebirds			3	
Swallows			2	
Swifts & hummingbirds			5	
Terns			1	
Thrashers & thrushes			7	1
Waterfowl			6	
Unidentified spp.	28	17	132	5

[a] *Wildlife species or group information is not identified within the ARMY wildlife strike database. However, records for species or groups involved in the strike event identified from pilot or aircrew comments are included in the table.*
[b] *Bats was comprised of bats of 'unidentified' species.*

Table 19. Proportion (%) of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'on' or over an airfield, by impact location on the aircraft, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011.

Impact Location	ARMY		USAF	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Radome / nose	18.5	22.2	8.6	33.3
Windscreen	18.5	27.9	20.8	
Fuselage	11.1	11.1	22.4	66.7
Main rotor system	25.9	16.7	20.7	
Engine	14.8	5.6	12.1	
Landing gear			6.9	
Weapons system			3.4	
External fuel tank			1.7	
Tail section	3.8	5.6	3.4	
Multiple locations	7.4	11.1		

4.2.2 'Off' Airfield Wildlife Strikes (Outside of the U.S.)

Among the military rotary-wing strike records where the wildlife strike was reported to have occurred away from an airfield (i.e., off-airfield) outside of the U.S., 36.5% (172 of 471) contained information regarding the identity of the animal struck down to the 'wildlife group' level. Birds accounted for 96.8% of the wildlife strikes the occurred on-airfield, whereas bats accounted for the remaining 3.2% of the strikes. The wildlife groups most frequently colliding with rotary-wing aircraft varied between the two Military Services. Larks (n = 31), perching birds (n = 27), warblers (n = 20), doves & pigeons (n = 19), and sparrows (n = 18) were the most commonly struck wildlife groups by USAF rotary-wing aircraft (Table 20). Although limited information is available regarding wildlife strikes with ARMY rotary-wing aircraft for strike events that occurred outside of the U.S. (95% of wildlife strikes had no wildlife species/group information), doves & pigeons (n = 4), raptors & vultures (n = 3), bats (n = 2), and waterfowl (n = 1) were the wildlife groups identified as being involved in strikes to ARMY aircraft.

Table 20. Number of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'off' an airfield, by wildlife group, for USAF rotary-wing aircraft outside of the U.S. during 1990−2011.

Wildlife Group	ARMY[a]		USAF	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Bats[b]	2	1	13	1
Doves & pigeons	4	2	19	9
Finches			1	
Larks			31	
Nightjars			1	1
Perching birds			27	
Pheasants & quails			6	
Raptors & vultures	3	2	1	
Shorebirds			5	
Sparrows			18	
Swallows			4	
Swifts & hummingbirds			11	
Thrashers & thrushes			3	1
Warblers			20	
Waterbirds			1	
Waterfowl	1	1	1	
Unidentified spp.	199	151	100	9

[a] *Wildlife species or group information is not identified within the ARMY wildlife strike database. However, records for species or groups involved in the strike event identified from pilot or aircrew comments are included in the table.*

[b] *Bats was comprised of common pipistrelles (Pipistrellus pipistrellus), European free-tailed bats (Tadarida teniotis), greater mouse-tailed bats (Rhinopoma microphyllum), Kuhl's pipistrelles (P. kuhlii), and bats of 'unidentified' species.*

When only damaging wildlife strikes to military rotary-wing aircraft away from an airfield outside of the U.S. are considered, 10.1% (18 of 178) of those reported strike records contained information regarding the identity of the animal struck. Doves & pigeons (n = 9) were the most common wildlife group involved in strikes that resulted in damage to the aircraft for USAF aircraft. In addition, a collision with a bat, a lark, and a thrush resulted in damaged USAF rotary-wing aircraft (Table 20). Although limited information is available regarding wildlife strikes with ARMY rotary-wing aircraft (95% of damaging wildlife strikes had no wildlife species/group information), doves & pigeons (n = 2), raptors & vultures (n = 2), one bat, and one waterfowl were identified as being involved in damaging strikes to ARMY rotary-wing aircraft.

Wildlife strikes were reported to have impacted all sections of military rotary-wing aircraft operating off-airfield outside of the U.S.; however, specific areas were impacted by wildlife with a much higher frequency compared to others. The number of reported wildlife strikes to various impact locations on rotary-wing aircraft varied for ARMY (χ^2 = 104.14, df = 9, P < 0.0001) and USAF (χ^2 = 66.57, df = 9, P < 0.0001). The highest proportion of impact locations was the windscreen and the main rotor system for ARMY aircraft, and the fuselage, windscreen, and engine for USAF aircraft (Table 21).

When only damaging wildlife strikes to military rotary-wing aircraft that occurred during off-airfield flight operations outside of the U.S. are considered, the number of reported wildlife strikes to various sections of rotary-wing aircraft varied for ARMY (χ^2 = 86.44, df = 9, P < 0.0001) but not USAF (χ^2 = 4.24, df = 9, P = 0.89) aircraft. Windscreens and main rotor systems were the most frequently impacted and damaged sections of ARMY aircraft (Table 21). Although the tail section was the most frequently struck and damaged part, all sections of USAF aircraft were damaged (Table 21).

The average cost of a damaging wildlife strike to a rotary-wing aircraft operating away from an airfield during deployments outside of the U.S. was $33,294 per incident (highest reported = $694,663) for ARMY aircraft and $56,126 per incident (highest reported = $329,046) for USAF aircraft.

Within the wildlife strike records for ARMY and USAF rotary-wing aircraft conducting off-airfield flight operations during deployments outside of the U.S., there was 1 reported human injury and no human fatalities. The injury was to a pilot operating an ARMY rotary-wing aircraft in Iraq.

Table 21. Proportion (%) of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'off' an airfield, by impact location on the aircraft, for ARMY and USAF rotary-wing aircraft outside of the U.S. during 1990−2011.

Impact Location	ARMY		USAF	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Radome / nose	13.5	14.7	16.3	13.3
Windscreen	33.0	34.4	21.3	6.7
Fuselage	7.0	7.0	21.9	13.3
Main rotor system	22.0	19.8	8.1	13.3
Engine	9.5	7.0	19.4	13.3
Landing gear			2.5	6.7
Weapons system	2.0	2.5	7.5	13.3
Tail section	0.5	0.6	3.0	20.1
Multiple locations	12.5	14.0		

4.3 Wildlife Strikes with Civil Helicopters

We found a total of 1,044 wildlife strikes with civil helicopters among the records of the FAA NWSD that occurred within the U.S. during 1990−2011. These helicopters were from a variety of public and private organizations, including U.S. federal government agencies (e.g., Department of Homeland Security), private companies (e.g., Rocky Mountain Helicopters), medical and emergency services, and private citizens.

During 1990−2008, an average of 27.9 (± 3.0 SE) reported wildlife strikes to civil helicopters occurred annually during flight operations within the U.S. that were reported to the FAA (Figure 13). The annual number of reported wildlife strikes to civil helicopters increased ($y = 2.02x - 4{,}005.1$; $R^2 = 0.78$, $F_{1,18} = 60.4$, $P < 0.0001$) by 1,320% during this time period. The average number of reported wildlife strikes to civil helicopters during 2009−2011 (171.3 ± 18.6 SE) was over 6 times higher ($t_{20} = -14.4$, $P < 0.0001$) than the average number of reported wildlife strikes during the previous 19 years.

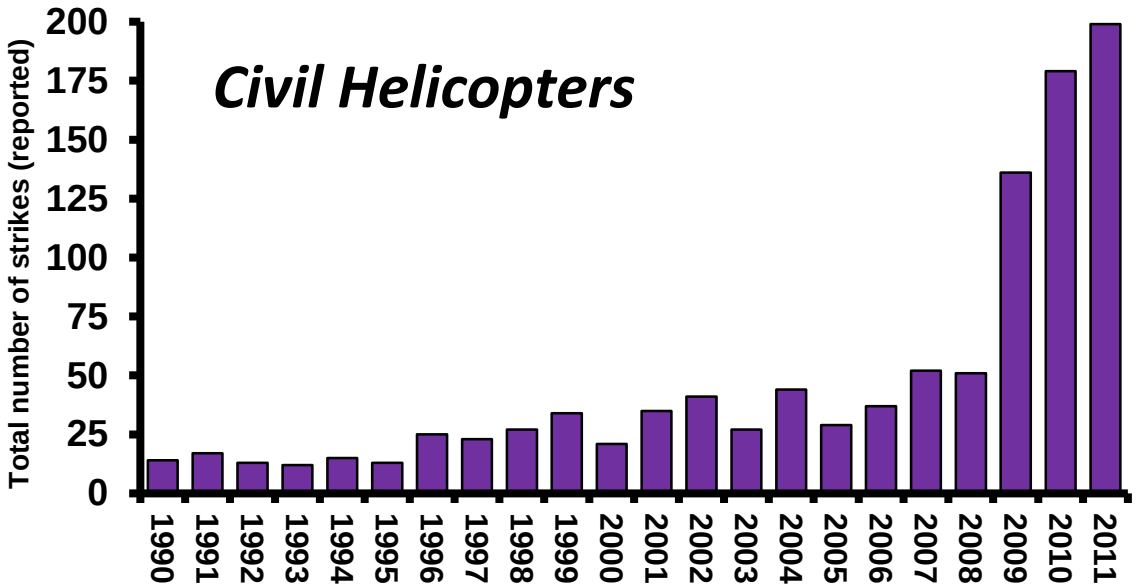

Figure 13. Total number of reported wildlife strikes with civil helicopters, each year, in the U.S. during 1990−2011.

The number of reported wildlife strikes with rotary-wing aircraft varied among months (season) for civil helicopters (χ^2 = 80.0, df = 11, P < 0.0001) and for military rotary-wing aircraft (all Services combined; χ^2 = 247.9, df = 3, P < 0.0001) during flight operations within the U.S. For both civil and military aircraft, the highest numbers of wildlife strikes per month occurred during fall (September and October) whereas the lowest number was found in winter (December through February; Figure 14).

The proportion of reported wildlife strikes with civil helicopters (χ^2 = 30.4, df = 3, P < 0.0001) and military rotary-wing aircraft (χ^2 = 247.9, df = 3, P < 0.0001) varied among the time of day for aircraft operations in the U.S. For both civil helicopters and military rotary-wing aircraft (all Services combined), most wildlife strikes occurred during day and night time periods and relatively few during dawn or dusk (Figure 15). More reported wildlife strikes occurred during the day for civil helicopters (χ^2 = 11.1, df = 1, P = 0.0008), whereas more strikes occurred at night for military rotary-wing aircraft (χ^2 = 143.4, df = 1, P < 0.0001; Figure 15).

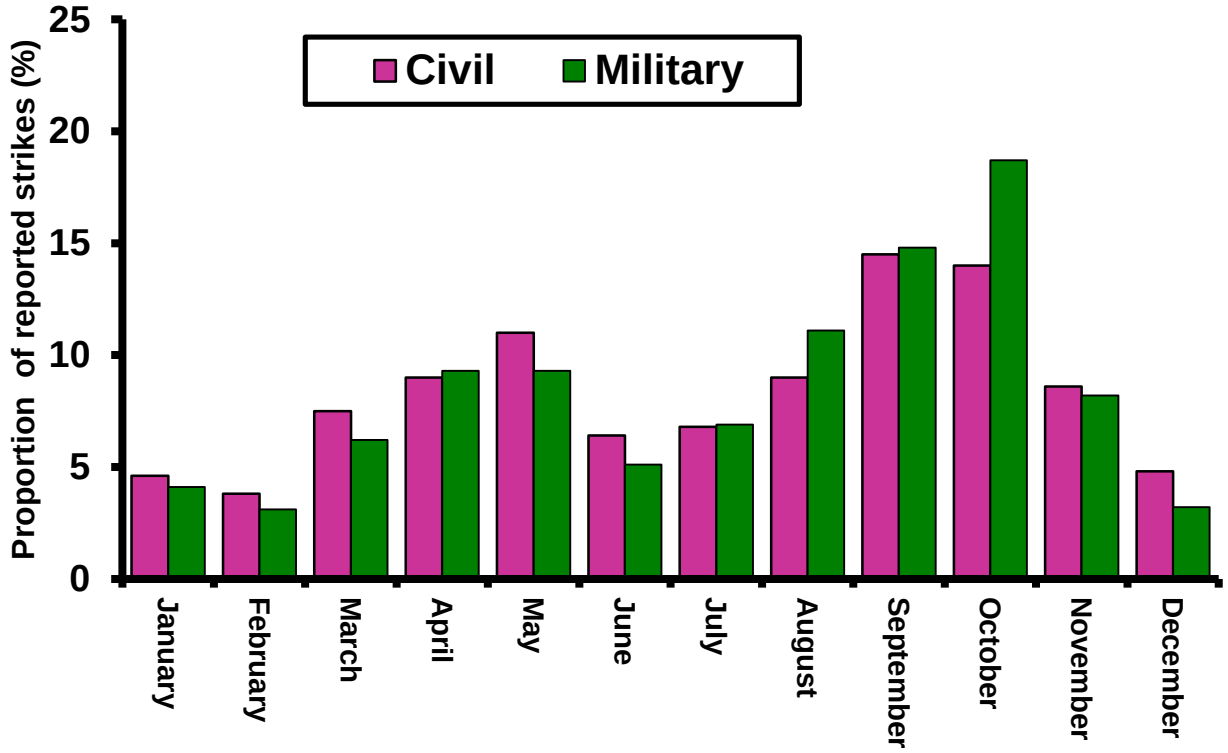

Figure 14. Proportion of reported wildlife strikes, by month, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1979−2011.

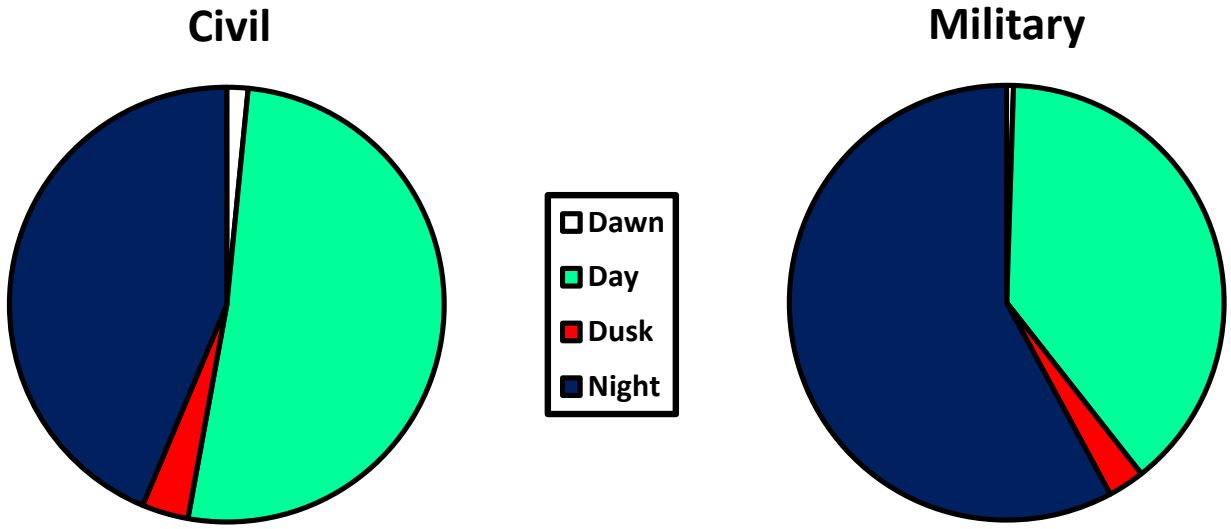

Figure 15. Proportion (%) of reported wildlife strikes, by time of day, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011.

Among the civil helicopter strike records, 37.2% (388 of 1,044) identified the animal struck down to the 'wildlife group' level (Table 22). Birds accounted for 97.2% of the wildlife strikes, whereas bats and large mammals (combined) accounted for the remaining 2.8% of the wildlife strikes identified to a 'wildlife group'. Gulls (n = 104), waterfowl (n = 77), and raptors & vultures (n = 76) were the wildlife groups most frequently struck by civil helicopters (Table 22). A total of 11 mammal strikes was reported, including 2 with Brazilian free-tailed bats (*Tadarida brasiliensis*), 4 with bats of 'unidentified' species, 2 with cattle (*Bos taurus*), 1 with a coyote (*Canis latrans*), 1 with a moose (*Alces alces*), and 1 with a white-tailed deer (*Odocoileus virginianus*).

Among the 930 wildlife strikes with civil helicopters that the specific geographic location (i.e., state) where the incident occurred could be determined, the majority were reported in Louisiana (n = 113), Texas (n = 94), California (n = 84), Arizona (n = 66), and Florida (n = 63). Wildlife strikes to military aircraft were reported in all U.S. states and the District of Columbia, with one exception: no strikes were reported within Rhode Island.

Among the civil helicopter (n = 1,025) strike records within the U.S., all contained information regarding the airframe model of the aircraft struck (Table 23). Among the reported wildlife strikes with civil helicopters, 46.3% involved H-53 airframes, 21.7% involved H-72 airframes, 10.9% occurred with H-68 airframe helicopters, and 6.4% were classified as variants of the H-6 airframe. Forty-two percent of the military rotary-wing aircraft (across all Military Services) reported to have been struck by wildlife were H-60 airframe variants, 16.7% were H-1 airframes, and all other airframes accounted for less than 10% each.

Wildlife strikes to civil helicopters were reported to have occurred during all phases of flight. When the phase of flight during which wildlife strikes occurred was reported (n = 973), wildlife strikes to civil helicopters occurred most frequently when rotary-wing aircraft were traveling enroute (Table 24). The proportion of wildlife strikes that occurred among the various phases of flight varied for both civil helicopters (χ^2 = 784.5, df = 9, P < 0.0001) and military rotary-wing aircraft (χ^2 = 830.1, df = 9, P < 0.0001).

During flight operations within the U.S., the number of reported wildlife strikes to various sections of rotary-wing aircraft varied for civil helicopters (χ^2 = 620.3, df = 9, P < 0.0001) and for military rotary-wing aircraft (χ^2 = 673.4, df = 9, P < 0.0001). The highest proportion of impact locations for reported wildlife strikes to civil helicopters during flight operations within the U.S. were the windscreen and multiple locations per strike event (Table 25). For military rotary-wing aircraft conducting flight operations within the U.S., the windscreen, main rotor system, radome / nose, and fuselage were the most frequently struck sections of the aircraft (Table 25).

The proportion of wildlife strikes occurring within the U.S. that were damaging to civil helicopters was 36.3% and to military rotary aircraft was 12.6% (Table 26). The proportion of wildlife strikes that were damaging was higher for wildlife strikes that occurred off-airfield

Table 22. Proportion (%) of reported wildlife strikes, by wildlife group, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011.

Wildlife Group	Civil		Military	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Bats[a]	1.5		9.0	5.2
Blackbirds & starlings	2.8	2.2	1.5	
Corvids	0.8	0.9	0.3	
Cuckoos	0.3		1.1	2.6
Doves & pigeons	5.7	3.1	4.4	3.9
Finches	0.8		2.5	3.9
Gulls	26.8	23.0	6.9	10.3
Herons, egrets & ibises	3.1	1.8	1.5	3.9
Large mammals[b]	1.3	1.3		
Larks			4.6	
Nightjars	0.3		1.4	
Owls	0.5	0.9	0.2	
Perching birds	0.3		11.6	6.5
Raptors & vultures	19.6	27.4	7.1	29.9
Seabirds	0.8	0.9	4.6	1.3
Shorebirds	2.1	1.8	5.2	7.8
Sparrows	3.6	0.9	5.9	1.3
Swallows	1.0	0.4	3.2	1.3
Swifts & hummingbirds			3.0	1.3
Terns			0.7	
Thrashers & thrushes	0.3	0.4	5.8	
Tropicbirds	2.8	3.1		
Vireos	0.5		1.8	1.3
Warblers	1.0		11.2	1.3
Waterbirds	4.3	6.2	1.5	5.2
Waterfowl	19.8	25.7	4.6	13.0
Woodpeckers			0.4	

[a] *Bats was comprised of big brown bats (Eptesicus fuscus), Brazilian free-tailed bats (Tadarida brasiliensis), Eastern pipistrelles (Perimyotis subflavus), evening bats (Nycticeius humeralis), hairy-tailed bats (Lasiurus ebenus), hoary bats (L. cinereus), pocketed free-tailed bats (Nyctinomops femorosaccus), red bats (L. borealis), Seminole bats (L. seminolis), silver-haired bats (Lasionycteris noctivagans), Western pipistrelles (Pipistrellus hesperus), and bats of 'unidentified' species.*

[b] *Large mammals was comprised of cattle (Bos taurus), coyote (Canis latrans), moose (Alces alces), and white-tailed deer (Odocoileus virginianus).*

Table 23. Number of reported wildlife strikes, by airframe model, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1979−2011.

Airframe Model	Civil	Military
H-1	16	420
H-3		65
H-6	66	11
H-13	2	
H-46		31
H-47		22
H-53		214
H-55	79	
H-57	475	282
H-58		59
H-60	26	1,055
H-64		55
H-65	27	187
H-67		18
H-68	112	2
H-72	222	
V-22		90

Table 24. Proportion (%) of reported wildlife strikes, by phase of flight, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1979−2011.

Phase of Flight	Civil	Military
Enroute	53.1	38.3
Terrain flight	11.9	28.9
Hovering	0.7	3.6
Approach	18.2	10.4
Pattern		4.8
Landing	0.5	3.1
Taxiing	2.6	2.7
‘Touch and go’		0.9
Take-off	0.8	3.6
Climbout	12.2	3.7

Table 25. Proportion (%) of reported wildlife strikes, by impact location on the aircraft, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1979−2011.

Impact Location	Civil	Military
Radome / nose	13.6	16.3
Windscreen	33.8	26.6
Fuselage	9.7	14.3
Main rotor system	17.9	17.8
Engine	1.0	12.3
Landing gear		1.1
Weapons system		1.1
External fuel tank		0.2
Tail section	1.5	2.7
Multiple locations	22.5	8.1

Table 26. Number of reported wildlife strikes, without or with damage where the strike occurred 'on' or 'off' an airfield, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011.

Location	Civil	Military
On-Airfield		
Non-damaging	110	667
Damaging	10	65
% Damaging[a]	*8 %*	*9 %*
Off-Airfield		
Non-damaging	514	1062
Damaging	345	185
% Damaging	*40 %*	*15 %*

[a] *The proportion of wildlife strikes where damage to the rotary-wing aircraft was reported among all reported wildlife strikes to rotary-wing aircraft (within the specified categories).*

compared to on-airfield wildlife strikes for civil helicopters (z = 46.15, $P <$ 0.0001) and military rotary-wing aircraft (z = 14.82, P = 0.0001) aircraft.

The average cost of a damaging wildlife strike (i.e., $ estimate of damaged parts and repair costs) to a civil helicopter within the U.S. was $41,158 per incident (highest reported = $1,500,000), whereas the average cost of a damaging strike to a military rotary-wing aircraft conducting flight operations within the U.S. was $129,168 per incident (highest reported = $24,800,000).

Collisions between wildlife and civil helicopters operating in the U.S. resulted in a total of 52 human injuries and 9 human fatalities during 1990−2011. The human injuries occurred during 47 wildlife strike incidents with civil helicopters. Most of the human injuries were consisted of cuts, lacerations, and/or bruising to pilots and copilots when a bird (or birds) impacted the windscreen of the aircraft, shattering the windscreen of the aircraft and sending glass and bird remains into the aircraft cabin and impacting the aircrew. Eight of the human fatalities that involve wildlife strikes to civil helicopters within in the U.S. occurred when a Red-tailed Hawk collided with a private helicopter in Louisiana during 2009. The pilot, co-pilot, and 6 passengers were lost in this strike event, which also involved the total destruction of the aircraft (monetary loss unknown) when it crashed.

4.3.1 'On' Airfield Wildlife Strikes (Civil Aircraft)

Among the civil helicopter strike records reported to have occurred on or over airfields (i.e., on-airfield) within the U.S., 53.3% (64 of 120) contained information regarding the identity of the animal struck down to the 'wildlife group' level. Birds accounted for 98.3% of the wildlife strikes the occurred on-airfield, whereas bats accounted for the remaining 1.7% of the military rotary-wing strikes when the animal was identified to a 'wildlife group'. Gulls (n = 27), doves & pigeons (n = 9), herons, egrets & ibises (n = 5), and waterfowl (n = 5) were the wildlife groups most frequently struck by civil helicopters (Table 27). A total of 4 on-airfield mammal strikes to civil helicopters were reported, including 1 with a bat of 'unidentified' species, 1 with a cow, 1 with a coyote, and 1 with a white-tailed deer.

When only on-airfield damaging wildlife strikes to civil helicopters within the U.S. are considered, 70% (7 of 10) of those reported strike records contained information regarding the identity of the animal struck. Two waterfowl, a gull, a shorebird, an owl, and an egret were involved in strikes that resulted in damage to the civil helicopters (Table 27). One on-airfield damaging mammal strike to a civil helicopter was reported; this strike event involved a cow and the helicopter was completely destroyed by the resulting crash due to the strike event.

Table 27. Number of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'on' or over an airfield, by wildlife species group, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011.

Species Group	Civil		Military	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Bats[a]	1		18	
Blackbirds & starlings	2		8	
Corvids			2	
Cuckoos			5	
Doves & pigeons	9		28	3
Finches	2		6	
Gulls	27	1	24	3
Herons, egrets & ibises	5	1	4	
Large mammals	3	1		
Larks			19	
Nightjars	1		6	
Owls	1	1	1	
Perching birds			22	3
Raptors & vultures	2		24	8
Seabirds			10	
Shorebirds	3	1	18	2
Sparrows	2		19	
Swallows	1		10	1
Swifts & hummingbirds			5	
Terns			1	
Thrashers & thrushes			21	
Vireos			2	
Warblers			27	
Waterbirds			3	1
Waterfowl	5	2	10	2
Woodpeckers			1	
Wrens			1	
Unidentified spp.	56	3	437	42

[a] *Bats was comprised of Brazilian free-tailed bats (Tadarida brasiliensis), Eastern pipistrelles (Perimyotis subflavus), evening bats (Nycticeius humeralis), hoary bats (Lasiurus cinereus), red bats (L. borealis), Seminole bats (L. seminolis), silver-haired bats (Lasionycteris noctivagans), and bats of 'unidentified' species.*

[b] *Large mammals was comprised of a cow (Bos taurus), a coyote (Canis latrans), and a white-tailed deer (Odocoileus virginianus).*

Wildlife strikes were reported to have impacted all sections of civil helicopters flying on or over airfields within the U.S.; however, specific areas were impacted by wildlife with a much higher frequency compared to others. The number of reported wildlife strikes to various sections of civil helicopters (χ^2 = 90.37, df = 9, P < 0.0001) and military rotary-wing aircraft (χ^2 = 189.89, df = 9, P < 0.0001) varied during on-airfield flight operations within the U.S. The highest proportion of wildlife strike impact locations (over half of the reported strikes) for on-airfield wildlife strikes was the main rotor system for civil helicopters; windscreens and main rotor systems were the most commonly struck sections for military rotary-wing aircraft (Table 28).

When only damaging wildlife strikes to civil helicopters are considered, the number of reported wildlife strikes to various sections of civil helicopters was similar (χ^2 = 8.00, df = 9, P = 0.53), whereas it varied (χ^2 = 29.63, df = 9, P < 0.0001) for military rotary-wing aircraft during on-airfield flight operations within the U.S. Main rotor systems were the most frequently impacted sections of civil helicopters during on-airfield wildlife strike events in the U.S. (Table 28). The windscreen and main rotor system were the most frequently struck and damaged parts of military rotary-wing aircraft during on-airfield flights operations in the U.S. (Table 28).

Table 28. Proportion (%) of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'on' or over an airfield, by impact location on the aircraft, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011.

Species Group	Civil		Military	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Radome / nose	2.7	10.0	13.6	7.0
Windscreen	13.5	10.0	22.6	29.8
Fuselage	7.2	10.0	11.5	5.3
Main rotor system	53.2	50.0	25.0	28.1
Engine	0.9		13.7	12.3
Landing gear			1.1	
Weapons system			0.4	
External fuel tank			0.4	
Tail section	1.8		2.8	10.5
Multiple locations	20.7	20.0	8.9	7.0

The average cost of a damaging wildlife strike to a civil helicopter on or over an airfield within the U.S. was $378,539 per incident (highest reported = $1,500,000), whereas the average cost of a damaging strike to a military rotary-wing aircraft was $16,497 per incident (highest reported = $248,709).

There was 1 reported human injury and no reported fatalities due to a wildlife strike to civil helicopters conducting flight operations on or over airfields within the U.S. A civilian helicopter pilot received cuts and lacerations when a bird impacted the windscreen of the aircraft, shattering the windscreen of the aircraft and sending glass and bird remains into the aircraft cabin and impacting the pilot.

4.3.2 'Off' Airfield Wildlife Strikes (Civil Aircraft)

Among the civil helicopter strike records reported to have occurred away from airfields (i.e., off-airfield) within the U.S., 36.6% (314 of 859) contained information regarding the identity of the animal struck down to the 'wildlife group' level. Birds accounted for 98.4% of the wildlife strikes the occurred on-airfield, whereas mammals accounted for the remaining 1.6% of the civil helicopter strikes when the animal was identified to a 'wildlife group'. Gulls (n = 75), raptors & vultures (n = 71), and waterfowl (n = 71) were the wildlife groups most frequently struck by civil helicopters (Table 29). A total of 5 off-airfield mammal strikes to civil helicopters was reported, including 1 with Brazilian free-tailed bat, 2 with bats of 'unidentified' species, 1 with a cow, and 1 with a moose.

When only off-airfield damaging wildlife strikes to civil helicopters within the U.S. are considered, 68.5% (215 of 314) of those reported strike records contained information regarding the identity of the animal struck. Raptors & vultures (n = 59), waterfowl (n = 55), and gulls (n = 49) were most frequently involved in strikes that resulted in damage (Table 29). A total of 2 off-airfield damaging mammal strikes to civil helicopters was reported, including 1 with a cow and 1 with a moose.

Wildlife strikes were reported to have impacted all sections of civil helicopters flying over areas away from airfields within the U.S.; however, specific areas were impacted by wildlife with a much higher frequency compared to others. The number of reported wildlife strikes to various sections of civil helicopters (χ^2 = 533.80, df = 9, P < 0.0001) and military rotary-wing aircraft (χ^2 = 406.65, df = 9, P < 0.0001) varied during off-airfield flight operations within the U.S. The highest proportion of impact locations for off-airfield wildlife strikes was windscreen and multiple impact locations for civil helicopters; windscreens were the most frequently impacted section of military rotary-wing aircraft (Table 30).

Table 29. Number of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'off' an airport, by wildlife species group, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011.

Species Group	Civil		Military	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Bats[a]	3		48	4
Blackbirds & starlings	9	5	4	
Corvids	3	2		
Cuckoos	1		4	2
Doves & pigeons	11	7	7	
Finches	1		14	3
Gulls	75	49	27	5
Herons, egrets & ibises	7	3	8	3
Large mammals	2	2		
Larks			18	
Nightjars			4	
Owls	1	1	2	
Perching birds	1		66	2
Raptors & vultures	71	59	31	14
Seabirds	3	2	24	1
Shorebirds	5	3	26	4
Sparrows	12	2	29	1
Swallows	3	1	14	
Swifts & hummingbirds			18	
Terns			4	
Thrashers & thrushes	1	1	26	
Tropicbirds	11	7		
Vireos	2		13	1
Warblers	4		63	
Waterbirds	17	14	6	3
Waterfowl	71	55	26	8
Woodpeckers			2	
Unidentified spp.	545	132	763	134

[a] *Bats was comprised of big brown bats (Eptesicus fuscus), Brazilian free-tailed bats (Tadarida brasiliensis), Eastern pipistrelles (Perimyotis subflavus), hairy-tailed bats (Lasiurus ebenus), hoary bats (L. cinereus), pocketed free-tailed bats (Nyctinomops femorosaccus), red bats (L. borealis), Seminole bats (L. seminolis), silver-haired bats (Lasionycteris noctivagans), Western pipistrelles (Pipistrellus hesperus), and bats of 'unidentified' species.*

[b] *Large mammals was comprised of a cow (Bos taurus) and a moose (Alces alces).*

Table 30. Proportion (%) of all wildlife strikes and damaging wildlife strikes where the aircraft was reported as being 'off' an airfield, by impact location on the aircraft, in the U.S. for civil helicopters and military rotary-wing aircraft (all Services combined) during 1990−2011.

Species Group	Civil		Military	
	All Strikes	Damaging Strikes	All Strikes	Damaging Strikes
Radome / nose	14.9	16.0	17.9	18.1
Windscreen	37.3	37.6	28.5	31.3
Fuselage	9.6	7.1	16.2	10.6
Main rotor system	12.1	6.2	14.0	16.3
Engine	1.1	1.1	11.4	10.0
Landing gear			0.8	0.6
Weapons system			0.7	0.6
External fuel tank			0.1	0.6
Tail section	1.1	1.8	2.2	5.6
Multiple locations	23.9	30.2	8.2	6.3

When only damaging wildlife strikes to civil helicopters are considered, the number of reported wildlife strikes to various sections of civil helicopters ($\chi^2 = 242.34$, df = 9, $P < 0.0001$) and military rotary-wing aircraft ($\chi^2 = 66.73$, df = 9, $P < 0.0001$) during off-airfield flight operations within the U.S. Windscreens and multiple impact locations were the most frequently impacted and damaged sections of civil helicopters, whereas the windscreen was the most frequently struck and damaged part of military rotary-wing aircraft (Table 30).

The average cost of an off-airfield damaging wildlife strike to a civil helicopter within the U.S. was $32,338 per incident (highest reported = $1,500,000), whereas the average cost of a damaging strike to a military rotary-wing aircraft conducting flight operations off-airfield within the U.S. was $169,015 per incident (highest reported = $24,800,000).

There were 50 reported human injuries and 9 human fatalities due to wildlife strikes to civil helicopters conducting flight operations off-airfield within the U.S. Two wildlife strike incidents resulted in the loss of 9 lives; one involved a Red-tailed Hawk and one involved an unidentified species of wildlife.

5. DISCUSSION

Overall, the total number of reported wildlife strikes with ARMY rotary-wing aircraft remained constant on an annual basis, as flight operations within the U.S. (which accounted for most flight operations in the 1990s) were replaced by flights (e.g., combat operations) during overseas deployments of ARMY rotary-wing squadrons to Iraq and Afghanistan during early and late in the 2000s.

A pattern of increased numbers of reported wildlife strikes each year to USAF rotary-wing aircraft was likely due to increased awareness and emphasis on the need for reporting of wildlife strikes to USAF aircraft, including rotary-wing airframes. In addition, annual increases in the number of reported wildlife strikes to USAF rotary-wing aircraft was due, in part, to a higher number of 'in theater' flight operations (e.g., Search and Rescue) during overseas deployments of USAF rotary-wing squadrons within Iraq and Afghanistan during the 2000s.

5.1 Wildlife Strikes with Military Rotary-wing Aircraft Within the U.S.

We found that there were annual increases in the numbers of reported wildlife strikes to USAF and NAVY rotary-wing aircraft conducting flight operations within the U.S. These increases were likely due to increased aircrew and aircraft maintenance crew awareness and a heightened emphasis on the need for reporting of wildlife strikes to USAF and NAVY aircraft, including rotary-wing airframes. Both the USAF and NAVY have comprehensive BASH programs that emphasize the collection of wildlife strike information, including biological samples to allow for the identification of the wildlife species involved. In contrast, the ARMY and USCG currently do not have formal BASH programs; thus, pertinent reporting requirements and protocols, logistical support, and identification of strike remains (i.e., to determine the species of wildlife involved) are unavailable or unused, reducing the amount and quality of wildlife strike reporting for these 2 Military Services. Although the information contained in the ARMY and USCG wildlife strike databases was extensive, there was no information (and apparently no protocols) for identifying the wildlife species involved in these wildlife strike events (or at least it was very limited for the ARMY database) and no specific information to suggest whether the wildlife strikes occurred on- or off-airfield for the USCG database. Such information is critical to understanding and alleviating the risk of wildlife strikes to military rotary-wing aircraft during flight operations within the U.S.

Compared to the other Military Services, the percentage of damaging strikes to ARMY rotary-wing aircraft was very high. Although the exact reason for this difference is unknown, it may be due to the lack of rigid reporting requirements. Damaging wildlife strikes to ARMY rotary-wing aircraft are more likely to be reported than non-damaging strikes. In contrast, it appears a much higher proportion of non-damaging wildlife strikes to USAF and NAVY aircraft are being reported. USCG personnel are not required to report wildlife strikes unless there is actual damage to the aircraft. Information gained from non-damaging wildlife strikes is critical for understanding the nature and extent of wildlife strikes to military aircraft and important to allow for the development of effective BASH plans and programs to alleviate the risk of wildlife

strikes. Any efforts to increase the wildlife reporting rates for ARMY and USCG military aircraft, especially non-damaging strikes, would be invaluable (and essential) for a better understanding of and the development of effective mitigation strategies to reduce the frequency and damage resulting from wildlife strikes to military rotary-wing aircraft. Formalized BASH programs for ARMY and USCG would likely improve overall reporting of wildlife strikes.

When considering only those wildlife strikes to military rotary-wing aircraft where the animal(s) involved were identified, birds accounted for the vast majority of wildlife-aircraft collisions; however, bats (comprised of many species) also collided with military rotary-wing aircraft during night-time flight operations.

Although variation among the Military Services would be expected due to the diverse geographic areas within the U.S. where flight operations occur, overall warblers, perching birds, shorebirds, seabirds, and bats were the wildlife groups that collided with military rotary-wing aircraft most often. However, raptors & vultures [e.g., Turkey Vulture (*Cathartes aura*)], doves & pigeons [e.g., Rock Pigeon (*Columba livia*)], and gulls [e.g., Ring-billed Gull (*Larus delawarensis*)] caused the most damage to military rotary-wing aircraft operating within airfield environments. During flight operations away from airfields (e.g., Naval Air Stations and Naval Outlying Landing Fields), raptors & vultures (e.g., Red-tailed Hawk), shorebirds [e.g., Sanderling (*Calidris alba*)], and waterbirds [e.g., American Coot (*Fulica americana*)] caused the most damage to military rotary-wing aircraft.

Wildlife strikes to military rotary-wing aircraft occurred on and damaged various sections of the aircraft in unequal proportion. Forward sections of the aircraft (e.g., windscreen and radome / nose) and the main rotor section (e.g., a large section of the aircraft in regard to surface area and movement) were struck and damaged by wildlife with a much higher frequency that the rest of the airframe. This finding is not completely unexpected, as a bird(s) flying toward the aircraft (and visa versa) would encounter the front of the aircraft first. Similarly, the large size of the rotating rotor blades on the top of the aircraft would intercept wildlife diving (e.g., dropping in altitude) or passing by the fuselage / airframe itself. In contrast, wildlife approaching the aircraft from below or from the side would have the potential to impact other parts of the airframe (e.g., tail section, fuselage). Further investigations into the behavioral responses of birds to rotary-wing aircraft is an interesting and important area for future research.

For ARMY and USAF rotary-wing aircraft conducting flight operations within the U.S., more wildlife strikes were reported to have occurred during flight operations off-airfield than during on-airfield flight procedures. This is potentially due to the aircraft spending a greater proportion of flight time off-airfield, engaged in terrain flight or traveling enroute, than conducting landing procedures or other on-airfield activities. In contrast, NAVY rotary-wing aircraft conducting flight operations within the U.S. reported wildlife strikes occurred with similar frequency on- and off-airfield. Relative to the other Military Services, the majority of military rotary-wing aircraft within the ‘training’ aircraft category were NAVY aircraft. We suspect that NAVY rotary-wing aircraft (especially training model airframes) spend proportionately more time

conducting on-airfield flight operations (e.g., take-offs, landings, pattern work) than rotary-wing aircraft from the other Military Services that have different mission types.

The majority of reported wildlife strikes to military rotary-wing aircraft from all Military Services occurred during the enroute and terrain flight phases of flight. This is in contrast to wildlife strikes to civil fixed-wing aircraft, as the frequency of wildlife strikes to fixed-wing aircraft is typically lowest during the enroute phase of flight (Dolbeer 2006, Dolbeer et al. 2012). However, fixed-wing aircraft flying enroute to a destination would typically be at a much higher altitude than rotary-wing aircraft and consequently above the airspace (and altitudes) typically used by birds and bats during their normal flight activity patterns (DeVault et al. 2005, Dolbeer 2006, Washburn and Olexa 2011).

5.2 Wildlife Strikes with Military Rotary-wing Aircraft Outside of the U.S.

Although wildlife strikes to USAF rotary-wing aircraft conducting flight operations during overseas deployments followed a season trend (i.e., wildlife strikes were highest in spring and fall), there did not appear to be a strong season trend in wildlife strikes to ARMY rotary-wing aircraft. We suspect this might be a result of the distribution of ARMY and USAF rotary-wing squadrons within 'in theater' operations. Bird movement patterns within the desert environments of the Middle East (e.g., Iraq) might not be as predictable as migratory movements of birds within the regions of Afghanistan.

Almost three-quarters of the reported wildlife strikes associated with ARMY rotary-wing aircraft occurred during the day. As most ARMY flight operations (e.g., combat missions, ground support) occurred during daylight hours, the distribution of wildlife strike events likely was a result of mission timing. In contrast, wildlife strikes to USAF rotary-wing aircraft occurred with equal frequency during day and night. We believe this finding is not unexpected as USAF rotary-wing squadrons were likely conducting SAR missions during both day and night periods.

The proportion of damaging reported wildlife strikes to ARMY rotary-wing aircraft was much higher than that to USAF rotary-wing aircraft conducting overseas flight operations. As with reported wildlife strikes to ARMY aircraft within the U.S., we believe that typically wildlife strikes to ARMY rotary-wing aircraft are being reported more frequently to the ARMY Safety Center (and consequently into the ARMY wildlife strike database) when monetary damage occurs to the aircraft. In contrast, it would appear a much higher proportion of non-damaging wildlife strikes to USAF rotary-wing aircraft are being reported. Similar to the wildlife strikes that occurred within the U.S., there was no information (and apparently no protocols) for identifying the wildlife species involved in wildlife strike events to ARMY aircraft (or at least it was very limited). Such information is critical to understanding and alleviating the risk of wildlife strikes to military rotary-wing aircraft during overseas deployments. Information gained from non-damaging wildlife strikes during overseas deployments and identification of the wildlife species involved is critical for understanding the nature and extent of wildlife strikes to military rotary-wing aircraft operating on or off foreign airfields and important to allow for the

development of effective BASH plans and programs to alleviate the risk of wildlife strikes during 'in theater' flight operations.

Overall, larks [e.g., Eurasian Skylark (*Alauda arvensis*) and Greater Short-toed Lark (*Calandrella brachydactyla*)], warblers [e.g., Blyth's Reed Warbler (*Acrocephalus dumetorum*)], sparrows [e.g., House Sparrow (*Passer domesticus*)], and quail [e.g., Common Quail (*Coturnix coturnix*)] were the wildlife groups that collided with USAF military rotary-wing aircraft most often during overseas flight missions and sorties. However, gulls [e.g., Black-headed Gull (*Chroicocephalus ridibundus*) and Mew Gull (*Larus canus*)] caused the most damage to military rotary-wing aircraft operating within airfield environments. During mission flight operations and sorties, doves & pigeons [e.g., Pin-tailed Sandgrouse (*Pterocles alchata*)], larks [e.g., Crested Lark (*Galerida cristata*)], and raptors & vultures (e.g., unidentified species) caused the most damage to military rotary-wing aircraft during off-airfield wildlife strike events.

We found that wildlife strikes to military rotary-wing aircraft during flight operations outside of the U.S. were similar to wildlife events within the U.S., in that the forward sections of the aircraft (e.g., windscreen and radome / nose) and the main rotor section (e.g., a large section of the aircraft in regard to surface area and movement) were struck and damaged by wildlife with a much higher frequency that the rest of the airframe.

For ARMY and USAF rotary-wing aircraft conducting flight operations outside of the U.S., more wildlife strikes were reported to have occurred during flight operations off-airfield than on-airfield. This is potentially due to the aircraft spending a greater proportion of flight time off-airfield, engaged in terrain flight or traveling enroute, than conducting landing procedures or other on-airfield activities. However, the proportion of strikes that were damaging to ARMY and USAF rotary-wing aircraft was similar between on- and off-airfield wildlife strikes. Although the total number of wildlife strikes that occurred was higher in off-airfield operations, the consequences of a wildlife strike (i.e., damage to the aircraft and the potential for human injury) are important both within airfield environments and during mission flight operations and sorties.

5.3 Wildlife Strikes with Civil Helicopters

Since 2009, there has been a 6-fold increase in the annual number of reported wildlife strikes with civil helicopters within the U.S. This huge increase in wildlife strike reports to the FAA's NWSD is likely the result of increased awareness of wildlife strike issues following the ditching of US Airways Flight 1549 in the Hudson River in January of 2009 (Marra et al. 2009) and the crash (and associated loss of 8 souls) of a civil helicopter in Louisiana also in 2009. This increase in wildlife strike information involving civil helicopters in the U.S. will be particular useful in determining patterns of wildlife strikes to civil helicopters and will help to make wildlife hazard management programs at civil airports and heliports more effective.

Almost half of the reported wildlife strikes to civil helicopters occurred while the aircraft was in the enroute phase-of-flight, whereas one-third of wildlife strikes to civil helicopters occurred while aircraft were in the climbout phase of flight. This finding is in contrast to wildlife strikes to civilian fixed-wing aircraft, as the frequency of wildlife strikes to fixed-wing aircraft is typically lowest during the enroute phase of flight (Dolbeer 2006, Dolbeer et al. 2012). However, civil fixed-wing aircraft (both private and commercial) flying enroute to a destination would typically be at a much higher altitude than civil helicopters and above the airspace typically used by birds and bats (DeVault et al. 2005, Dolbeer 2006, Washburn and Olexa 2011). The occurrence of a high frequency of reported wildlife strikes with civil helicopters during the climbout phase of flight suggests that wildlife hazard management efforts within airfield environments might be effective in reducing the risk of wildlife strikes to civil helicopters conducting flight operations on or near airports and heliports.

Overall, gulls (mostly of unidentified / unknown species), raptors & vultures (e.g., Red-tailed Hawk and Turkey Vulture), and waterfowl [e.g., Canada Goose and Mallard (e.g., *Anas platyrhnychos*)] were the wildlife groups that collided with civil helicopters most often. Similarly, these were the same wildlife groups (and species of birds) that caused damage to civil helicopters during flight operations away for airports and heliports. On-airfield wildlife strikes were much less common, but raptors & vultures [e.g., Great Horned Owl (*Bubo virginicus*)], waterfowl (e.g., Mallard), and shorebirds [e.g., Killdeer (*Charadrius vociferus*)] struck and damaged civil helicopters within airport environments. Although collisions between large mammals (e.g., cows) and civil helicopters were quite rare, when these incidents did occur significant damage to the aircraft (or the complete loss of the helicopter) was typically the result.

We found that wildlife strikes to civil helicopters during flight operations within the U.S. typically involved the bird(s) impacting (and potentially damaging) the windscreen (e.g., forward section of the aircraft), the main rotor system, or multiple areas on the helicopter. As with military rotary-wing aircraft, this finding is not completely unexpected, as a bird(s) flying toward the aircraft (and visa versa) would encounter the front of the aircraft first. The large size of the windscreen on many civil helicopter models likely allows for a greater chance of a wildlife strike to the windscreen as well. Similarly, the large size of the rotating rotor blades on the top of the aircraft would intercept wildlife passing by the fuselage / airframe.

Although on-airfield wildlife strikes with civil helicopters represents a serious safety issue, wildlife strikes to civil helicopters during off-airfield flight operations accounted for a greater chance of a damaging wildlife strike. Further, the majority of human injuries and fatalities involving wildlife strikes to civil helicopters occurred during off-airport flight operations. Further analyses of collisions between civil helicopters and wildlife might allow for the determination of patterns associated with wildlife strikes to civil helicopters and thus provide information that could be useful in reducing the risk of such events.

5.4 Comparison of Wildlife Strikes with Military Rotary-wing Aircraft and Civil Helicopters

Overall, wildlife strikes with military rotary-wing aircraft and civil helicopters conducting flight operations within the U.S. were generally similar. Wildlife strikes occurred more frequently off-airfield for both military rotary-wing aircraft and civil helicopters, but on-airfield wildlife strike events were important as well. The windscreen and main rotor system were the most commonly struck and damaged sections of both military rotary-wing aircraft and civil helicopters, but reports of impacts to multiple locations on the aircraft were more common for civil helicopters. Identification of the wildlife species involved and the reporting of non-damaging wildlife strikes were important issues for both military and civilian flight operations, and although progress is occurring, additional awareness efforts and data gathering is needed. There were a few notable differences in regard to the wildlife species involved: bat strikes to military rotary-wing aircraft were more common than to civil helicopters, gulls were more prominent in regard to damaging strikes to civil helicopters, and large mammals strikes, although rare, occurred only with civil helicopters.

5.5 Recommendations for Aircrews, Flight and Mission Planners, Aircraft Engineers, and Airfield Managers

Aircrews from military rotary-wing aircraft would benefit from an increased understanding of the negative consequences of wildlife strikes to military aircraft. Aircrews could familiarized themselves with details and summaries of past wildlife strike events that occurred within the areas where they will be conducting flight operations, thus providing an increased awareness of potential BASH issues. Further, aircrews could utilize model systems, such as the USAF Avian Hazard Advisory System (AHAS), to determine the relative levels of risks posed by wildlife while conducting flight operations (e.g., training missions) within defined areas during specified time periods. Given the critical need for reporting of wildlife strike data, especially non-damaging strikes, we recommend that aircrews make reporting of wildlife strikes to rotary-wing aircraft a priority. In particular, key fields of information (such as the altitude or phase of flight the aircraft was in at the time of the strike event) would be useful and important facts that could be provided by military aircrews. We recommend the development and implementation of wildlife strike identification protocols, logistical tools (e.g., wildlife strike kits), and reporting regulations to allow for the identification of wildlife species involved in strikes to ARMY and USCG rotary-wing aircraft to be determined and included in the appropriate safety databases.

Flight and mission planners have the potential to reduce the number and severity of wildlife strikes to military rotary-wing aircraft during off-airfield flight operations by considering what wildlife hazards might exist along military training routes (MTR) or within military operation areas (MOA) used for flight training operations. For example, we recommend avoiding or minimizing low-level flights (e.g., terrain flight operations) over or near landfills and other known wildlife attractants to decrease the risk of wildlife-aircraft collisions. Consultations with BASH managers and specialists, such as Military Services BASH team members, USDA Wildlife Services personnel, or private contractors who are qualified airport wildlife biologists

would be particular helpful for identifying such wildlife attractants. Also, wildlife hazard modeling systems, such as the USAF AHAS, could be used by flight and mission planners to determine the relative levels of risks posed by wildlife while conducting flight operations (e.g., training missions) within defined areas during specified time periods.

We recommend that aircraft engineers consider alternative designs and materials for reinforcing sections of rotary-wing aircraft that are most commonly struck and damaged during wildlife strike events. Designing rotary-wing aircraft windscreens to better withstand the impact of wildlife (e.g., large birds) without breaking could greatly reduce the damage and human injuries associated with wildlife strikes to military rotary-wing aircraft and civil helicopters. Also, reinforcement and redesign of critical areas of the main rotor system to withstand wildlife strikes would be another area of important consideration.

Airfield managers at Army Air Fields, Air Force Bases, Naval Air Stations, Marine Corps Air Stations, and other military airfields and installations have the potential to reduce the number and severity of on-airfield wildlife strikes to military rotary-wing aircraft during on-airfield flight operations by implementing an integrated wildlife damage management program (Transport Canada 1994, MacKinnon et al. 2001, Cleary and Dolbeer 2005). Evaluation of existing wildlife strike data, identification and mitigation of wildlife attractants [e.g., wildlife forages (Washburn et al. 2011) and water management structures (Blackwell et al. 2008)], effective management of airfield plant communities to reduce wildlife hazards (Washburn and Seamans 2012), effective exclusion of large mammals (DeVault et al. 2008), non-lethal harassment (Marsh et al. 1991), and wildlife population control methods (Dolbeer et al. 1993), and other methods and techniques are critical components of an effective BASH program (DeVault et al. 2013). Consultations with BASH managers and specialists, such as Military Services BASH team members, USDA Wildlife Services personnel, or private contractors who are qualified airport wildlife biologists, would be particular helpful for identifying such wildlife attractants.

5.6 Limitations of the Study

As with any effort, there are limitations to this study that should be considered when the findings are interpreted. Prior to 2001, wildlife strike information regarding military rotary-wing aircraft was not available for all of the Military Services. Consequently, caution is warranted when making general conclusions regarding wildlife strikes to military rotary-wing aircraft across all Military Services during that time period. Reporting requirements and logistical opportunities vary among the Military Services and among time; thus, the information within this report is based on wildlife strikes that were reported to the appropriate Safety Centers. This information might or not might accurately reflect the actual occurrence of wildlife strikes to military rotary-wing aircraft and civil helicopters during the given time periods. However, within certain caveats, we believe it is representative of overall trends in wildlife strikes to rotary-wing aircraft. The frequency of wildlife strikes to military rotary-wing aircraft and civil helicopters was not standardized to the actual number of flight hours; thus, any perceived change in the rate of wildlife strikes could be due to changes in actual flight operations, variation in airframe use over

time, and other pertinent factors. This represents an important area for future investigations of wildlife strikes to military rotary-wing aircraft.

6. BENEFIT TO THE MISSION

Our efforts to understand and evaluate the unique threats posed to military rotary-wing aircraft from wildlife strikes will provide the basis for the development of strategies to reduce such incidents and thus provide a safer flying environment for military personnel within all Military Services. In addition, this report (and the information contained therein) should allow for an increased awareness and understanding of issues related to wildlife strikes to military rotary-wing aircraft, both for flight operations within the U.S. and during overseas deployments and 'in theater' flight missions and sorties.

Based on the results from our analyses, we provided recommendations for (1) aircrew training to raise awareness of safety issues related to bird strikes, (2) aircraft engineers to reduce air crew and airframe risk from wildlife strikes, and (3) airfield managers and BASH program personnel to reduce wildlife strike hazards within military airfield environments, and (4) flight and mission planners to reduce the risk of bird strikes during military training exercises and mission flight operations.

A reduction in wildlife strikes to military rotary-wing aircraft will also reduce mortality of many bird species, potentially including wildlife species of state concern and/or species listed under the Endangered Species Act, and other large charismatic birds that hold considerable public interest and concern, such as Ospreys (*Pandion haliaetus*) and Bald Eagles (*Haliaeetus leucocephalus*).

7. LITERATURE CITED

Allan, J. R. 2002. The costs of bird strikes and bird strike prevention. Pages 147−155 *in* L. Clark, J. Hone, J. A. Shivik, R. A. Watkins, K. C. Vercauteren, and J. K. Yoder (eds.), Human conflicts with wildlife – economic considerations. Proceedings of the Third NWRC Special Symposium, U.S. Department of Agriculture, Wildlife Services, National Wildlife Research Center, Fort Collins, CO.

Blackwell, B. F., L. M. Schafer, D. A. Helon, and M. A. Linnell. 2008. Bird use of stormwater-management ponds: decreasing avian attractants on airports. Landscape and Urban Planning 86:162–170.

Cleary, E. C., and R. A. Dolbeer. 2005. Wildlife hazard management at airports, a manual for airport personnel. Second edition. U.S. Department of Transportation, Federal Aviation Administration, Office of Airport Safety and Standards, Washington, D.C.

Cleary, E. C., R. A. Dolbeer, and S. E. Wright. 2006. Wildlife strikes to civil aircraft in the United States 1990−2005. U.S. Department of Transportation, Federal Aviation Administration National Wildlife Strike Database, Serial Report Number 12. Washington, D.C. 63 pp.

DeGraff, R. M., N. G. Tilghman, and S. H. Anderson. 1985. Foraging guilds of North America birds. Environmental Management 9:493–536.

DeVault, T. L., J. L. Belant, B. F. Blackwell, and T. W. Seamans. 2011. Interspecific variation in wildlife hazards to aircraft: implications for airport wildlife management. Wildlife Society Bulletin 35:394–402.

DeVault, T. L., B. F. Blackwell, and J. L. Belant (Editors). 2013. Wildlife in airport environments: Preventing animal-aircraft collisions through science-based management. Johns Hopkins University Press and The Wildlife Society, Bethesda, MD.

DeVault, T. L., J. E. Kubel, D. J. Glista, and O. E. Rhodes, Jr. 2008. Mammalian hazards at small airports in Indiana: impact of perimeter fencing. Human-Wildlife Conflicts 2:240−247.

DeVault, T. L., B. D. Reinhart, I. L. Brisbin, Jr., and O. E. Rhodes, Jr. 2005. Flight behavior of black and turkey vultures: implications for reducing bird-aircraft collisions. Journal of Wildlife Management 69:601−608.

Dolbeer, R. A. 2006. Height distribution of birds records by collisions with aircraft. Journal of Wildlife Management 70:1345−1350.

Dolbeer, R. A., J. L. Belant, and J. L. Sillings. 1993. Shooting gulls reduces strikes with aircraft at John F. Kennedy International Airport. Wildlife Society Bulletin 21:442−450.

Dolbeer, R. A., S. E. Wright, and E. C. Cleary. 2000. Ranking the hazard level of wildlife species to aviation. Wildlife Society Bulletin 28:372−378.

Dolbeer, R. A., S. E. Wright, J. Weller, and M. J. Begier. 2012. Wildlife strikes to civil aircraft in the United States 1990−2011. U.S. Department of Transportation, Federal Aviation Administration National Wildlife Strike Database, Serial Report Number 18. Washington, D.C. 83 pp.

Eden, P. 2004. The encyclopedia of modern military aircraft. Amber Books Ltd., London, United Kingdom. 512 pp.

Federal Aviation Administration (FAA). 2000. Rotorcraft flying handbook. U.S. Department of Transportation, Federal Aviation Administration, Flight Standards Service, FAA-H-8083-21. Washington, D.C. 270pp.

MacKinnon, B., R. Sowden, and S. Dudley. 2001. Sharing the skies: an aviation guide to the management of wildlife hazards. Transport Canada, Aviation Publishing Division, AARA, 5th Floor, Tower C, 330 Sparks Street, Ottawa, Ontario, K1A 0N8, Canada. 316 pp.

Marra, P. P., C. J. Dove, R. A. Dolbeer, N. F. Dahlan, M. Heacker, J. F. Whatton, N. E. Diggs, C. France, and G. A. Henkes. 2009. Migratory Canada geese cause crash of US Airways Flight 1549. Frontiers in Ecology and the Environment 7:297−301.

Marsh, R. E., W. A. Erickson, and T. P. Salmon. 1991. Bird hazing and frightening methods and techniques. California Department of Water Resources, Contract Number B-57211. 233 pp.

Montgomery, M. R., and G. L. Foster. 2006. A field guide to airplanes. Third edition. Houghton Mifflin Company, New York, NY. 294 pp.

Thorpe, J. 2010. Update on fatalities and destroyed civil aircraft due to bird strikes with appendix for 2008 & 2009. Proceedings of the International Bird Strike Committee 29:1−9.

Transport Canada. 1994. Wildlife control procedures manual. Environmental and Support Services, Airports Group. TP11500E. Ottawa, Canada.

United States Army (U.S. Army). 2012. Fundamentals of flight (FM 3-04.203). Independent Publishers Group, Chicago, IL. 384 pp.

Washburn, B. E., G. E. Bernhardt, and L. A. Kutschbach-Brohl. 2011. Using dietary analyses to reduce the risk of wildlife-aircraft collisions. Human-Wildlife Interactions 5:204–209.

Washburn, B. E., and T. J. Olexa. 2011. Assessing BASH risk potential of migrating and breeding osprey in the mid-Atlantic Chesapeake Bay region. Final Report to the U.S. Department of Defense, Legacy Resources Management Program, Arlington, VA. 146 pp.

Washburn, B. E., and T. W. Seamans. 2004. Management of vegetation to reduce wildlife hazards at airports. Proceedings of the 2004 FAA Worldwide Airport Technology Transfer Conference:1−7.

Washburn, B. E., and T. W. Seamans. 2012. Foraging preferences of Canada geese: Implications for reducing human-goose conflicts. Journal of Wildlife Management 75:600−607.

Zakrajsek, E. J., and J. A. Bissonette. 2005. Ranking the risk of wildlife species hazardous to military aircraft. Wildlife Society Bulletin 33:258−264.

Zar, J.H. 1996. Biostatistical analysis. Third edition. Prentice-Hall Press, Upper Saddle River, NJ. 618 pp.