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Enhancing the Aeronautical Decision-Making Knowledge and Skills of General Aviation Pilots to Mitigate the Risk of Bird Strikes: A Quasi-Experimental Study

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The purpose of this study was to investigate if a training workshop exploring aeronautical decision-making (ADM) concepts would improve collegiate aviation pilots' knowledge and skills to mitigate the risk of aircraft accidents resulting from bird strikes. Most research and management efforts to mitigate the risk of aircraft accidents resulting from wildlife strikes have focused on airports since empirical data indicate that almost 80% of these strikes occur in this environment. Pilots play an important role in the prevention of wildlife strikes, and research indicates there are opportunities to improve training. Researchers used a one-group pretest-posttest quasi-experimental design. The population of this study consisted of flight instructors and students from two Part 141 four-year degree-awarding collegiate aviation programs. The safety management of wildlife hazards by pilots (N=107) workshop elicited a statistically significant mean increase in the post-test scores (M = 36.15, SD = 5.251) compared to the pretest scores (M = 22.29, SD = 7.23), a statistically significant mean increase of 13.858 points, 95% [12.419, 15.298], CI t(105) = 19.088, p < .0005, d = 1.85. The possible benefits of providing Part 141 collegiate pilots with ADM training and education to prevent bird strikes include reducing the direct and other monetary losses resulting from bird strikes and supporting the sustainable growth of the U.S. aviation industry.

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Introduction

Wildlife Hazards to Aviation

On March 04, 2008, a Cessna 500 crashed just after takeoff from Wiley Post Airport (PWA) in Oklahoma City (OK). PWA is a public-use general aviation (GA) airport that is not certificated under Title 14 Code of Federal Regulations (CFR) Part 139. According to the National Transportation Safety Board (NTSB), the airplane was maintaining approximately 200 knots and level at 2,000 feet above ground level (AGL) when it collided with a flock of White Pelicans, one of the largest bird species in North America (NTSB, 2009). Because of the aircraft's airspeed as well as the mass of the bird, “the kinetic energy (KE) resulting from the strikes notably exceeded the airplane certification standards” (Mendonca et al., 2018, p. 5). The aircraft was destroyed by impact forces and a post-crash fire. Both pilots and three passengers were killed because of this accident. Both the Avian Hazard Advisory System (AHAS) (Air Force Safety Center, 2021) and the Federal Aviation Administration (FAA) airport facility directory (FAA, 2022a) entries for PWA contained warning remarks about the high risk of bird strikes at and around PWA. The NTSB (2009), O’Callaghan (n.d.), and Mendonca and Carney (2018) suggested that effective aeronautical decision-making (ADM) by the pilots of this aircraft could have significantly reduced the risk of a mishap resulting from bird strikes.

According to Dolbeer et al. (2022), there were 138,663 reported wildlife strikes to aviation from 2012 through 2021 in the U.S., and almost 5% (N = 6,218) of them caused damage to the aircraft. During the same period, the number of reported wildlife strikes has increased by almost 5%, from 10,643 in 2012 to 15,370 in 2021. Between these years, almost 97% of the total wildlife strikes involved birds. From 1990 to 2021, there were 77 aircraft damaged beyond repair resulting from wildlife strikes. Eighteen of these wildlife strikes resulted in 41 fatalities. Ninety-four percent (N=17) of these strikes involved birds. Moreover, 260 strikes resulted in 337 human injuries. Ninety-three percent (N=238) of these incidents also involved birds. Approximately 97% of the aircraft destroyed were general aviation (GA) aircraft. It is worth mentioning that 56% of those accidents occurred at GA airports.

For commercial and GA aircraft, 82% and 87% of the total wildlife strikes occur in the airport environment (at ≤ 1,500 feet AGL), respectively. Information obtained from the analysis of wildlife strike data indicates that the likelihood of a damaging strike is higher at and above 500 feet AGL. Conversely, considering that almost 97% of the wildlife strikes occur up to 3,500 feet AGL[1], the probability of an aircraft accident resulting from a bird strike is significantly lower when the aircraft is flying above this altitude. While the number of wildlife strikes per one million aircraft movements involving commercial operators increased from 23.92 in 2012 to 33.55 in 2021 (40%), for GA aircraft, this rate increased from 1.69 to 2.80 (66%) during the

[1] For the purpose of this study, the bird-rich zone is defined as the airspace where most bird strikes occur (at ≤ 3,500 feet AGL) (Mendonca et al., 2018).

same period (Dolbeer et al., 2022). The reasons for this growing safety concern at and around GA airports are complex. For example, several GA airports are located in rural areas where hazardous wildlife species to aviation thrive. Moreover, GA airports frequently lack the financial and human resources to develop safety strategies to reduce the risk of wildlife strikes (Cleary & Dickey, 2010).

The FAA requires certificated airports to take safety actions when a triggering event under Title 14 CFR Part 139.337 has been experienced, for example, "an air carrier aircraft experiences multiple wildlife strikes" (Cleary & Dolbeer, 2005, p. 60). Wildlife hazard management plans (WHMP) by airport operators have reduced the number of damaging strikes at certificated airports. Most regulatory and outreach efforts as well as federal funds toward the safety management of wildlife hazards to aviation have been directed Title 14 CFR Part 139 airports. Few federal efforts have targeted the GA community, including airport operators (Cleary & Dickey, 2010). Moreover, GA Airports usually lack financial resources and have limited staff, which limits their capabilities of developing and implementing safety strategies to mitigate the risk of wildlife strikes. Most importantly, analyses of wildlife-strike data have indicated that a multifaceted approach to mitigate the risk of wildlife strikes, especially outside the airport safety management efforts, is vital. Dolbeer et al. (2022) have recommended research, outreach, partnerships, and the use (or innovative use) of new technologies to address this safety hazard afflicting the aviation industry. DeFusco and Unangst (2013), MacKinnon (2004), and Mendonca et al. (2018) have suggested training and education efforts focusing on flight crew members as a strategy to prevent aircraft accidents resulting from strikes.

Aeronautical Decision Making

The FAA (2016a) defines ADM as "a systematic approach to the mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances" (p. 2-1). There are several structured ADM models that can be used by pilots during their ADM processes (.i.e., Pilot, Aircraft, EnVironment, External Pressures [PAVE]). All these ADM frameworks can help pilots identify hazards and mitigate the risks associated with those hazards (FAA, 2009, 2016a). Risk management, an integral component of ADM, is "a decision-making process designed to systematically identify hazards, assess the degree of risk, and determine the best course of action" (FAA, 2008, p. 4). The FAA (n.d.) recommends deliberate training for pilots to gain and/or improve their ADM knowledge and skills. Previous studies (Keller et al., 2015; Li & Harris, 2008; Mendonca et al., 2018) have indicated that ADM is a skill that can be taught. ADM training could be effective in enhancing the risk management, judgment, and decision-making skills of aviation professionals.

Kochan et al. (1997) conducted a series of studies whose goals included the following objectives: to identify and compile ADM skills (i.e., procedural knowledge) that could be used during ADM training of novice GA pilots; and to develop training to improve pilots' ADM competencies. Findings indicated that ADM expertise could have little association with flight time after a certain number of flight hours (~2,000 hours). The identified ADM skills of "expert pilots" included enhanced situational awareness (Airbus, n.d.) and effective communication. Moreover, findings suggested that hazard awareness and identification as well as risk management knowledge and skills are fundamental for effective ADM processes. Li and Harris

(2001) examined the efficacy of an ADM course in improving the decision-making processes of military pilots in China. Their judgment, risk management, and decision-making processes were evaluated during a series of emergency situations presented in a Northrop F5-E full flight simulator. Their findings suggested that ADM training can improve pilots' risk management knowledge and skills. Keller et al. (2017) investigated the effectiveness of two different training protocols that included ADM and other concepts pertaining to visual flight rules in deteriorating-weather condition encounters. The authors used a pretest-posttest experimental design. The training protocols did not statistically improve the participants' (GA pilots) post-test scores. According to Keller et al. (2017), confounding variables (i.e., previous risk management training) could have biased the result. They also suggested that immersive training could assist in enhancing the pilots' ADM skills to mitigate the risk of weather-related aircraft accidents. O'Hare et al. (2010) conducted a study to examine whether case-based training would improve the ADM process in a simulated flight. The scenarios included encounters with adverse weather. Findings showed that the participants who reflected on a set of cases involving pilots flying into adverse weather conditions and ADM concepts made safer and more timely decisions than other participants who only recalled the material. The authors concluded that case reflection during pilots' ADM training could improve aviation safety. Nonetheless, to the best of our knowledge, few studies have been conducted to examine safety training as a strategy that could help pilots mitigate the risk of aircraft accidents resulting from wildlife strikes. Most importantly, the FAA (n.d.) has encouraged ADM training for pilots incorporating case studies as a strategy to enhance flight safety. According to the FAA (2016a), "the ability to make good decisions is based upon direct or indirect experience and education" (p. 2-3).

Hazards, such as human fatigue, weather, and wildlife, are inherent components of flight operations. Nonetheless, when a pilot is aware of these hazards and follows effective ADM processes, the risks associated with the identified hazards can be reduced and frequently even eliminated. For example, pilots can reduce the probability and the severity of a bird strike by minimizing the flight time and the aircraft airspeed, respectively, while flying through the bird-rich zone (Dolbeer, 2006; Dolbeer et al., 2022; NTSB, 2009). Moreover, previous research studies (Blackwell et al., 2012; Dolbeer & Barnes, 2017; Doppler et al., 2015; Larkin et al., 1975) have suggested that some types of lighting could enhance some bird species' response to an approaching aircraft. Thus, the use of the aircraft's external lights can help reduce the probability of bird strikes involving some bird species (e.g., Canada geese) (MacKinnon, 2004).

Safety Management of Wildlife Hazards to Aviation

According to the FAA (2016a), safety risk management (SRM) is a pillar of ADM. The first step in the SRM process is the identification of hazards (International Civil Aviation Organization [ICAO], 2018). Sources of information about wildlife hazards to aviation include the AHAS (Air Force Safety Center, 2022), the Automatic Terminal Information Service (ATIS), the FAA airport facility directory (FAA, 2022b), Notices to Air Mission (NOTAM) (FAA, 2022c), the aeronautical information manual (AIM) (FAA, 2022d), the airport facility directory (FAA, 2022a), and air traffic control (ATC) (MacKinnon, 2004). It is important to note that the FAA annual and special wildlife-strike reports also provide essential information that must be used to improve aviation safety (Dolbeer et al., 2022). For example, pilots should be aware that the majority of wildlife strikes occur between July and October (migration season) and that the probability of a strike is higher during the arrival phase of the flight (descent, approach, landing roll) (Dolbeer et al., 2022). Nonetheless, the risk of a damaging strike is higher during the departure phases of the flight (takeoff roll and initial climb out). The reasons for that include increasing kinetic energy (KE) (Eschenfelder & Hull, 2006; NTSB, 2009) and a possible loss of thrust at low aircraft energy states and a relatively low altitude in urban areas (Nicholson & Reeds, 2011). Yet, the aircraft is usually heavier (often at maximum takeoff weight) and thus less maneuverable, making evasive actions more difficult. Pilots must understand the reasons why the risk of an aircraft accident resulting from a wildlife strike is higher during the departure phases of flight so that they can exercise their ADM skills and thus improve the safety of their flights.

The aviation system is reliable but complex. Therefore, it is unrealistic to foresee all possible risks involving wildlife hazards. Wildlife strikes, such as occurred with U.S. Airways Flight 1549 (Marra et al., 2009; NTSB, 2010), will require effective ADM processes and immediate actions by pilots using standard operating procedures. Several factors could (e.g., operational constraints by air traffic control) hamper the commercial pilots' ADM processes and resulting a safety risk management process to prevent bird strikes. However, pilots, especially GA aviators, generally have enough time and resources to identify hazards, assess risks, and develop risk management strategies to mitigate risks during flight operations. For example, GA pilots can delay their departure (or arrival) in case of reported bird activity at and/or around the airport. They can also divert to an alternate airport without causing operational and management disruptions in case an air carrier's captain makes a similar decision. "It is important to note that an effective ADM process provides greater latitude for later options, with a significant enhancement of aviation safety" (Mendonca et al., 2018, p. 3).

The safety management of wildlife hazards requires a multifaceted approach. This approach should include airport and aircraft certification standards and guidance materials (Eschenfelder & Hull, 2006), the use of technologies or innovative use of current technologies (Mendonca et al., 2021), and actions by flight crews (MacKinnon, 2004). In fact, pilots play a crucial role in the safety management of wildlife hazards in aviation. For example, pilots can mitigate the severity and/or probability of strikes through appropriate preflight planning, the application of effective ADM processes, and the use of adequate flight procedures (Avrenly & Dempsey, 2013; MacKinnon, 2004). Moreover, pilots have the professional responsibility to report wildlife strikes in accordance with the FAA guidelines (FAA, 2013). Information obtained from the analyses of wildlife strike data provides the scientific basis during the development (and assessment of the effectiveness) of wildlife hazard management plans by airport operators. Additionally, wildlife strike data and information provide the foundation for integrated research as well as FAA national standards and guidance materials to reduce wildlife strikes (Dolbeer et al., 2022). Several initiatives by the FAA with aviation stakeholders (e.g., commercial air carriers) and other government groups have improved the reporting of wildlife strikes under the FAA wildlife-strike report voluntary system as well as the quality of the U.S. national wildlife strike database. However, strike reporting is not consistent across all stakeholders, especially involving the GA community. Thus, aviation stakeholders have advocated for actions that could enhance the quantity and quality (e.g., completeness) of wildlife strikes (FAA, 2013). The various actions undertaken by the FAA, in partnership with other government and aviation industry groups from 2009 to 2013, have enhanced the quantity and quality of reporting of wildlife strikes involving civil aircraft under a voluntary system.

To date, most research and other safety management efforts have focused on airports (Cleary & Dickey, 2010; DeFusco et al., 2015; DeFusco & Unangst, 2013; Mendonca et al., 2020; Rillstone & Dineen, 2013). The safety efforts by airport operators have been successful in mitigating wildlife strikes at the airport jurisdiction. However, such safety strategies have had little effect on wildlife strikes beyond the airport environment (Dolbeer & Barnes, 2017). Additionally, little has been done involving pilots, especially GA aviators. Safety training and education provide aviation professionals with the knowledge, skills, and abilities to carry out their jobs efficiently and safely (ICAO, 2018). Safety training promotes a high level of safety awareness. According to Manuele (2017), safety training should be tailored precisely to the actual needs of those being trained. Additionally, the inherent hazards encountered during flight operations must be considered in the tailoring of the pilot's training. Safety training and education can help pilots develop their ADM competence to identify the inherent hazards of their jobs as well as to develop effective risk mitigation techniques.

Mendonca et al. (2018) conducted a study to investigate if a safety training protocol that included ADM, safety culture, and the safety management of wildlife hazards to aviation concepts would improve Title 14 CFR Part 141 pilots' knowledge and skills to mitigate the risk of bird strikes. The researchers utilized a pretest-and post-test experimental design. Mendonca et al. (2018) also collected qualitative data through open-ended questions in both the pre-and post-test. Findings indicated that the experiment (safety training) significantly increased the post-test scores of the experimental group. A finding of concern obtained from the qualitative data was that the safety management of wildlife hazards by pilots is barely explored during ground and flight training. This study had a number of limitations, including a small sample size (N=17).

The current study built upon Mendonca et al. (2018) and had a similar purpose of investigating if a training workshop exploring ADM applied to the safety management of wildlife hazards would improve the GA pilots' knowledge and skills to mitigate the risk of aircraft accidents resulting from bird strikes. After all, it is practically impossible to mitigate the risk of aircraft accidents resulting from bird strikes without pilots' participation, for example, by effectively applying ADM concepts throughout their flights (Dolbeer, 2006; Eschenfelder & DeFusco, 2010; MacKinnon, 2004; Dolbeer et al., 2022), and/or by reporting wildlife strikes to the FAA (Cleary & Dickey, 2010; FAA, 2013). This quasi-experimental study is in alignment with the FAA's (2022e) overarching objectives of reducing civil aviation and commercial space transportation-related accidents and incidents.

Methodology

Population and Sample

The population of this study consisted of flight instructors and students from two accredited CFR Part 141 flight training and four-year degree-awarding universities, one located in the Midwestern region of the United States and the other one located in Central Florida. This "safety management of wildlife hazards by pilots" workshop was included in the syllabuses of aviation safety-related courses (e.g., crew resource management) delivered during the spring and fall academic semesters of 2020 and during the spring of 2021. All students (N = 107) enrolled in these courses were then required to complete this training as described in the procedures section of this manuscript. It is important to mention that pilots were eligible to participate in this study if they were at least 18 years old, directly involved with their universities' professional flight programs, and if they had flown in the previous six months. Please see Table 1 for the participants' demographics and flight experience information.

Table 1
Summary of Participant Demographic Information

Enrollment Status		
First Year	5	4.6%
Sophomore	13	12.2
Junior	38	35.5
Senior	49	45.8%
Combined Degree Program	2	1.9%
Certifications and Rating Frequencies		
Student Pilot	3	2.8%
Private	18	16.8%
Private - Instrument	5	4.6%
Commercial	23	21.5%
Commercial - Instrument	13	12.3%
Certified Flight Instructor (CFI)	25	23.4%
CFI – Instrument (CFII)	13	12.1%
Multi-Engine	5	4.5%
Multi-Engine Instrument	2	2%
Airline Transport Pilot	0	
Flight Hours		
Minimum	**Maximum**	**Mean**
38	915	226.5

Research Design

Quasi-experimental studies, which usually require fewer resources than true-experimental studies, are appropriate when a control group and/or randomization is not possible (Siedlecki, 2020). "Without either of these, the power of the research to uncover the causal nature of the relationship between the independent and dependent variables is greatly reduced" (Salkind, 2012, p. 230). Nonetheless, quasi-experimental studies are pragmatic because they meet some requirements of causality as well as include participants that are often excluded in true-experimental studies. In the current study, researchers used a one-group pretest-posttest quasi-experimental design (Leedy et al., 2019). The dependent variables were the pre-and post-test scores. The independent variable consisted of a safety training protocol incorporating ADM and the safety management of wildlife hazards concepts. In order to enhance the credibility of the quantitative findings, the researchers added a qualitative section to the post-test (Patton, 2015).

Instruments

The safety management of wildlife hazards by pilots' workshop as well as the questions utilized in both the pre-and post-test, were developed after a thorough literature review of previous studies on the safety management of wildlife hazards in aviation (Avrenly & Dempsey, 2014; Cleary & Dolbeer, 2005; Cleary & Dickey, 2010; DeFusco et al., 2015; Dolbeer, 2020; Dolbeer et al., 2022). Moreover, the review covered ADM concepts (FAA, 2016a), including hazard awareness and identification and risk management. Most importantly, how these concepts are applicable to the safety management of wildlife hazards to aviation by pilots (Eschenfelder, 2005; MacKinnon, 2004; Mendonca et al., 2018; Nicholson & Reed, 2011). Please see the Appendix for the questions utilized in the pre-and post-test.

Cognitive, behavioral, connective, transformative, and constructivist educational learning theories provide instructional designers with a rich source of instructional techniques and strategies that facilitate learning (Western Governors University, 2020). However, no single educational learning theory prescribes a comprehensive set of principles and techniques that could effectively facilitate and influence the learning process in every single context (e.g., aviation; medicine) and/or involving different learners (e.g., adults; seniors). Thus, we incorporated elements of different educational theories during the development and delivery of the workshop. The goal was to create a proper match between the workshop content and objectives as well as the learner's needs and expectations (Ertmer & Newby, 2013).

"The validity of a measurement instrument is the extent to which the instrument measures what it is actually intended to measure" (Leedy & Ormrod, 2005, p. 92). The list of questions utilized in the pre-and post-test underwent a content validation process, as suggested by Sekaran and Bougie (2013). The researchers of this study asked a group of students and faculty members to review the assessment instrument for grammar, syntax, and organization and whether the assessment instrument flowed logically. After addressing the students' and faculty members' suggestions and concerns, we then followed the content validity index (CVI) method to further increase the validity and reliability of the measurement instrument (DeVon et al., 2007; Polit & Beck, 2006). See Mendonca et al. (2018) for further information about the development of the safety management of wildlife hazards by pilots' workshops as well as the processes researchers utilized to validate the measurement instrument.

The pre-and and post-test had every 20 multiple-choice questions (see the Appendix). Each question was worth 2 points. We added a question to the pretest asking participants how often (never / rarely / sometimes / often / always) the safety management of wildlife hazards topic had been addressed during their ground and/or flight training. Additionally, the post-test contained five open-ended questions to help researchers better understand what the quantitative data meant (Patton, 2015). Noteworthy to mention that pretest multiple choice questions were randomly scrambled for the post-test. A Cronbach's alpha analysis for the pretest indicated coefficients of 0.702, an acceptable reliability value. A Cronbach alpha for the post-test indicated a coefficient of 0.878, a high-reliability value.

Procedures

All participation was in accordance with the Institution Review Board (IRB) guidelines. As previously noted, students in aviation safety-related courses (e.g., CRM) during the spring and fall semesters of 2020 and the spring semester of 2021, in which the researchers were also the instructors, were required to participate in the workshop. Participants were asked to complete a quiz (pretest) a week before the workshop. After completion of the pretest, they were reminded that there would be a week dedicated to the topic "safety management of wildlife hazards to aviation," during which there would be a presentation on this and other related topics. Yet, they were expected to review some materials before class to include the Sharing the Skies Manual (chapter 10) (MacKinnon, 2004) and the Pilot Handbook of Aeronautical Knowledge (chapter 2) (FAA, 2016a). They were also told they would be required to complete a quiz after the workshop and that only their highest grade (pretest or post-test) would count towards their final grade in that specific course. The pre-and post-test were completed in a paper format. After transcribing the pretest and post-test grades of the students to an excel spreadsheet using random codes and also posting the students' grades on the learning management system (e.g., Canvas), the researchers returned the students' files (pretest and post-test). Therefore, the participants' results were only identifiable by a randomly assigned code (excel spreadsheet).

The "safety management of wildlife hazards by pilots" had four primary sections, which included an overview of wildlife hazards to aviation, bird-hazard information acquisition and interpretation (Cleary & Dolbeer, 2005; Dolbeer et al., 2021; Eschenfelder & Hull, 2006; Eschenfelder & DeFusco, 2010; Kelly, 2002; MacKinnon, 2004; Mendonca et al., 2018; Nicholson & Reed, 2011), the ADM tenets (especially the safety risk management process) (FAA, 2016a), and a review of information derived from previous studies that could leverage the participants' ADM knowledge and skills to mitigate the risk of aircraft accidents resulting from bird strikes. Elements of existing ADM frameworks, such as the PAVE checklist and the "Perceive, Process, and Perform" (3P) model (FAA, 2016a), were briefly addressed in class. It is important to mention that the ADM models generally help pilots organize their thoughts, become aware of safety hazards, identify hazards before and during flight operations, assess risks, analyze mitigation strategies, and use the most effective safety measures. The hazardous attitudes and respective antidotes regarding wildlife strikes were also debated in class. For example, we emphasized that wildlife strikes could happen to any pilot and that pilots are not helpless since they can take actions (i.e., reduce flight time and/or airspeed while flying through the bird-rich zone if operationally possible) that could help mitigate the risk of bird strikes. Multiple short bird hazard scenarios were presented during the class discussions. The participants were asked to apply their ADM knowledge to mitigate the risk, severity, and/or probability of bird strikes considering these bird-hazard scenarios. For example, we asked, "you are the captain of a single-pilot jet aircraft. You are descending from 10,000 feet to 1,500 feet. Air traffic control (ATC) and other aircraft reported birds at 5,500 feet and below. Which actions could you take to mitigate the risk of an accident due to birds, if operationally possible?" Expected answers were to include reduced flight time and airspeed in the bird-rich zone and the use of the aircraft's external lights. Participants were also expected to report to ATC any other pertinent safety-related information.

In addition, a case study involving a Cessna 500 that crashed after an in-flight collision with large birds was conducted (NTSB, 2009). Participants were asked to, in small groups, identify and explain procedures that pilots could have adopted to mitigate the risk, probability, and/or severity of bird strikes in that specific mishap. During these group discussions, participants were asked to apply the PAVE, 3Ps, and the 5Ps (Plan, Plane, Pilot, Passengers, Programming) ADM models, the risk management process elements (i.e., risk assessment), and the wildlife hazard management concepts (i.e., sources of wildlife hazard information) and explain how that specific accident could have been (hopefully) prevented. The instructors then conducted a brief review and answered the participants' final questions.

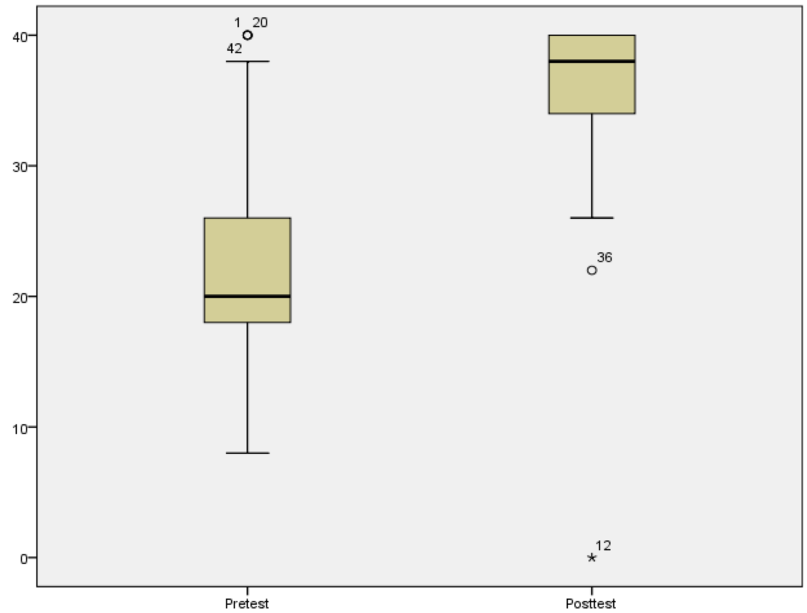
Data Analysis

Descriptive data from the participants were investigated so that researchers could have a better understanding of the data (Salkind, 2012). A paired t-test using SPSS ® was conducted to investigate whether there was a significant difference between the pre-and post-test scores before and after the safety management of wildlife hazards by pilots' workshop. The researchers used the deductive approach to analyze the qualitative data. The goal was to investigate the extent to which the qualitative data support existing ADM and/or safety management of wildlife hazards to aviation concepts (Patton, 2015).

Results and Discussion

Identifying information was not used during the analyses of data, making all research findings anonymous. One hundred and seven students (pilots) from five different courses that occurred in the spring and fall semesters of 2020 and during the spring semester of 2021 participated in the study. Researchers used the paired sample t-test to investigate whether there was a significant mean difference between the participants' pre-and post-test scores. Five outliers were detected that were more than 1.5 box lengths from the edge of the box in a boxplot. However, an inspection of their values did not reveal them to be extreme, and they were kept in the analysis (Laerd, 2021). The difference scores for the post-test and pretest were normally distributed, as assessed by a visual inspection of a Normal Q-Q Plot. The safety management of wildlife hazards by pilots workshop elicited a statistically significant mean increase in the post-test scores ($M = 36.15$, $SD = 5.251$) compared to the pretest scores ($M = 22.29$, $SD = 7.23$) (see Figure 1), a statistically significant mean increase of 13.858 points, 95% [12.419, 15.298], CI $t(105) = 19.088$, $p < .0005$, d = 1.85.

Figure 1
Comparative Boxplot of the Pretest-Posttest



In the pretest we asked participants, using a five-point Likert rating scale, how often (never / rarely / sometimes / often / always) the safety management of wildlife hazards topic had been addressed during their ground and/or flight training. Most responses indicated they had never (N=12) or rarely (N=51) received any guidance/instruction on that topic during their flight activities. Notwithstanding, 18, 15, and 10 pilots indicated this topic sometimes had, often, or always, respectively, been addressed during ground and/or flight training. The researchers also asked participants if they had taken any academic course addressing the safety management of wildlife hazards to aviation. Only sixteen participants stated they had participated in an academic course that covered this topic. Nonetheless, 37 responses suggested that a focus on pilots' strategies to mitigate the risk of aircraft accidents resulting from bird strikes had not been covered in class. One student stated, "no, besides this course." Another student said, "[…] not in much detail as this class". Another student stated, "I have seen this topic in another course but with a focus on airport wildlife hazard management." A participant said, "[…] first time I had a professor integrate aeronautical-decision making elements and wildlife hazards". Participants were also asked (pretest) if they had had a strike before (and how many). Only16 participants indicated they had experienced bird strikes before, each one of them just a single safety occurrence.

Previous aircraft accidents (FAA, 2022e; NTSB, 2009, 2010) have indicated that wildlife is an inherent risk affecting aviation safety. Nonetheless, effective ADM by pilots (FAA, 2016a) can certainly help mitigate the risks associated with wildlife hazards to acceptable levels (MacKinnon, 2004; NTSB, 2009). According to the FAA (2022d), "it is a pilot's inherent responsibility to be alert at all times for and in anticipation of all circumstances, situations, and conditions affecting the safe operation of the aircraft" (para. 1). Safety training and education to include ADM is a fundamental prerequisite for aviation safety. They ensure aviation professionals develop the skills and knowledge needed to identify, comprehend, and report workplace hazards as well as to develop strategies to effectively mitigate the risks associated with their jobs. Additionally, safety training and education help shape their professional and safety culture. For example, ADM training ensures pilots will have the competencies needed to identify the sources of wildlife hazards to aviation, interpret wildlife hazard data and information, and develop adequate strategies to mitigate the risk of aircraft accidents resulting from strikes. In summary, ADM training and education ensure pilots will have the competencies to safely and effectively perform their duties. Findings of the current study suggest that the topic of safety management of wildlife hazards incorporating ADM concepts had not been frequently addressed during academic courses as well as during flight and/or ground training of the participants of this study.

According to MacKinnon (2004), flight crews can mitigate the risk of wildlife strikes through “prudent flight planning and the use of appropriate aircraft operating techniques” (para. 2). According to Avrenly and Dempsey (2014), pilots should maintain the best angle of climb speed (Vx) in order to reduce both the probability and severity of bird strikes. Dolbeer (2006) suggested pilots should reduce flight time as well as the aircraft airspeed whenever flying in the bird-rich zone in order to reduce the probability and severity, respectively, of bird strikes. In case of a bird encounter, pilots should pull up consistently with good flying techniques since many bird species will dive to avoid an approaching aircraft (Eschenfelder & DeFusco, 2010). Previous research has indicated that the use of the aircraft external lights could enhance the avoidance behavior of certain bird species (Blackwell et al., 2012; Dolbeer & Barnes, 2017).

Qualitative data facilitate the study and understanding of issues in detail and depth. Moreover, they help researchers explain “things that cannot be measured” (Patton, 2015, p. 87). The researchers used the qualitative deductive analysis approach to analyze the qualitative data (Hsieh & Shannon, 2005). This qualitative data analysis methodology can help researchers determine the extent qualitative data explain existing concepts and quantitative results. Yet, demonstrating a link between the quantitative and qualitative researchers can increase the reliability of their study. Participants’ responses to the open-ended questions are provided “as is”. Thus, they might include grammatical and spelling errors. In the post-test, participants were asked to identify and explain the safest strategy pilots should adopt to mitigate the probability and severity of a bird strike while flying in the bird-rich zone. Almost 80% (N=82) of the participants' responses indicated they would reduce their flight time and airspeed while flying below 3,500 feet AGL to reduce both the probability and severity of wildlife strikes. Some of their answers, which are in alignment with effective ADM concepts to mitigate the risk of bird strikes (Dolbeer, 2015; MacKinnon, 2004), are shown below.

> “Get to the highest altitude in the shortest amount of time.”
>
> “Reduce time in the bird-rich zone. Reduce airspeed and increase the angle of descent or climb out at Vx.”
>
> “Turn on exterior lights, decrease airspeed, and decrease time in bird rich zone. Turning on the lights lets the birds see you, ‘decreases airspeed decreases severity of bird strike, and decrease time in bird rich zone reduces the probability.”

> "Pilots should avoid flying in the bird rich zone whenever possible. When it is necessary to do so, climbs should be made at Vx and descents at a high rate of descent without excessive airspeed to minimize time in the bird-rich zone."

> "Less time in bird rich zone, slowdown in bird rich zones to lessen the impact, if you encounter bird pull up on yoke to avoid, use aircraft external lights."

The reporting of wildlife strikes to aviation is voluntary in the U.S. Nonetheless, the FAA (2013) recommends aviation professionals should report strikes following the FAA guidelines. As previously noted, information obtained from the analyses of wildlife-strike data provides the scientific foundation for the safety efforts by aviation stakeholders. Participants were asked why pilots are expected to report wildlife strikes and how they could do it. Ninety-five percent (N=101) of the participants indicated they would report wildlife strikes to the FAA. Interestingly, most of their responses also suggested they generally understood the importance of reporting strikes to the FAA for aviation safety. Some of their answers are as follows:

> "Reporting a bird strike can be good for multiple reasons […]. Please report any bird strikes to the FAA bird strike page on their website".

> "You should report a bird strike to the FAA wildlife strike database and to the ATC controller controlling you".

> "The reporting of bird strikes by pilots enhances safety management […). Reports should be done at the FAA wildlife strike database".

> "Reporting bird strikes is crucial for flight safety. You can report a bird strike through FAA's website".

> "So that more data can be collected by the FAA and future strikes be prevented. Strikes can be reported to the FAA, ATC, and the safety office".

According to the FAA (2016a), pilots should integrate risk management into planning at all levels, including preflight planning. When flight crews follow effective ADM practices, hazards are identified and the associated risks reduced or even eliminated. The first step in the safety risk management process is the identification of hazards. Pilots must, before the beginning of each flight become familiar with all available information concerning that flight (FAA, 2022d). During the workshop researchers explained how pilots can obtain useful wildlife hazard information from those "wildlife hazard" sources, and how this information should be utilized during the pilots' ADM processes. In the post-test, we asked participants what aeronautical resources pilots could use, during their ADM processes, to gather information about the presence of birds at and around airports. All participants indicated they were familiar with key resources they could use to obtain wildlife-hazard data and information during their ADM processes. Some of their responses are shown below.

> "ATC, NOTAMS, ATIS, AHAS, AIM, and FAA wildlife page"

> “They can use the US Air Force Avian Hazard Advisory System, ATC, NOTAMS”.

> “The U.S. Avian Hazard Advisory System website is a resource pilots can use to gather information about the presence of birds at their destination or departure airport”.

> “Pilots can use resources such as NOTAMS, ATIS, ATC, AHAS, FAA Wildlife strike website, AIM and more”.

Empirical data (Avrenly & Dempsey, 2014; Eschenfelder, 2005) and previous aircraft accidents (NTSB, 2009, 2010) have indicated that the risk of an aircraft accident resulting from a bird strike is higher during the departure phase of flight (takeoff roll and initial climb-out). The faster rotation of the engine as well as the increasing airspeed (both high KE) during these phases of flight can help explain this difference. Researchers explored the KE concept during the safety workshop explaining how pilots should take that into consideration during their ADM processes (e.g., reduce the aircraft airspeed and/or engine rotation while flying through the bird rich zone, if operationally possible, to reduce KE in case of a strike). The KE concept was further explored during the case study involving the Cessna 500 accident (NTSB, 2009).

We asked participants in which phase(s) of flight the risk of an aircraft accident due to bird ingestion(s) is the highest. We also asked them to explain the reasons for that. Eighty-two percent (N=87) of the participants made similar statements. Their responses suggested they understood how the KE concept is important for accident prevention regarding bird hazards. Some of their responses are as follows:

> “The risk of an aircraft accident due to bird ingestions is during takeoff roll and climb out. This is because the engine is at a high-power setting and more likely to cause damage if a bird strike is encountered”.

> “During takeoff and climb due to the heavy requirement of thrust needed to complete the phase of flight. Also during these phases of flight the aircraft is near the ground thus leaving less time to glide to safety”.

> “Climb is the most dangerous because the aircraft is increasing airspeed and using full power”.

> “The highest risk due to bird strikes is during takeoff and initial climb out. This is because airplane engines are running at a high-power setting and can be damaged or totally knocked out while running at this high-power setting. Another reason is that typically the airplane is at lower altitudes and may not have enough gliding distance in the event of a strike”.

> “The takeoff/departure and landing/approach are the phases that bird ingestion is highest. This is because this area and altitude is where most birds and wildlife are concentrated in”.

According to the FAA (2016b), air traffic control should issue advisory information for at least 15 minutes on pilot-reported and/or observed bird activity at and around airports to increase the flight crews' awareness of bird hazards. Flight crews should utilize this information to exercise their ADM processes and thus improve aviation safety. In the post-test, we also asked participants why they were expected to inform ATC about the presence of birds they have observed during flight operations. All participants made similar statements. See below some of their answers:

> "Informing ATC about the presence of birds is crucial because ATC then can alert other pilots that might not be aware of birds in the area".
>
> "So that ATC can vector airplanes away from the area".
>
> "So that they can inform other pilots and aircraft in and around the airport and local area of the hazard".
>
> "To enable other pilots to be situationally aware and make safe decisions you should inform ATC about the presence of birds observed while flying".
>
> "This enables ATC to warn other aircraft of the presence of wildlife which can help in mitigating the risk of bird strikes".

In the last open-ended question in the post-test, we asked participants what wildlife mitigation techniques and guidance they had been provided during their careers as pilots and by whom. A few of their responses are as follows:

> "If you see birds when on approach, just continue the approach, they usually dive away – […] my private pilot instructor".
>
> "Birds typically avoid our planes because of our lights, so just follow our normal light SOP and you should have no problem with birds – my instrument Instructor".
>
> "I was taught during my private pilot training outside of XXXX University to climb if you see birds and they will dive; however, other than that I have not been informed about anything related to wildlife mitigation techniques besides this class".
>
> "I have never really been given any guidance to avoiding wildlife mitigation other than not to hit them or to swerve out of their way".
>
> "Speaking truthfully, outside of this XXXX course I had never really been taught much about wildlife mitigation techniques. When presented with birds in the airplane I was simply told to avoid them any way possible".
>
> "I was taught to climb if I encountered birds because most birds tend to dive when they are startled by an aircraft. I have found this advice to be true, and it has helped me avoid multiple bird strikes".

> "While in flight if a bird is approaching you just remain in the same state of flight, don't move, just stay straight and level (flight instructor)".
>
> "My instructors have only ever told me to avoid birds by flying away from the direction they were going".
>
> "My instructor emphasized to pull up if we approach a bird and to use scanning to techniques to prevent a bird strike from occurring".
>
> "I have always been told when approaching birds to keep flying straight because they will move to avoid you, and that if you move you may turn directly into them".
>
> "My instructors have taught me to always be aware of my surroundings especially during arrival and departure. I have been taught to always use all the available resources to be situationally aware of any wildlife in the vicinity".
>
> "The only wildlife mitigation techniques and guidance I have been provided during my flight training were during my aviation safety class, by the professor".
>
> "I was told by my private instructor (not at XXXX University) to always pull up when near birds, because they have a tendency to dive".

Participants' responses to the open-ended questions suggest that their ADM knowledge and skills mitigate the risk of aircraft accidents resulting from strikes improved after the safety training protocol. For example, their responses indicated they understood the importance of reducing flight time and airspeed, if operationally possible, to reduce both the probability and severity of strikes. All participants demonstrated a certain awareness of the key resources pilots could use to obtain bird hazard information that is needed during their ADM processes. Quoting one pilot "make use of the AHAS, AIM, and ATC information to improve your situational awareness and risk management process". All respondents demonstrated a sound understanding of the importance of reporting wildlife hazards to ATC for accident prevention purposes. In summary, their responses to the open-ended questions suggested that after the safety training participants had the ability to think analytically and clearly about the safety management of bird hazards. In addition, their responses to the open-ended questions in the post-test suggested they had adequate knowledge to discuss several mitigation strategies applicable to the safety management of bird hazards by pilots.

Discussion

Training and education are key components of any business plan (Rodrigues & Cusick, 2012), and "safety training is no exception" (p. 319). Effective ADM is a vital aspect of risk management in aviation, without which superior results cannot be achieved. A large amount of research has indicated that ADM is trainable (Buch, 1984; Jensen, 1987; Keller, 2015; Li & Harris, 2001; Mendonca et al., 2018; O'Hare et al., 2009). Pilots frequently make critical decisions to mitigate the inherent risks affecting aviation safety. The analyses of wildlife-strike data in the U.S. have suggested that birds pose a growing economic and safety concern for the aviation industry (Dolbeer et al., 2022). Eschenfelder and DeFusco (2010), Eschenfelder and Hull (2006), Dolbeer (2006), MacKinnon (2004), and Mendonca et al. (2018) have advocated for pilots' training and education as a strategy to mitigate the risk of aircraft accidents resulting from wildlife strikes. Therefore, ADM training focusing of the safety management of birds by pilots is essential to provide those professionals with the required knowledge and skills to make swift and accurate decisions to improve safety.

One hundred and seven pilots from two accredited CFR Part 141 flight training and four-year degree-awarding universities participated in the safety training workshop exploring ADM applied to the safety management of wildlife hazards. Results using parametric tests indicated that there was a statistically significant difference between the pre-and post-test scores of the participants. These findings suggested that training and education focusing on hazard awareness, the safety management of wildlife hazards to aviation, and ADM concepts, as suggested by the FAA (2016a), Keller et al. (2017), and Mendonca et al. (2018) can help prevent aircraft accidents resulting from bird strikes. Additionally, ADM training could improve the quantity and quality of wildlife-strike reports, as suggested by Dolbeer (2015). As previously noted, wildlife-strike data and information is vital for accident prevention efforts by aviation stakeholders.

Participants' responses to the open-ended questions in the post-test generally reflected the "safety management of wildlife hazards to aviation applying ADM" concepts covered during the workshop. For example, when asked about the safest strategy to mitigate the risk of an aircraft accident while flying through the bird-rich zone, their responses echoed the ADM concepts by Dolbeer (2006), Eschenfelder and DeFusco (2010), the FAA (2016a), and MacKinnon (2004). The researchers acknowledge that some of the participants' responses to these open-ended questions, despite adequate (or sometimes incorrect), were not in alignment with was covered during the workshop. For instance, when asked why pilots should report bird strikes, one participant stated, "[…] the airport can start taking immediate action to scare them away. Maintenance can be ready to meet you on the ground". Moreover, when asked about the resources aviation professional could use to obtain wildlife hazard information, one participant incorrectly indicated they could gather such information by consulting a meteorological terminal air report (METAR). Nonetheless, the qualitative findings of this study corroborate the quantitative findings and leverage the idea that a training workshop exploring ADM applied to the safety management of wildlife hazards can certainly improve the safety of the aviation industry.

Two primary themes became apparent during the analysis of the qualitative data. The topic safety management of bird hazards to aviation by pilots incorporating the ADM tenets has not been adequately covered during flight training and education in at least two Part 141 college aviation universities. One participant indicated that this was the first time they had seen a professor explain ADM models focusing on the safety management of bird strikes in aviation. Another theme that emerged from participants' responses to the open-ended questions was that an immersive workshop focusing on the safety management of bird hazards incorporating safety risk management processes and a case study, as suggested by the FAA (n.d.), Kochan et al. (1997), and Mendonca et al. (2018) has the potential to improve aviation safety. More specifically, the safety of the GA community. The participants' responses suggested that they became familiar with the ADM tenets applicable to bird hazard mitigation after the workshop. For example, the participants' responses suggested that they were familiar with key aeronautical resources (i.e., AHAS; NOTAMs) pilots should use to obtain information about the presence of birds at and around airports during their ADM processes. Yet, they understood how the KE and bird-rich zone concepts, as suggested by Dolbeer et al. (2006) and MacKinnon (2004) are important during their ADM processes. Empirical information indicates that high-quality training and education have a greater impact on aviation safety and efficiency than "just the total flight hours accumulated by entry-level pilots" (Mendonca et al., 2021).

A finding of concern, which shed some light on Mendonca et al. (2018) was that the participants of this study had been scarcely provided with guidance to mitigate the risk of bird strikes during flight activities. Yet, much of the guidance provided is not underpinned by empirical information related to ADM concepts applied to the safety management of wildlife hazards in aviation. Training and education are needed for a pilot to gain and/or improve their ADM knowledge and skills. The FAA (2007; 2016a) suggests that case-based and/or scenario-based training can help pilots improve their ADM competencies. We recommend flight instructors should incorporate "bird-hazard scenarios" during ground and flight training in order to help pilots in Part 141 collegiate aviation environment enhance their ADM knowledge and skills to mitigate the risks associated with birds during flight operations. Similarly, we recommend this subject be addressed in academic classes in which ADM concepts are taught to flight students pursuing an academic degree in Part 141 collegiate aviation environment. These recommendations are in alignment with previous studies by Keller (2015), Keller et al. (2020), and Li and Harris (2001).

Conclusion

The aviation industry is a vital contributor to the increasing U.S. economic productivity and prosperity (FAA, 2020a). The U.S. civil aviation system accounts for approximately 5.5% of the U.S. gross domestic product, generates almost $2 trillion in economic activities, and supports more than four million direct and seven million indirect jobs with $490 billion in earnings. The outbreak of the COVID-19 pandemic caused devastating financial and economic losses and significant uncertainties to the aviation industry (ICAO, 2021). Notwithstanding, over the long term, the capabilities and strengths developed by the aviation industry during the last decade will again become evident. Moreover, prospering U.S. and world economies provide the foundation for the U.S. aviation industry to thrive in the next decades. The U.S. commercial aviation industry is forecast to grow by 4.9% per year until 2041. The long-term outlook for the general aviation (GA) industry is also promising. The number of GA hours flown is forecast to increase an average of 0.7 per year until 2040 while the GA fleet is expected to grow by approximately 0.1% during the same period (FAA, 2020b).

Annually, it is estimated that wildlife strikes cost the U.S. civil aviation industry 139,469 hours of aircraft downtime and $328 million in direct and indirect costs (Dolbeer et al., 2022). Empirical information indicates that pilots play a major role in the aircraft accident prevention process. By applying ADM concepts before and during their flights, crews could significantly reduce the risk of a mishap resulting from a strike. The ever-increasing risk of aircraft accidents resulting from wildlife strikes and the optimistic forecast for the U.S. aviation industry require a multifaceted approach to address this safety hazard. This approach should include integrated research, new technologies and/or innovative use of current technologies, and pilots' training and education. The possible benefits of providing Part 141 collegiate pilots with ADM training and education to prevent bird strikes include:

1. Reducing the direct and other monetary losses resulting from bird strikes;
2. Reducing the number of human injuries and fatalities resulting from bird strikes;
3. Increasing the quantity and improving the quality of wildlife strike reports by pilots;
4. Supporting the sustainable growth of the U.S. aviation industry; and
5. Providing these professional pilots unique opportunities to develop or enhance competencies (e.g., risk management) that are valued by the aviation industry.

Limitations and Future Studies

There are a number of limitations associated with this study. The non-probability sampling technique as well as the absence of a control group limits the generalizability of our findings (Sekaran & Bougie, 2013). A convenient sample, for example, is not representative of the entire collegiate flight student population enrolled in accredited CFR Part 141 flight training and four-year degree-awarding universities. The participants of the current study, however, are not unlike their peers in other similar universities. Thus, our findings could provide an interesting picture of the importance of ADM training for accident prevention regarding bird hazards. Another possible caveat to the study findings was the reliability and validity of the assessment tools. Researchers used the assessment instruments utilized by Mendonca et al. (2018). A Cronbach alpha for the pretest and for the post-test of the current study indicated a coefficient of 0.702 (acceptable) and of 0.878 (high –reliability), respectively. Moreover, we supported the quantitative findings with qualitative data as suggested by Patton (2015) in order to increase the credibility of our findings. Nonetheless, we acknowledge that the findings of this study need to be interpreted with caution.

Further research is warranted to better understand why collegiate aviation pilots have received little guidance and instruction on the safety management of wildlife hazards to aviation. Moreover, future studies could investigate if improvement in knowledge regarding the safety management of bird hazards by pilots would be associated with improvements in pilots' practices. We cannot rule out the possibility that some of our findings were biased by demand effects and/or due to other confounding and/or extraneous variables not measured. At last, despite the limitations of this study, findings could provide the scientific foundation for collegiate aviation program leaders' efforts to enhance aviation safety.

References

Airbus (n.d.). *Flight operations briefing notes, human performance: Enhancing situational awareness*. https://www.smartcockpit.com/docs/Enhancing_Situation_Awareness.pdf

Air Force Safety Center (2022). *United States avian hazard advisory system*. https://www.safety.af.mil/Divisions/Aviation-Safety-Division/BASH/

Avrenli, K. A., & Dempsey, B. J. (2014). Statistical analysis of aircraft-bird strikes resulting in engine failure. *Journal of the Transportation Research Board, 2449*, 14-23. https://doi.org/10.3141/2449-02

Blackwell, B. F., DeVault, T. L., Seamans, T. W., Lima, S. L., Baumhardt, P., & Juricic, E. F. (2012). Exploiting avian vision with aircraft lighting to reduce bird strikes. *Journal of Applied Ecology*, *49*, 758-766. https://doi.org/10.1111/j.1365-2664.2012.02165.x

Buch, G., & Diehl, A. (1984). An investigations of the effectiveness of pilot judgment training. *The Journal of the Human Factors and Ergonomics Society, 26*(5), 557-564. https://doi.org/10.1177/001872088402600507

Cleary, E. C., & Dickey, A. (2010). *Guidebook for addressing aircraft/wildlife hazards at general aviation airports* (ACRP Report No. 32). Transportation Research Board on the National Academies. http://www.trb.org/Publications /Blurbs/163690.aspx

Cleary, E. C., & Dolbeer, R. A. (2005). *Wildlife hazard management at airports: A manual for airport personnel*. Federal Aviation Administration. http://www.faa.gov/airports/airport_safety/wildlife/resources/media/2005_faa_manual_complete.pdf

DeFusco, R. P., & Unangst, E. T. (2013). *Airport wildlife population management: A synthesis of airport practice* (ACRP Synthesis 39). The National Academy of Sciences, Engineering, and Medicine. https://www.nap.edu/catalog/22599/airport-wildlife-population-management

DeFusco, R. P., Unangst, E. T. J., Cooley, T. R., & Landry, J. M. (2015). *Applying an SMS approach to wildlife hazard management* (ACRP Report No. 145). The National Academy of Sciences, Engineering, and Medicine. https://www.nap.edu/catalog/22091/applying-an-sms-approach-to-wildlife-hazard-management

DeVon, H. A., Block, M. E., Wright, P. M., Ernst, D. M., Hayden, S. J., Lazzara, D. J., Savoy, S. M., & Polston, E. K. (2007). A psychometric toolbox for testing validity and reliability. *Journal of Nursing Scholarship, 39*(2), 155-164. https://doi.org/10.1111/j.1547-5069.2007.00161.x

Dolbeer, R. A. (2006). Height distributions of birds as recorded by collisions with civil aircraft. *Journal of Wildlife Management, 70*(5), 1345-1350.

https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1496&context=icwdm_usdanwrc

Dolbeer, R. A. (2015). *Trends in reporting of wildlife strikes with civil aircraft and in identification of species struck under a primarily voluntary reporting system, 1990-2013*. Federal Aviation Administration. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1190&context=zoonoticspub

Dolbeer, R. A. & Barnes, W. J. (2017). Positive bias in bird strikes to engines on left side of aircraft. *Human-Wildlife Interactions*, *11*(1), 33-40. https://doi.org/10.26077/hp2d-c437

Dolbeer, R. A. (2020). Population increases of large birds in North America pose challenges for aviation safety. *Human-Wildlife Interactions, 14*(3), 345-357. https://doi.org/10.26077/53f9-edc3

Dolbeer, R. A., Begier, M. J., Miller, P. R., Weller, J. R., & Anderson, A. M., & (2022). *Wildlife strikes to civil aircraft in the United States: 1990–2021* (Serial Report Number 28). Federal Aviation Administration. https://www.faa.gov/sites/faa.gov/files/2022-07/Wildlife-Strike-Report-1990-2021.pdf

Doppler, M. S., Blackwell, B. F., DeVault, T. L., Juricic, E. F. (2015). Cowbird responses to aircraft with light tuned to their eyes: Implications for bird-aircraft collisions. *The Condor Ornithological Applications*, *117*(2), 165-177. Retrieved from http://www.bioone.org/doi/full/10.1650/CONDOR-14-157.1

Ertmer, P. A., & Newby, T. J. (2013). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly, 26*(2), 43-71. https://northweststate.edu/wp-content/uploads/files/21143_ftp.pdf

Eschenfelder, P. (2005, May). *High speed flight at low altitude: Hazard to commercial aviation?* (Paper presentation). Seventh Bird Strike Committee USA/Canada Annual Meeting, Vancouver, Canada.

Eschenfelder, P., & Hull, S. (2006, August 21-24). *Reduction of risk: a flight crew guide to the avoidance and mitigation of wildlife strikes to aircraft* (Paper presentation). Eighth Bird Strike Committee USA/Canada Meeting, St Louis, Missouri, United States.

Eschenfelder, P., & DeFusco, R. (2010, August). Bird strike mitigation beyond the airport. *AeroSafety World*, *5*(7). https://flightsafety.org/asw-article/bird-strike-mitigation-beyond-the-airport/

Federal Aviation Administration (FAA). (n.d.). *The art of aeronautical decision-making: Course table of contents*. https://www.faasafety.gov/files/gslac/courses/content/28/216/The%20Art%20of%20Aeronautical%20Decision.pdf

Federal Aviation Administration (FAA). (2008). *Aeronautical decision making* (FAA-P-8740-69 AFSH-8083-2). https://www.faasafety.gov/files/gslac/library/documents/2011/Aug/56413/FAA%20P-8740-69%20Aeronautical%20Decision%20Making%20%5Bhi-res%5D%20branded.pdf

Federal Aviation Administration (FAA). (2009). *Risk management handbook* (FAA-H-8083-2). https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/media/faa-h-8083-2.pdf

Federal Aviation Administration (FAA). (2013). *Reporting wildlife aircraft strikes* (Advisory Circular 150/5200-32B). https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_150_5200-32B.pdf

Federal Aviation Administration (FAA). (2016a). *Pilot's handbook of aeronautical knowledge* (FAA-H-8083-25B). https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/pilot_handbook.pdf

Federal Aviation Administration (FAA). (2016b). *Air traffic organization policy: Air traffic control* (JO 7110.65W CHG). https://www.faa.gov/documentlibrary/media/order/atc.pdf

Federal Aviation Administration (FAA). (2020a). *The economic impact of civil aviation on the U.S. economy*. https://www.faa.gov/about/plans_reports/media/2020_nov_economic_impact_report.pdf

Federal Aviation Administration (FAA). (2020b). *FAA aerospace forecast: Fiscal years 2020-2040. https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2020-40_FAA_Aerospace_Forecast.pdf*

Federal Aviation Administration (FAA). (2022a). *FAA airport/facility directory*. https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/dafd/search/advanced/

Federal Aviation Administration (FAA). (2022b). *Automatic terminal information service procedures.* https://www.faa.gov/air_traffic/publications/atpubs/atc_html/chap2_section_9.html

Federal Aviation Administration (FAA). (2022c). *NOTAMs, TFRs, and aircraft safety alerts.* https://www.faa.gov/pilots/safety/notams_tfr/

Federal Aviation Administration (FAA). (2022d). *Aeronautical information manual. https://www.faa.gov/air_traffic/publications/atpubs/aim_html/*

Federal Aviation Administration (FAA). (2022e). *AVS FY 2022 business plan.* https://www.faa.gov/about/plansreports/avs-fy-2022-business-plan

Federal Aviation Administration (FAA). (2022f). *Some significant wildlife strikes to civil aviation aircraft in the United States, January 1990 – March 2022.* https://www.faa.gov/sites/faa.gov/files/airports/airport_safety/wildlife/significant-wildife-strikes-1990-mar-2022.pdf

International Civil Aviation Organization (ICAO). (2018). *Safety management manual* (Doc. 9859). https://skybrary.aero/sites/default/files/bookshelf/5863.pdf

International Civil Aviation Organization (ICAO). (2021). *Economic impacts of COVID-19 on civil aviation*. https://www.icao.int/sustainability/Pages/Economic-Impacts-of-COVID-19.aspx

Jensen, R. S., Adrion, J., & Lawton, R. S. (1987). *Aeronautical decision making for instrument pilots*. US Department of Transportation. http://www.cfijapan.com/study/ADM_IFR.pdf

Keller, J. (2015). *Unexpected transition from VFR to IMC: An examination of training protocols to mitigate pilot gaps in knowledge and performance* (Publication No. 10099231) [Doctoral dissertation, Purdue University]. ProQuest Dissertations Publishing.

Keller, J., Carney, T., Xie, A., Major, W., & Price, M. (2017). VFR-into-IMC: An Analysis of Two Training Protocols on Weather-Related Posttest Scores. *Journal of Aviation Technology and Engineering*, *7*(1), 2-18. https://doi.org/10.7771/2159-6670.1150

Kelly, T. A. (2002, September). Managing bird strike risk with the avian hazard advisory system. *United States Air Force Flying Magazine: Safety, 58*(9). http://www.usahas.com/Downloads/Article%20Managing%20Bird%20Strike%20Risk%20With%20AHAS%20Flying%20Safety%20Sep%202002%20Kelly.pdf

Kochan, J. A., Jensen, R. S., Chubb, G. P., & Hunter, D. R. (1997). *A new approach to aeronautical decision-making: The expertise method*. https://www.faa.gov/data_research/research/med_humanfacs/oamtechreports/1990s/media/AM97-06.pdf

Larkin, R. P., Torre-Bueno, J. R., Griffin, D. R., Walcott, C. (1975). Reactions of migrating birds to light and aircraft. *Proceeding of the National Academy Science, 72*(6), 1994-1996. *https://www.pnas.org/content/pnas/72/6/1994.full.pdf*

Leedy, P. D., & Ormrod, J. L. (2020). *Practical research: Planning and design*. Pearson Education Limited.

Li, W-C., & Harris, D. (2008). The evaluation of the effect of a short aeronautical decision-making training program for military pilots. *The International Journal of Aviation Psychology, 18*(2), 135-152. https://doi.org/10.1080/10508410801926715

MacKinnon, B. (2004). *Sharing the skies manual – An aviation industry guide to the management of wildlife hazards.* Government of Canada, Transport Canada. http://www.tc.gc.ca/eng/civilaviation/publications/tp13549-menu-2163.htm

Manuele, F. A. (2017). *On the practice of safety*. John Wiley & Sons, Inc.

Marra, P. P., Dove, C. J., Dolbeer, R. A., Dahlan, N. F., Heacker, M., Whaton, J. F., Diggs, N. E., France, C., & Henkes, G. A. (2009). Migratory Canada geese cause crash of US airways flight 1549. *Frontiers in Ecology and the Environment, 7*(6), 297-301. https://doi.org/10.1890/090066

Mendonca, F. A. C., & Carney, T. Q. (2018, March 5-8). *General aviation pilots' strategies to mitigate bird strikes* [Conference session]. *104th Purdue Road School Transportation Conference & Expo*, West Lafayette, IN, United States. https://docs.lib.purdue.edu/roadschool/2018/presentations/49/

Mendonca, F. A. C., Carney, T. Q., & Fanjoy, R. O. (2018). Enhancing the safety training of GA pilots to reduce the risk of bird strikes: An experimental pilot study. *International Journal of Aviation, Aeronautics, and Aerospace, 5*(4), 1-27. https://doi.org/10.15394/ijaaa.2018.1281

Mendonca, F. A. C., Keller, J., & Dillman, B. G. (2021). Competency-based education: A framework for a more efficient and safer aviation industry. *Journal of the International Society of Air Safety Investigators, 54*(1), 19-23. https://www.isasi.org/Documents/ForumMagazines/Forum-2021-JanToMarch.pdf

National Transportation Safety Board (NTSB). (2009). *Crash of Cessna 500, N113SH following an in-flight collision with large birds - Oklahoma City, Oklahoma* (NTSB/AAR-09/05-PB2009-910405). www.ntsb.gov/investigations/AccidentReports/ Reports/AAR0905.pdf

National Transportation Safety Board (NTSB). (2010). *Loss of thrust in both engines, US airways flight 1549 and Subsequent Ditching on the Hudson River: US Airways Flight 1549 Airbus A320-214, N106US Airbus Industry A320-214, N106US* (NTSB/AAR-10/03). http://www.ntsb.gov/investigations/AccidentReports/ Reports/AAR1003.pdf

Nicholson, R., & Reed, W. S. (2011, July). *Strategies for prevention of bird-strike events*. BOEING. https://www.boeing.com/commercial/aeromagazine/articles/2011_q3/4/

O'Callaghan, J. (n.d.). *Bird-strike certification standards and damage mitigation*. National Transportation Safety Board. https://www.ntsb.gov/news/events/documents/oklahoma_city_ok-2_web_bird_strike_cert_and_damage_john_ocallaghan.pdf

O'Hare, D., Mullen, N., & Arnold, A. (2009). Enhancing aeronautical decision making through case-based reflection. *The International Journal of Aviation Psychology, 20*(1), 173-178. https://doi.org/10.1080/10508410903415963

Patton, M. Q. (2015). *Qualitative research & evaluation methods*. SAGE Publications, Inc.

Polit, D. F. & Beck, C. T. (2006). The Content Validity Index: Are you sure you know what's being reported? Critique and recommendations. *Research in Nursing & Health, 29*(5), 489-497. https://doi.org/10.1002/nur.20147

Rillstone, D. J., & Dineen, C. M. (2013). *Airport responsibility for wildlife management* (ACRP Legal Research Digest No. 20). The National Academy of Sciences, Engineering, and Medicine. https://www.nap.edu/catalog/22517/airport-responsibility-for-wildlife-management

Salkind, N.J. (2012). *Exploring research*. Upper Saddle River.

Siedlecki, S. L. (2020). Quasi-experimental research designs. *Clinical Nurse Specialist, 26*(3). 131-135. https://pubmed.ncbi.nlm.nih.gov/32796378/

Sekaran, U., & Bougie, R. (2013). *Research methods for business*. SAGE Publications, Inc.

Western Governors University (2020). *Five educational learning theories*. https://www.wgu.edu/blog/five-educational-learning-theories2005.html#close

Appendix: Questions Utilized during the Assessments

1. Which factor should pilots consider while planning their flights to mitigate the risk of a bird strike?
    a. Birds tend to be more active during the day and dusk
    b. **Birds tend to be more active during dusk and dawn**
    c. Birds tend to be more active during dusk and night
    d. Birds tend to be more active during dawn and day

2. The likelihood of a damaging bird strike is higher:
    a. Below 200 feet AGL
    b. **Above 500 feet AGL**
    c. Above 5,500 feet AGL
    d. Below 500 feet AGL

3. During initial climb out, pilots should clear bird-hazard risk areas by using airspeeds and flap configurations that provide:
    a. The best rate of climb (Vy)
    b. **The best angle of climb (Vx)**
    c. The takeoff safety speed (V2)
    d. The aircraft design maneuvering speed (Va)
        3.1. Why would you use that configuration?

4. The degree of severity resulting from a bird strike is influenced by several factors, especially:
    a. The altitude of the aircraft and its airspeed
    b. The outside air temperature (OAT) and the aircraft configuration
    c. The aircraft airspeed and the mass of the bird
    d. The mass of the bird and the altitude of the aircraft
    e. The phase of flight and the altitude of the aircraft

5. The probability of a bird strike, while flying in a bird-rich zone, is an inverse function of the aircraft:
    a. Airspeed
    b. **Rate of climb**
    c. Configuration
    d. Angle of attack

6. There is some empirical evidence that the following aircraft systems may assist pilots in mitigating the risk of bird strikes involving certain species of birds:
    a. Aircraft external lights and transponder
    b. **Aircraft weather radar and external lights**
    c. Aircraft traffic collision avoiding system (TCAS) and external lights
    d. Aircraft ground proximity warning systems (GPWS) and weather radar

7. The risk of damage to the aircraft engine(s) due to bird ingestions is higher:
    a. **During takeoff run and initial climb-out**

b. During the approach and landing
c. During landing and takeoff run
d. During cruise and descent

8. The bird-rich zone is defined as the airspace where most bird strikes occur. Which actions could aviators take to mitigate the risk of bird strikes in regards to the bird-rich zone?
   a. **Reduce flight time and airspeed while flying in the bird-rich zone**
   b. Increase flight time and the airspeed while flying in the bird rich zone
   c. Increase flight time but decrease airspeed while flying in the bird rich zone
   d. Decrease flight time but increase airspeed while flying in the bird rich zone

9. You are cleared by air traffic control (ATC) to descend from 6,000 feet to 1,500 feet and you are aware that you will fly through an area where other pilots reported the presence of birds. Which actions could you take to mitigate the risk of a bird strike, if operationally possible?
   a. Increase your rate of descent and the aircraft airspeed
   b. **Increase your rate of descent without increasing the aircraft airspeed**
   c. Reduce your rate of descent and increase the aircraft airspeed
   d. Increase the aircraft airspeed without increasing your rate of descent

10. The severity of a bird strike is a direct function of:
   a. The aircraft rate of climb and mass of the bird
   b. The aircraft angle of attack and airspeed
   c. **The aircraft airspeed and mass of the bird**
   d. The aircraft airspeed and rate of climb

11. You are the captain of a single-pilot jet aircraft. You are descending from 10,000 feet to 1,500 feet. Air traffic control (ATC) and other aircraft reported birds at 5,500 feet and below. Which actions could you take to mitigate the risk of an accident due to birds, if operationally possible?
   a. Increase airspeed and rate of descent
   b. **Decrease airspeed and use idle-power setting**
   c. Increase airspeed and use idle-power setting
   d. Decrease rate of descent and increase power

12. You are planning a cross-country flight that will most likely pass along a major U.S. migratory flyway. Where can you obtain information about the migration patterns of birds as well as a forecast of bird movements within a low-level flight arena for the contiguous 48 States?
   a. The FAA Wildlife Hazard Management Website
   b. The U.S. Department of Agriculture (USDA) – Wildlife Services Website
   c. The U.S. Bird Strike Committee Website
   d. **The U.S. Avian Hazard Advisory System Website**

13. You are flying solo at 2,000 feet when you see a flock of birds at around the same altitude. The recommended action you can take to mitigate bird strikes, if operationally possible, will be:
   a. **Pull up, consistent with good flying techniques to attempt to pass over them**
   b. Dive, consistent with good flying techniques to attempt to pass below them

c. Turn right or left, consistent with good flying techniques to attempt to avoid them
d. A combination of “B” and “C”

14. You are the captain of a Boeing 787. You are on final approach close to the runway at Chicago O’Hare International Airport when you observe a flock of birds. You realize that your aircraft will probably hit some birds. Which actions would you take to mitigate the risk of bird strikes, if operationally possible?
a. Initiate a go-around and then attempt a second approach
b. **Fly through the birds and land**
c. Initiate a go-around and divert to another airport
d. Fly through the birds and then initiate a go-around

15. You are planning a local flight for the next weekend. You will take some friends on a one-hour ride, and will fly no farther than 35 miles away from KLAF. What can you do to reduce the probability of bird strikes?
a. Fly above 1,000 feet as much as possible
b. Fly below 3,500 feet as much as possible
c. **Fly above 4,500 feet as much as possible**
d. Fly below 2,500 feet as much as possible

16. You are about to takeoff at an airport with reported bird activity. The most effective way for you to reduce the probability of a bird strike after takeoff will be to:
a. Fly at the lowest airspeed possible
b. Minimize the rate of climb
c. Fly at the highest airspeed possible
d. **Maximize the rate of climb**

17. You have just taken off and are about to fly through a bird-rich zone. You should ________ the ________ to reduce the severity of a possible bird strike.
a. Increase / airspeed
b. **Decrease / airspeed**
c. Increase / rate of climb
d. Decrease / rate of climb

18. You will most likely fly through an area where the presence of birds is expected. The following factors could directly impact the amount of damage to the aircraft in case of a bird strike:
a. Engine thrust and aircraft rate of descent
b. Aircraft rate of descent and airspeed
c. **Engine thrust and aircraft airspeed**
d. Aircraft airspeed and configuration

19. Bird strikes during _________ are substantially more hazardous with respect to engine failure than those during _______ and __________.
1. Climb
2. Landing roll

3. Approach
4. Takeoff run
5. Descent
    a. 1, 3, and 5
    b. 5, 1, and 2
    c. 3, 1, and 4
    d. 5, 3 and 4

20. In case you have a bird strike, you should report this incident to the:
    a. **FAA**
    b. National Transportation Safety Board
    c. Chief-pilot
    d. Bird Strike Committee USA
    e. U.S. Department of Agriculture (USDA) – Wildlife Services
    f. Flight safety officer

a. If operationally possible, what is the safest strategy pilots should adopt to mitigate the probability and severity of a bird strike while flying in the bird-rich zone? Why?

b. Why should you report bird strikes? How can you report a bird strike?

c. What aeronautical resources can pilots use, during their decision-making process, to gather information about the presence of birds at and around airports?

d. In which phase(s) of flight is the risk of an aircraft accident due to bird ingestion(s) the highest? Can you explain why?

e. Why should you inform air traffic control (ATC) about the presence of birds that you observe while you are flying?

f. What wildlife mitigation techniques and guidance have you been provided during your career as a pilot? By whom?