Safety Management of Wildlife Hazards to Aviation: An Analysis of Wildlife Strikes in Part 139 Airports in Florida 2011-2020

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Purpose: The purpose of this study is twofold: 1) To investigate wildlife strike reporting trends in Part 139 airports in the State of Florida for comparison with national data; 2) To evaluate the existence of a difference between the seasons of the year and reported wildlife strikes in Part 139 airports in the state of Florida between 2011-2020. The study evaluates the Wildlife Strike Index per season while accounting for the following parameters: time of day, part struck, type of operator, and level of damage resulting from the strike.

Design/Methodology: The researchers in this study answered the research questions through the analysis, revision, and evaluation of the existing data. The data analyzed in this study were collected between May 1 and May 20, 2021. This study used the Federal Aviation Administration Air Traffic Activity System (ATADS) and the National Wildlife Strike Database (NWSD) to collect information on aircraft operations and reported wildlife strikes, respectively.

Findings: There is a relationship between the average wildlife strike for each season and the seasons of the year, when analyzing the Part 139 Airports in the state of Florida between 2011-2020. There is no significant difference between the relative percentage and location of strikes considering the Wildlife Strike Index for Time of Day, Damage Level, Part Struck when comparing the obtained wildlife strike reports within the scope of the study.

Originality/value: Researchers did not find any other study using a regional scope to analyze reported wildlife strikes in the State of Florida. This is study will provide valuable information to aviation safety stakeholders to improve their wildlife strike mitigation strategies by using a regional scope of reported wildlife strikes in Part 139 airports in the state of Florida between 2011-2020. Further analysis of reported wildlife strikes is provided by identifying a statistically significant difference in the likelihood a wildlife strike through the different seasons of the year.

Introduction

A vital step toward mitigating the risk of aircraft accidents due to wildlife strikes is the collection, analyses, and understanding of wildlife strike data. Previous studies have focused on gathering and analyzing wildlife encounters over the entire United States (Anderson et al., 2015; DeVault et al., 2018; Dolbeer, 2020; Dolbeer et al., 2021), this way not considering regional and other factors such as bird migration patterns, local wildlife populations, and seasons of the year as they may have a different impact on the risk of strikes in individual regions (Defusco & Unangst, 2013). Dolbeer et al. (2021) and Mendonca et al. (2017) have advocated for the analyses of wildlife strike data in a regional level for accident prevention efforts. The species, population size, and number of birds as well as wildlife habitat conditions at and around the airports, for example, vary drastically across the United States, demanding an approach that will look at the specific patterns as they relate to a specific region (Federal Aviation Administration [FAA], 2020a).

Analyses of wildlife strike data specifically focused on airports certified under the Title 14 Code of Federal Regulations (CFR) Part 139[1] (Electronic Code of Federal Regulations, 2021) in the state of Florida will permit a more effective safety approach to these occurrences. The goal of this study is to supplement the FAA wildlife-strike annual reports with information derived from the analysis of wildlife strike reports from Part 139 airports in Florida from 2011 through 2020. Specifically, the purpose of this study is twofold: 1) to discover new information based upon the findings of relevant data analyzed that can be used for the safety management of wildlife; 2) to investigate if there is a statistically significant difference in the wildlife strike

[1] Part 139 – Certification of Airports: Includes airports that "serve scheduled and unscheduled air carrier aircraft with more than 30 seats; serve scheduled air carrier operations in aircraft with more than 9 seats but less than 31 seats; and the FAA Administrator requires to have a certificate" (Federal Aviation Administration [FAA], 2020, para. 1).

index[2] in Part 139 airport in the state of Florida from 2011-2020 among the four seasons of the year.

Literature Review

The aviation industry plays an important role in the American economy, being responsible for approximately 10% of the total U.S. economic activity (FAA, 2020a). The civil aviation industry also generates approximately 10.9 million jobs and contributes to 5.2% of the United States' gross domestic product (GDP). As a result of the COVID-19 pandemic, the number of aircraft operations declined by approximately 3.5% in 2020 compared to 2019 (FAA, n.d.-a). However, despite this decline the number of operations within the United States is forecasted to increase from approximately 44 million to over 60 million operations in the next two decades.

Wildlife strikes to aviation is a growing safety and economic concern in the U.S. Aircraft accidents and incidents resulting from strikes across the United States from 1990-2020 have resulted in $768.9 million of direct repair costs, $101.3 million in other indirect costs, and 1,154,221 hours of aircraft downtime. These values have indicated an average of 96.9 hours of aircraft downtime per wildlife strike and a repair cost of $163,005 per damaging occurrence. However, the costs of a wildlife strikes can add to an even higher figure as only approximately 47% and 91% of wildlife strikes involving general aviation and commercial transport aircraft, respectively, are reported. According to Dolbeer et al (2021) a wildlife strike that has resulted in damage to the aircraft is more likely to get reported. Thus, the resulting cost figures may also be even more significant due to the increase in air traffic over the past decades (FAA, 2020b).

Within the timeframe analyzed in this study, there were 142,668 wildlife strikes reported through the U.S. National Wildlife Strike Database (NWSD). The majority of these strikes

[2] Wildlife-strike index is the number of wildlife strikes per 100,000 aircraft operations.

occurred during the day (n= 58,743), and 35.7% percent of strikes (n= 50,907) occurred during the arrival phases of flight (descent, approach, and landing roll). During this period there were 11 human fatalities resulting from wildlife strikes. National wildlife-strike data obtained from 2011-2020 indicate that 97% (n= 92,411) of all wildlife strikes with a known type of operator involved commercial aircraft. Only approximately 3% (n= 2,750) of all strikes occurred during dawn or dusk, while 64.4% (n= 58,743) of strikes occurred during the daytime. In the period analyzed in this study, 6,540 of the 142,668 reported wildlife strikes through the NWSD resulted in some damage to the aircraft. Moreover, information obtained from the analyses of wildlife strike data have indicated a significant increase in the number of wildlife strikes as well as damaging wildlife strikes since 2010. For example, the number of strikes and damaging strikes increased by 75% and 41% from 2011 through 2019 in the U.S., respectively. There was an 84% increase, from 9,241 to 17,050, in the number of wildlife strikes involving commercial aircraft between 2009 and 2019 (Dolbeer et al., 2021). In the same period, the number of aircraft operations rose from 25.45 million to 26.21 million (FAA, n.d.-a). All those factors interact to form the basis of this safety issue that needs effective mitigation by aviation stakeholders.

The reasons for this ever-increasing safety and economic concern are dynamic and complex. Successful environmental programs by government and private organizations have contributed to impressive increases in wildlife populations at and around airports. For example, Sandhill Cranes are considered the seventh most hazardous wildlife species to aviation operations in the U.S. (Dolbeer, 2020). The population of this hazardous bird species "increased over 3-fold from about 200,000 to 700,000 birds from 1990–2020" (Dolbeer et al., 2021, p. 20). Other reasons for the increased risk of wildlife strikes include birds becoming increasingly adapted to urban areas, quieter turbofan engines decreasing animals' ability to detect an incoming aircraft, and an increase in the number of aircraft operations (Cleary & Dolbeer, 2005).

The scientific analysis of wildlife strikes to aviation is paramount for aviation safety. Information obtained from the scientific analyses of wildlife strikes may provide the foundation for the development and implementation of safety management efforts to mitigate the risk of aircraft accidents resulting from strikes (Altringer et al., 2021). With the large increase in the number of wildlife strikes and aircraft operations over the past decade, the FAA recommends further action by airport operators to mitigate the risk of wildlife strikes (FAA, 2020b).

The FAA has issued annual reports providing information obtained from the scientific analyses of wildlife strikes in the U.S. (Dolbeer et al., 2021). However, this report is limited to a nationwide scope. Nonetheless, a regional scope may provide further insight of the highly variable conditions (e.g., migration patterns, weather, local habitats) that may affect wildlife strikes across the United States (Drey et al., 2014, Pfeifer et al., 2018). This study will address these regional considerations as this perspective may provide additional information to reported wildlife strike trends, especially as it relates to the seasons of the year.

This study was an attempt to answer the following research questions:

1. What are the descriptive statistics (type of operator, time of day, damage level, part struck, and phase of flight) in Part 139 airports in the state from 2011-2020?
2. What is the number of wildlife strike reports per 100,000 operations for each season of the year during 2011-2020 in Part 139 airports in the state of Florida?
3. Is there a difference between the average Wildlife Strike index between each season of the year from 2011-2020 in Part 139 airports in the state Florida?

Methodology

Data Collection

The researchers in this study answered the research questions through the analysis, revision, and evaluation of the existing data. The data analyzed in this study were collected between April 1 and April 20, 2021. We used the FAA Air Traffic Activity System (ATADS) and the FAA National Wildlife Strike Database (NWSD) to collect information on aircraft operations and reported wildlife strikes, respectively. These data sets are available to the public and can be accessed electronically. To accurately analyze the reported wildlife strikes considering the seasons of the year, data were obtained ranging from December 21, 2010, until December 20, 2020.

The researchers determined all the Part 139 airports in the state of Florida by referring to the *Part 139 Airport Certification Status List* [3] (FAA, 2021d). After determining the relevant airports to the study (see Table 1), the researchers referred to the ATADS database to obtain the number of aircraft operations per season of the year during the December 21st, 2010, to December 20th, 2020, period. The Florida Keys Marathon International Airport (MTH) and Eglin Air Force Base/Destin-Fort Walton Beach Airport (VPS) were not included in this research study since aircraft operations data were not available for these airports. We used the U.S. NWSD to obtain the number of reported wildlife strikes that occurred at and within the vicinities of all Part 139 airports in Florida during the same period. The data obtained from this database were filtered by season of the year, type of operator, time of day, damage level, part struck, and phase of flight. Wildlife strikes that resulted in at least some damage to the aircraft were considered as damaging strikes. The percentage of strikes obtained for the part struck consider only the

[3] Part 139 Airport Certification Status List – The document is electronically published on faa.gov and allows users to filter fully certified airports by state.

selections with a known part struck different than the “other” category. It is important to mention that in order to answer research question 1, we also collected wildlife strike as well as aircraft operations data from January 01, 2011, through December 31, 2020. Due to the yearly variations in the start of each season of the year, this study assumed that all seasons started and ended at the same day of the year (see Table 2).

Table 1

Part 139 Airports in the State of Florida

Identifier	Airport Name	City
APF	Naples Municipal Airport	Naples, FL
DAB	Daytona Beach International Airport	Daytona Beach, FL
ECP	Northwest Florida Beaches International Airport	Panama City, FL
EYW	Key West International Airport	Key West, FL
FLL	Fort Lauderdale / Hollywood International Airport	Fort Lauderdale, FL
GNV	Gainesville Regional Airport	Gainesville, FL
JAX	Jacksonville International Airport	Jacksonville, FL
LAL	Lakeland Linder International Airport	Lakeland, FL
MCO	Orlando International Airport	Orlando, FL
MIA	Miami International Airport	Miami, FL
MLB	Melbourne International Airport	Melbourne, FL
OCF	Ocala International Airport – Jim Taylor Field	Ocala, FL
PBI	Palm Beach International Airport	West Palm Beach, FL
PGD	Punta Gorda Airport	Punta Gorda, FL
PIE	Saint Petersburg – Clearwater International Airport	Saint Petersburg – Clearwater, FL
PNS	Pensacola International Airport	Pensacola, FL
RSW	Southwest Florida International Airport	Fort Myers, FL
SFB	Orlando Sanford International Airport	Orlando, FL
SGJ	Northeast Florida Regional Airport	Saint Augustine, FL
SRQ	Sarasota / Bradenton International Airport	Sarasota – Bradenton, FL
TIX	Space Coast Regional Airport	Titusville, FL
TLH	Tallahassee International Airport	Tallahassee, FL
TPA	Tampa International Airport	Tampa, FL
VRB	Vero Beach Regional Airport	Vero Beach, FL

Table 2

Average Season Start Date

Season	Start Date	Average Duration (Days)
Winter	December 21	89
Spring	March 20	92
Summer	June 20	94
Fall	September 22	90

Aircraft operations are defined as (FAA, n.d.-b):

> The number of arrivals and departures from the airport at which the airport traffic control tower is located. There are two types of operations: local and itinerant. 1. Local operations are those operations performed by aircraft that remain in the local traffic pattern, execute simulated instrument approaches or low passes at the airport, and the operations to or from the airport and a designated practice area within a 20−mile radius of the tower. 2. Itinerant operations are operations performed by an aircraft, either IFR, SVFR, or VFR, that lands at an airport, arriving from outside the airport area, or departs an airport and leaves the airport area.

The type of aircraft operator obtained from the ATADS and NWSD databases were adjusted to fit the following categories: Commercial, General Aviation (GA), Military/Government, or Unknown. Commercial operators included all operators excluding private aircraft owners, government, and military aircraft. The ATADS provides information about itinerant and local aircraft operations. Itinerant aircraft operations are subdivided in commercial, GA, and military. For local aircraft operations the ATADS provides data for military and civil aircraft operations. However, this database does not distinguish between GA and commercial operations when reporting local civil aircraft operations. For this reason, the same ratio of GA (38%) and commercial operators (62%) for itinerant operations was assumed to determine the number of local aircraft operations for GA and commercial operators.

The times in which dawn, day, dusk, and night begin and end vary significantly throughout the year. To account for these variations, the researchers assumed a constant local time for the beginning and end for each time of day. These values were obtained by determining the beginning of civil twilight, sunrise, sunset, and end of civil twilight at the geographic center of the state of Florida using the FAA website (FAA, n.d.-c). The National Oceanic and Atmospheric Administration (NOAA) definitions of Dawn, Day, Dusk, and Night were used for the purpose of this study (NOAA, n.d.). Table 3 shows the established start time for each part of the day and their duration in minutes, for the purpose of this study.

Table 3

Time of Day Start Time

Phase of Day	Start Time	Duration (Minutes)
Dawn	05:46:00 am	24
Day	06:11:00 am	728
Dusk	06:19:00 pm	24
Night	06:43:00 pm	664

Data Analysis

Using the parameters established above, the researchers grouped the obtained data to their respective year and organized them also considering the seasons of each year using Microsoft Excel. Additionally, we organized the collected data considering the type of operator, time of day, damage level, part struck, and phase of flight for an exploratory analysis. To determine the damage level of the aircraft the following categories were used: damaging, non-damaging, and unknown. Upon completion of these steps a wildlife strike index was calculated for each season of the year, representing the number of wildlife strikes per 100,000 operations.

A Kruskal-Wallis H test was performed using IBM SPSS Statistics to determine if there were differences in the wildlife strike index in Part 139 airports between the seasons of the year in the state of Florida from 2011-2020. To determine the significance of these obtained values, an Alpha (α) – 0.05 was used. The researchers hypothesized that there would not be a statistically significant difference in the wildlife strike index through the different seasons of the year.

Results and Discussion

From 2011 through 2020 there were 8,962 wildlife strikes in Part-139 airports in the state of Florida. Approximately five percent (n= 457) of the total strikes resulted in damage to the aircraft. One aircraft was damaged beyond repair as a result of wildlife strike during the period studied. To determine the damage level of the aircraft the following categories were used: damaging, non-damaging, and unknown. Findings indicated that approximately two thirds of all reported wildlife strikes involved commercial aircraft operators, accounting for 5,962 wildlife strikes (see Table 4). The average wildlife strike index also varied significantly when evaluating the different types of operators (see Table 4). It is important to note that unlike civilian aircraft, U.S. military aircraft are required to report wildlife strikes (U.S. Air Force, 2020). Thus, despite representing 2.1% of aircraft movements, military operators were only responsible for 0.6% of reported wildlife strikes. When considering a nationwide scope using the same criteria to define the type of operator, commercial operators represented 97% (n= 92,411) of all wildlife strikes with a known type of operator. Meanwhile, this same group represented 97.5% (n= 5,962) of all reported wildlife strikes with a known type of operator in Part 139 airports in the state of Florida during the same year.

Table 4

Wildlife Strikes per Type of Operator (2011-2020)

Operator	Wildlife Strikes	Aircraft Operations	Wildlife Strike Index
Commercial	5,962	21,291,930	28.00

General Aviation	92	12,850,410	0.72
Military	63	942,624	6.68
Unknown	2,845	-	-
Total	**8,962**	**35,084,964**	**25.54**

Analysis of the relevant data indicated that 48.2% (n=4,318) of the reported wildlife strikes within the scope of this study occurred during the daytime, while only 17.6% (n= 1,580) of the strikes occurred at night (see Table 5). The higher number of reported wildlife strikes occurring within the daytime may be a result of the higher number of aircraft flying during this period (FAA, 2020e). Interestingly, national wildlife strike data obtained from the NWSD (2011-2020) indicate that the day was the period with the highest number of wildlife strikes, representing 64.4% (n= 58,743) of all reported wildlife strikes. Yet only approximately 3% (n= 2,750) of all strikes in the entire U.S. occurred during dawn or dusk.

Table 5

Number of Reported Wildlife Strikes per Time of Day and per Seasons of the Year

Time of Day	Dawn	Day	Dusk	Night	Unknown	Total
Winter	3	717	22	181	463	**1,386**
Spring	12	771	22	359	584	**1,748**
Summer	12	1673	53	524	1071	**3,333**
Fall	11	1157	28	516	783	**2,495**
Total	**38**	**4,318**	**125**	**1,527**	**2,901**	**8,962**

Over the period analyzed in this study, 4.6% (n= 6,540) of all wildlife strikes in the U.S. and 5.1% (n= 457) of all wildlife strikes in the Part 139 airports in Florida, respectively, resulted in some level of damage to the aircraft. Interestingly, winter was the season with the highest percentage of damaging wildlife strikes with 8.2% (n= 113) in Part 139 airports Florida. Meanwhile, the summer season had the highest number of wildlife strikes (n=53,769) but the lowest percentage of damaging strikes 3.18% (n= 106). There were 2,495 and 1,748 strikes during the fall and spring seasons, respectively. Yet, 141 and 97 wildlife strikes in the fall and spring seasons, respectively, resulted in damage to the aircraft. Further information on the number of wildlife strikes that resulted in damage to the aircraft is provided in Appendices A and B.

The aircraft part most struck by wildlife within the scope of this study was the nose (n=948) followed by the windshield (n=917). Nationally, the windshield of the aircraft was the area with the great majority of collisions, representing approximately 13.9% (n= 15,431) of all wildlife strikes with a known part struck. On the other hand, there were no reported wildlife strikes to the aircraft propeller within the data analyzed in this study in the state of Florida, and only 29 reports indicated animals struck the lights of the aircraft. A detailed analysis of the number of wildlife strikes that impacted each part of the aircraft is provided in Appendices C and D.

The arrival phases of flight (arrival, approach, and landing roll) and the departure phases of flight represented 61.7% (n= 3,834) and 36.6% (n= 2,224), respectively, of the total wildlife strikes in Florida. Twenty-eight percent (n= 2,523) of the wildlife strikes in which the phase of flight was reported occurred during approach (see Table 9). Interestingly, 63.5% (n= 50,907) of all reported wildlife strikes in the United States occurred during the arrival phases of flight (descent, approach, arrival, and landing roll).

Table 9

Number of Reported Wildlife Strikes per Phase of Flight (2011-2020)

Phase of Flight	Reported Wildlife Strikes	Percentage of Total Strikes (%)
Approach	2523	28.15
Arrival	36	0.40
Climb	926	10.33
Departure	191	2.13
Descent	56	0.62
Landing Roll	1219	13.60
Local	34	0.38

Parked	5	0.06
Take-off Run	1107	12.35
Taxi	30	0.33
Unknown	2835	31.63
Total	**8,962**	**100**

Regarding the second research question, the four seasons of 2019 represented the 1-year period with most wildlife strikes (n= 1,377) while 2011 had the lowest (n= 611) (see Table 10). In addition to having the most strikes, 2019 also had the highest number of damaging strikes (n= 68) among all Part 139 airports in the state of Florida. Table 10 shows the findings obtained with the relevant data, each year indicated in the table below represents a 4 season period.

Table 10

Wildlife Strikes per season of the year

Year	Variables	Winter	Spring	Summer	Fall
	Strikes	86	145	194	186
	Damaging Strikes	13	10	9	17
2011	Aircraft Operations	849,480	856,120	781,969	820,942
	Wildlife Strike Index	10.12	16.94	24.81	22.66
	Damaging Strike Index	1.53	1.17	1.15	2.07
	Strikes	133	104	229	169
	Damaging Strikes	15	8	12	10
2012	Aircraft Operations	859,857	902,970	822,903	831,641
	Wildlife Strike Index	15.47	11.52	27.83	20.32
	Damaging Strike Index	1.74	0.89	1.46	1.20
	Strikes	88	134	271	199
	Damaging Strikes	11	9	11	14
2013	Aircraft Operations	875,407	916,531	841,887	830,349
	Wildlife Strike Index	10.05	14.62	32.19	23.97
	Damaging Strike Index	1.26	0.98	1.31	1.69
	Strikes	134	188	321	251
	Damaging Strikes	9	11	7	12
2014	Aircraft Operations	816,563	910,021	814,589	858,830
	Wildlife Strike Index	16.41	20.66	39.41	29.23
	Damaging Strike Index	1.10	1.21	0.86	1.40
	Strikes	122	185	281	235
	Damaging Strikes	8	9	11	12
2015	Aircraft Operations	859,545	958,453	826,176	860,929
	Wildlife Strike Index	14.19	19.30	34.01	27.30
	Damaging Strike Index	0.93	0.94	1.33	1.39
2016	Strikes	135	174	356	279

	Damaging Strikes	4	10	12	26
	Aircraft Operations	895,592	943,813	852,414	868,130
	Wildlife Strike Index	15.07	18.44	41.76	32.14
	Damaging Strike Index	1.68	1.06	1.41	2.99
	Strikes	131	188	410	309
	Damaging Strikes	9	8	9	16
2017	Aircraft Operations	909,487	944,037	826,176	909,345
	Wildlife Strike Index	14.40	19.91	49.63	33.98
	Damaging Strike Index	0.99	0.85	1.09	1.76
	Strikes	143	238	440	296
	Damaging Strikes	16	8	18	8
2018	Aircraft Operations	946,681	994,797	961,134	970,238
	Wildlife Strike Index	15.11	23.92	45.78	30.51
	Damaging Strike Index	1.69	0.80	1.87	0.82
	Strikes	228	289	530	330
	Damaging Strikes	17	21	14	16
2019	Aircraft Operations	1,013,573	1,050,341	936,361	1,007,301
	Wildlife Strike Index	22.49	27.51	56.60	32.76
	Damaging Strike Index	1.68	2.00	1.50	1.59
	Strikes	186	103	301	241
	Damaging Strikes	11	3	3	3
2020	Aircraft Operations	1,021,128	549,201	638,536	718,652
	Wildlife Strike Index	18.22	18.75	47.14	33.54
	Damaging Strike Index	1.08	0.55	0.47	0.42
	Strikes	1,386	1,748	3,333	2,495
	Damaging Strikes	113	97	106	134
Total	Aircraft Operations	9,047,313	9,026,284	8,302,145	8,676,357
	Wildlife Strike Index	15.32	19.37	40.15	28.76
	Damaging Strike Index	1.25	1.07	1.28	1.54

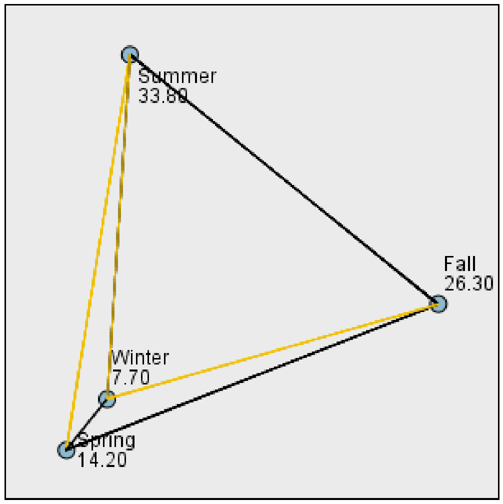
Note. The wildlife strike index indicate the total number of wildlife strikes per 100,000 aircraf operations.

All Part 139 airports are required to develop and implement safety measures to mitigate the risk of aircraft accidents resulting from wildlife strikes. During the safety risk management processes, a risk assessment is made to assess the effects of multiple factors, including seasonal patterns, in wildlife patterns around the airport (Rillstone & Dineen, 2013). Investigating and understanding the differences of the wildlife strike index among the seasons of the year may provide valuable information to aviation stakeholders that can be used during the development and assessment of wildlife hazard mitigation techniques. The regional scope used in this study provides further insight into the likelihood of wildlife strikes and damaging wildlife strikes through the seasons of the year in Part-139 airports in the state of Florida.

Answering the last research question of this study, a Kruskal-Wallis test was conducted to determine if there were differences in reported wildlife strikes per 100,000 operations between the four seasons of the year: Fall (n = 10), Winter (n = 10), Spring (n = 10), and Summer (n = 10). The Kruskal-Wallis test was selected over an ANOVA because there was an outlier in the spring season and three outliers in the summer season. Distributions of reported wildlife strikes per 100,000 operations were not similar for all groups, as assessed by visual inspection of a boxplot. Median in reported wildlife strikes per 100,000 operations were statistically significantly different between the four seasons of the year, $\chi2(3) = 30.297$, $p < .001$. Subsequently, pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. This post hoc analysis revealed statistically significant differences in reported wildlife strikes per 100,000 operations between the Winter (7.70) and Fall (26.30) ($p = .002$), between the Winter (7.70) and Summer (33.89) ($p = .000$), and between the Spring (14.20) and Summer (33.89) ($p = .001$) seasons of the year, but not between the Spring and Fall and between Fall and Summer seasons of the year. Figure 1 indicates the mean rank and test statistics, with the yellow lines representing significant differences.

Figure 1

Pairwise Comparisons of the Wildlife Strike Index per Seasons of the Year



Conclusion

The collection and analysis of wildlife-strike data is a vital step towards mitigating the hazard that wildlife poses to aviation since a problem can only be solved when it is well understood (Cleary & Dolbeer, 2005). The data obtained in this study indicated some similarities with the number of reported wildlife strikes per type of operator, time of day, damage level, part struck, and phase of flight with all the information available through the NWSD. An example of this similarities is that most wildlife strikes hit the nose of the aircraft, the arrival phases of flight are responsible for most strikes, and about 5% of all wildlife strikes result in damage to the aircraft. Findings suggested that there was a statistically significant difference in the likelihood of a wildlife strike through the different seasons of the year. Understanding that the seasons of the year could have an impact in the probability of wildlife strikes will permit aviation safety stakeholders to tailor their safety efforts, not only being more effective but also optimizing the use of their often limited financial and labor resources. Our findings suggested that there is a higher likelihood of wildlife strikes during the summer and fall seasons of the year. Additionally, there is a higher chance of a damaging strike during the winter and fall seasons at Part 139 airports in Florida.

Commercial and GA aviation have evolved into the safest, most far-reaching, and sustainable transportation mode over the last century. The aviation industry contributes to the health, well-being, and quality of life of millions of people worldwide. The U.S. air transportation industry plays a significant role in the U.S. and global economies. According to the FAA (2020a), the U.S. aviation industry "across both direct and catalytic sectors, amounts to more than five percent of the U.S. gross domestic product, contributes $1.8 trillion in total economic activity and supports nearly 11 million jobs" (p. 3). The number of commercial passengers is expected to grow from 100 million in 2021 to almost 450 million in 2041 (FAA, n.d.-a). Similarly, the general aviation aircraft fleet is forecast to grow by 0.1% over the same period in the U.S. Globally, the passenger and freighter aircraft fleet is set to more than double till 2038 (AIRBUS, 2019). During the same period passenger traffic will grow at almost 4.5% worldwide (International Civil Aviation Organization, 2021). Therefore, the number of wildlife strikes to aviation is also expected to grow over the next decades. A better understanding of wildlife strikes to aviation can assist in the development of more effective safety strategies to reduce the risk of wildlife strikes to aviation. Most importantly, it may assist in the sustainable growth of the U.S. and global aviation industries.

There are limitations to the current study. The ATADS did not provide information about aircraft operations at Florida Keys Marathon International and Eglin Air Force Base/Destin-Fort Walton Beach Airports. Moreover, the database also did not specify if local airport operations represent GA or commercial operations. Another limitation to this study is the quantity and especially quality of the reported wildlife strikes. According to Dolbeer (2015), recent analyses suggested that approximately 91% of wildlife strikes in 2013 involving commercial operators are reported while only 50% to 59% of strikes involving general aviation were reported from 2009-2013. Yet, previous studies (Anderson et al., 2015; Ball et al., 2021; Dolbeer & Barnes, 2017; Mendonca et al., 2017; Misra et al., 2021) have indicated that missing data and information in the NWSD (e.g., incomplete strike reports) as factors limiting their findings. In the current study, for example, almost 33% (n=2,901) of the reported strikes did not provide information about the time of the day the strike occurred. It is important to incorporate such data in the future if they become available. Yet, further studies are recommended to address the incompleteness of strikes reports. Researchers assumed that the reported wildlife strike data, although incomplete, was accurate. These limitations could bias the findings of this study. Nonetheless, the researchers consider that findings presented in this study can aid the development of strategies to reduce the risk of bird strikes to aviation at Part 139 airports in Florida.

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Appendix A: Number of Damaging Wildlife Strikes vs. Total Reported Wildlife Strikes

Year	Total Strikes Reported	Damaging Strikes Reported	Wildlife Strike Index	Damaging Wildlife Strike Index	Percentage of Damaging Strikes (%)
2011	611	49	18.47	1.48	8.02
2012	635	45	18.58	1.32	7.09
2013	692	45	19.98	1.30	6.50
2014	894	39	26.29	1.15	4.36
2015	823	40	23.48	1.14	4.86
2016	944	52	26.52	1.46	5.51
2017	1038	42	28.66	1.16	4.05
2018	1117	50	28.84	1.29	4.48
2019	1377	68	34.36	1.70	4.94
2020	831	27	28.39	0.92	3.25
Total	**8962**	**457**	**25.54**	**1.30**	**5.10**

Note. Part 139 airports in the state of Florida 2011-2020, each year represents a 4-season period.

Appendix B: Percentage of Total Reported Wildlife Strikes that Resulted in Damage

Year	Winter	Spring	Summer	Fall
2011	15.12	6.90	4.64	9.14
2012	11.28	7.69	5.24	5.92
2013	12.50	6.72	4.06	7.04
2014	6.72	5.85	2.18	4.78
2015	6.56	4.86	3.91	5.11
2016	2.96	5.75	3.37	9.32
2017	6.87	4.26	2.20	5.18
2018	11.19	3.36	4.09	2.70
2019	7.46	7.27	2.64	4.85
2020	5.91	2.91	1.00	4.15
Total	**8.15**	**5.55**	**3.18**	**5.65**

Note. Part 139 airports in the state of Florida 2011-2020.

Appendix C: Aircraft Components Struck per Seasons of the Year

Part Struck	Winter	Spring	Summer	Fall	**Total**
Radome	108	150	284	213	**755**
Windshield	125	191	334	267	**917**
Nose	139	178	350	281	**948**
Engine	81	108	123	136	**448**
Propeller	0	0	0	0	**0**
Wing or Rotor	169	155	217	181	**722**
Fuselage	110	139	237	200	**686**
Landing Gear	45	75	94	86	**300**
Tail	9	13	15	24	**61**
Lights	8	6	7	8	**29**
Other	336	346	769	553	**2004**
Unknown	401	542	1140	769	**2852**
Total	**1531**	**1903**	**3570**	**2718**	**9722**

Note. Part 139 airports in the state of Florida 2011-2020.

Appendix D: Aircraft Components Struck (Damaging & Non Damaging)

Part Struck	Damage	Non-Damaging	Total	Percentage of Damaging (%)	Percent of Non-Damaging (%)
Radome	758	10885	11823	6.4	92.1
Windshield	731	14510	15562	4.7	93.2
Nose	883	14246	15431	5.7	92.3
Engine	1704	7598	9595	17.8	79.2
Wing or Rotor	2531	13643	16562	15.3	82.4
Propeller	299	1510	1852	16.1	81.5
Fuselage	661	9973	10903	6.1	91.5
Landing Gear	598	4844	5601	10.7	86.5
Lights	354	218	577	61.4	37.8
Tail	433	816	1271	34.1	64.2
Other	894	12346	23120	3.9	53.4

Note. Part 139 airports in the state of Florida 2011-2020.

Appendix E: Wildlife Strikes per Phase of Flight

Phase of Flight	Winter	Spring	Summer	Fall	**Total**
Approach	447	549	721	806	**2523**
Arrival	4	3	19	10	**36**
Climb	167	197	288	274	**926**
Departure	27	21	89	54	**191**
Descent	5	3	8	40	**56**
Landing Roll	189	219	525	286	**1219**
Local	10	6	8	10	**34**
Parked	3	1	1	0	**5**
Take-off Run	133	200	533	241	**1107**
Taxi	3	7	8	12	**30**
Unknown	398	542	1133	762	**2835**

Note. Part 139 airports in the state of Florida 2011-2020.