Visualizations of Wildlife Strikes by Airplanes in the U.S.

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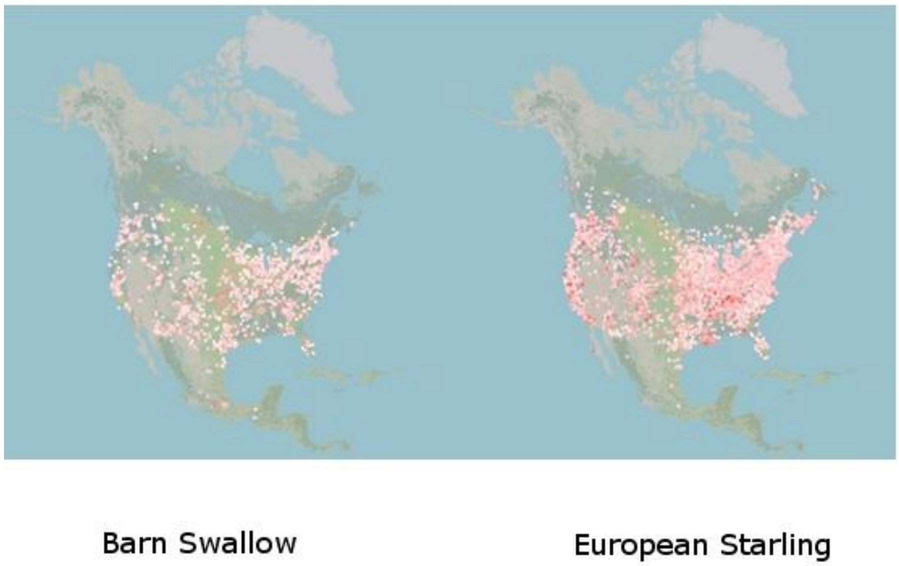

Fig.1. Migration/Habitat Region created using the ebird.org Migration Animation Application

Abstract— Wildlife strikes are the consequence of various factors. These factors include migration of species, weather, time-of-day, phase of flight and the region of the flight's route. However, some of the practical questions remain to be addressed with concrete observational data. For example, how exactly are various factors related and to what extent do they impact wildlife strikes on airplanes? In this project, we focus on the aforementioned factors and tried to ascertain levels of contribution for each factor. We found that the migration patterns of certain species, airport location and weather were among the main contributing factors. Additionally, time of day and phase of flight had significant effects on wildlife strikes. Our initial thought placed most of the incidents in states that were along the coast. However, we found that there is not much difference between coastal or inland States. Each of these factors is explored using visualizations in order to better understand why some areas are more affected than others.

INTRODUCTION

Over the past few years there has been increasing attention focused on the potential risks wildlife pose in aviation. While the civil and military communities recognize the threat of wildlife strikes, incidents such as the forced emergency landing of US Airways Flight 1549 in the Hudson River in 2009 have brought it into the public eye making us more aware of the potential dangers.

According to the FAA the threat of wildlife strikes is increasing. The number of annual strikes reported has increased from 1,793 in 1990 to 9,474 in 2009 [1].

The FAA attributes this increase to three primary reasons. The first is that there has been an increase in the populations of wildlife species commonly involved in strikes in the last few decades and they have adapted to living in urban environments, including airports. Second, air traffic has increased since 1980. Passenger enplanements in the USA increased from 1980 to 2009 at about a rate of 2.8 percent per year, and commercial air traffic increased at a rate of 1.2 percent per year (Federal Aviation Administration 2010). Third, commercial air carriers have replaced their older three- or four-engine aircraft fleets with more efficient and quieter, two-engine aircraft.

The Federal Aviation Administration (FAA) has had ongoing efforts and is involved in programs to improve the situation. One of its efforts includes developing a voluntary reporting system to collect wildlife strike related data. This data is available to the public in the FAA Wildlife Strike Database.

In 2009 the U.S. Department of Transportation's Federal Aviation Administration along with the U.S. Department of Agriculture's Animal and Plant Health Inspection Service Wildlife Services prepared a summary report of its findings using data from the FAA Wildlife Strike Database. The title of the report is *Wildlife Strikes to Civil Aircraft in the United States 1990 – 2009*.

The report concluded that although the threat poses an economic and safety risk to civil aviation, progress is being made in damaging strikes. Many airports have implemented management actions to mitigate these risks over the past decade and it credits these actions for the reduction in damaging strikes from 2000-2009. The report provides four recommended action items. First, while focus has been on airports the report advocates that the public must broaden its view on wildlife management and consider habitats. Second, further research and development of avian radar and bird migration forecasting and study of avian perception to enhance aircraft detection and wildlife strike avoidance. Third, federal regulations and guidance of wildlife hazards at airports should continue and revise as necessary. Finally, there is a need for increased and more detailed reporting of wildlife strikes [1].

While this report offered multiple tables of data and a few graphs, it is quite lacking in visualizations of the data contained in the FAA Wildlife Strike Database. In our paper we explore the data in the FAA Wildlife Strike Database and demonstrate how various information visualizations can be applied to the data to reveal patterns and facts which could help in understanding the data and in creating mitigation plans to avoid these safety risks. For instance, can the data reveal to us whether or not airports are doing all they can to minimize wildlife strikes? Can the use of visualizations reveal any problems that the FAA's analysis has not already revealed? What geographic region is the most problematic and why? Which species of birds are most problematic? Can visualizations answer this? Can they help us understand the role of weather and species migration in bird strikes? Could these lead to additional recommendations?

1 Our Approach

In order to properly analyze and answer our questions we downloaded the FAA Wildlife Strike Database. We combined the data in this database with tools to create visualizations we thought might reveal patterns and trends to help us answer our questions. We chose this approach instead of online queries as having the full database downloaded gave us much more flexibility in how the data was analyzed. This approach also allowed our analysis to have much more depth. The visualizations we created covered the following categories:

1. Bird strikes by State
2. Bird strikes by Weather and Region
3. Bird strikes by Species
4. Phase of Flight and Time of Day
5. Airports
6. Bird Migration and Traits

1.1 The Data

The FAA Wildlife Strike Database records strikes that are reported by those connected to flights. This includes pilots, flight attendants and other supporting airport representatives. This database has data from 1990 to the present. Data contained is voluntarily reported. There are currently over 132,000 records in this database, which contain 94 fields that can be queried on customized interest. The database can be queried online, however, we chose to download the entire database into Microsoft Access and connect it to chosen visualization tools.

Since the data reported is voluntary, we found that there were a large number of null and unknown values that skewed the query results. As such, we mitigated that by excluding nulls and unknowns as necessary. Overall, the database is quite informative and has an impressive dataset to use as our base information source for the stated problem.

1.2 The Tools

The main visualization tools chosen were Tableau and Many Eyes. Tableau provides superb visualizations and also performs basic analytics of data. According to their website, Tableau is designed to allow the user to work with difficult databases and spreadsheets thereby making them more usable [3]. This mission fit perfectly with the intended analysis of the large FAA Wildlife Strike Database making it the ideal primary tool.

Many Eyes is an IBM Research experiment which provides 21 different visualization types in six categories [4]. These range from relationship diagrams (such as network diagrams), to analyzing text (such as Word Cloud Generators), to world maps. While Many Eyes does not provide the high level of data integration of Tableau, it does allow advanced data customization through a data upload and creation process. The advantage of this tool is the increased options for visualization outputs far beyond those of Tableau.

Also used was the Migration Animation Application from www.ebird.org which allows the user to view and explore their bird location, habitat, and migration data. This java executable file provides low-level animation of migration patterns for almost 150 types of birds [2]. This tool is fairly limited in scope; however, it was deemed to be highly valuable for understanding basic bird migration and movement.

The final set resources and tools used were a variety of text based resources such as the www.ebird.org website, birdweb.org, and the Cornell Lab of Ornithology digital resources. These resources were used throughout the paper with the main usage being for specific bird species research. This can mainly be seen in the discussion about the Horned Lark in Colorado, as well as throughout the Migration & Traits section.

For all data analysis activities, we limited the searches for a 10-year period of 2002 through 2011. Additionally, except for where irrelevant all results excluded null and unknown values. Utilizing Tableau we connected directly to the Access database and generated a variety of visualizations using queries limited to our above criteria and topics. A similar process was followed with Many Eyes; however, we manually uploaded the data from the FAA Strike Database for the same 10-year period of 2002 through 2011.

This process was repeated in an iterative fashion as potential trends and issues were identified. Once the final issues were selected for review, the chosen visualizations topics were reviewed and expanded upon using external research methods. During this phase the ebird.org Migration Animation Application was used to generate map based visualizations to expand on the migration discussion below.

The overall methodology used was initially intended to be exploratory, followed by a more systematic review of the resulting data trends. Following the informal data visualization creation, the main issues were selected and reevaluated using more specific visualizations and research resources.

This approach allowed us to review the data prior to developing any clear expatiations of the information; however, based on general knowledge of bird habits and the airplane flight process there were some. Specifically, we had several informal ideas that there might be an increase in strikes during certain times of the day, year, or location. These expectations are discussed in further detail in the Discussion section below.

2 VISUALIZATIONS

The tools we chose provided various output options for the visualization displays. Visualizations captured included bar graphs, treemaps, bubble chart and a geographical representation of the strikes across the USA. Each visualization used in this report highlights a specific topic and also allows a deeper interaction with the information described in the database. We wanted to show various methods of displaying the wildlife strikes.

The topics of the subsections that follow were chosen in such a way that they would answer the questions we had that were discussed in the introduction. We started at the highest level in each area of interest and from there drilled down into more detailed analysis using visualizations. For example an initial assumption we had was that bird strikes would be higher in coastal regions. We started with States, and then drilled down to FAA Regions. The subsections are organized in such a way to answer the logical progression of questions that the visualizations attempt to answer.

The visualization types are expanded on in more detail in the sections that follow.

2.1 Bird Strikes by State

Using the Bubble Chart visualization tool available in Many Eyes we were able to very quickly identify the U.S. States with the most wildlife bird strikes. A query was run on the data from the FAA Wildlife Strike Database to cover the 10-year period of 2002 through 2011. Due to the skewing of results that occurred when nulls and unknowns were included, we chose to exclude null and unknown States and species. The data was then uploaded to Many Eyes and the visualization was created from the uploaded data set. In the Bubble Chart the size of the circles are in direct correlation with the number of incidents depicted in that circle. In Figure 6, Appendix A the size of the circle reflects the aggregate number of incidents and the color of the circle depicts the state in which the incident occurred. Using this visualization we were able to easily identify the top five States as follows:

1. Texas
2. California
3. Florida
4. New York
5. Colorado

While the first four states were not so surprising due to their coastal locations and size, the last one was a little more surprising and raised the question of ***why is Colorado amongst those with the highest bird strike rates?***

2.2 Bird Strikes by Weather and Region

According to the Bird Strike Committee USA, over 219 people have died because of wildlife strike related incidents. Aviation organizations are challenged to increase the safety of flights while also protecting wildlife that may traverse flight routes. Studying the data on weather can help in planning for such events.

Using Tableau to query the Federal Aviation Administration (FAA) Wildlife Strike Database, we were able to determine factors that caused some of the wildlife strikes. Weather was highlighted as a contributing factor. The database lists rain, fog, snow and a combination of these three climate conditions as precipitation values. These values can be aggregated over a specified timeframe and narrowed to specific areas with Tableau. Several of these types of queries were completed on the downloaded FAA database. From the queried data, we were able to view different types of precipitation and aggregate monthly and yearly time frames. We used the region category to further narrow the areas of concern. We utilized the FAA's current regional division method to isolate the queries. The FAA divides the regions as follows: Eastern (AEA), New England (ANE), Western Pacific (AWP), Central (ACE), Southern (ASO), South West (ASW), Northwest Mountain (ANM) and Great Lakes (AGL). Resulting queries show that the ASO region had the highest amount of incidents followed by AEA, AGL, AWP and ASW respectively. The aforementioned regions became our core areas to search for strikes that were connected to weather conditions. We then searched each region for the airport with the highest amount of strikes and the associated weather condition. We found that fog and rain were substantial factors on incidents. Additionally, we saw that the incident count was also high when the precipitation value was "none." It is unclear whether this value represents unreported weather condition at the time of the incident or if the weather was pleasant at the time of the incident. Figure 2 depicts the FAA regions and the incident count aggregated by year and Figure 7, Appendix A displays the filtered states from the associated regions.

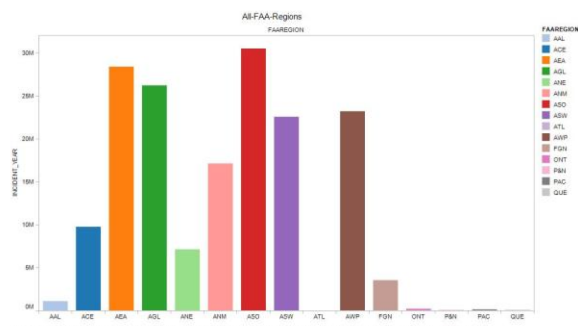

Fig.2. Tableau display of all FAA Regions. Colors differentiate the regions.

Of the listed regions, we used the three most problematic areas to further narrow the data to specific states and mapped specific airports. We found that Florida, California and Texas had the highest impacts. Airport data was then filtered on these states to identify which airports reported the most incidents. We found that Sacramento International in California, Pensacola Regional in Florida and Dallas Fort Worth International in Texas reported the most incidents in the associated regions. Figure 3 depicts the listed airports and the amount of incidents per month as well as the associated weather condition at the time of the reported incident. Additionally, the visualization shows that the Sacramento airport is directly impacted by fog and rain while Dallas Forth Worth and Pensacola are mostly affected by rain. We further noticed a spike in specific months for each area. Take note of November, December and January for the Sacramento airport and October, November and December for the Dallas and Pensacola airports.

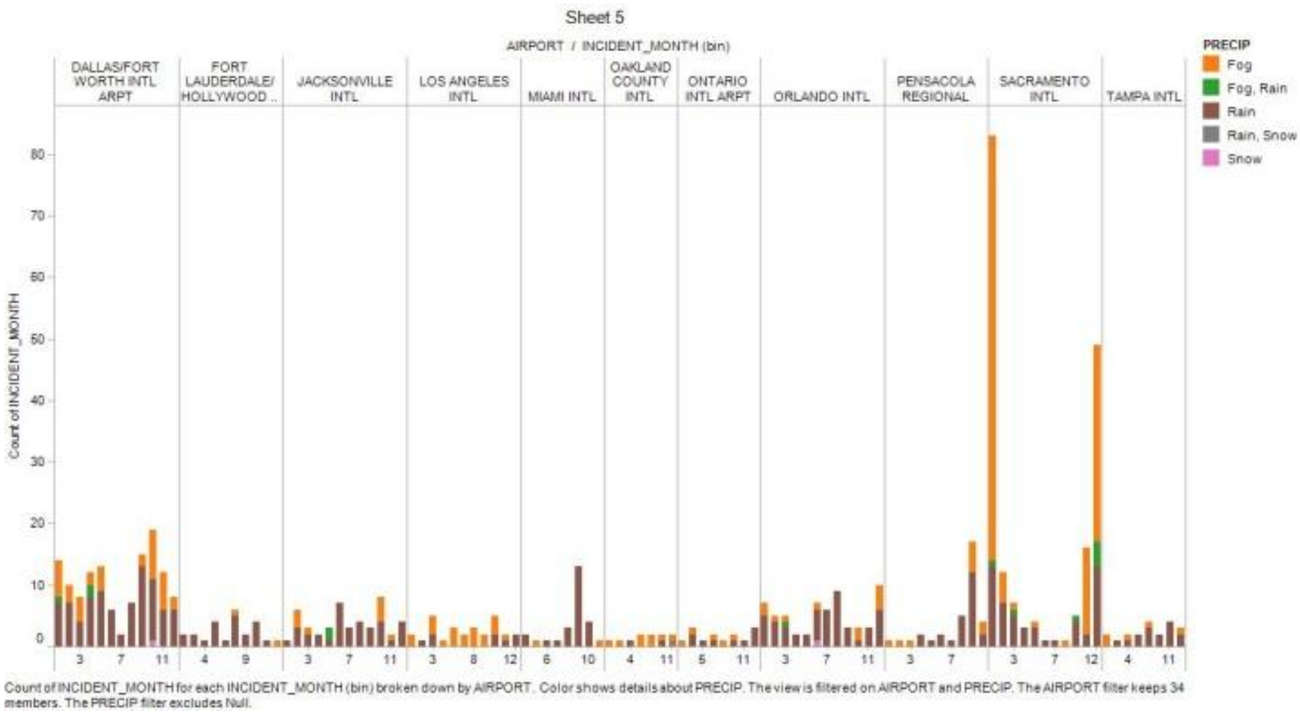

Fig.3.Tableau display of Precipitation by specific airports

2.3 Bird Strikes by Species

Using the Treemap visualization in Many Eyes we were able to identify the Top Species with the most incidents. A data set containing data from 2002 - 2011 on the Species by State and Phase of Flight was uploaded to Many Eyes and a treemap visualization was created. Unknown species were excluded so that those species that were known could be easily visualized. In Figure 4 you can very easily see that the top 8 species nationwide are Mourning Dove, Killdeer, American Kestrel, Gulls, Horned Lark, European Starling, Barn Swallow, Sparrows

In addition, the treemap offers a good deal of flexibility and allows the user to get a quick overview, zoom and filter, then obtain details-on-demand [6]. In doing that and applying the filters we were able to identify that the top three birds for each of the top 7 states were as follows:

1. Texas - Mourning Dove, Rock Pigeon, Killdeer
2. California - Rock Pigeons, Gulls, American Kestrel
3. Florida - Mourning Dove, Gulls, Killdeer
4. New York - Herring Gull, Gulls, European Starling
5. Colorado - Horned Lark, Mourning Dove, Western Meadow Lark
6. Ohio - Killdeer, Mourning Dove, Barn Swallow
7. Illinois - American Kestrel, Killdeer, Mourning Dove

An interesting observation in this visualization was that in Colorado there is an extremely high rate of bird strikes by the Horned Lark. ***This raised the question of, why is this number so high in Colorado?***

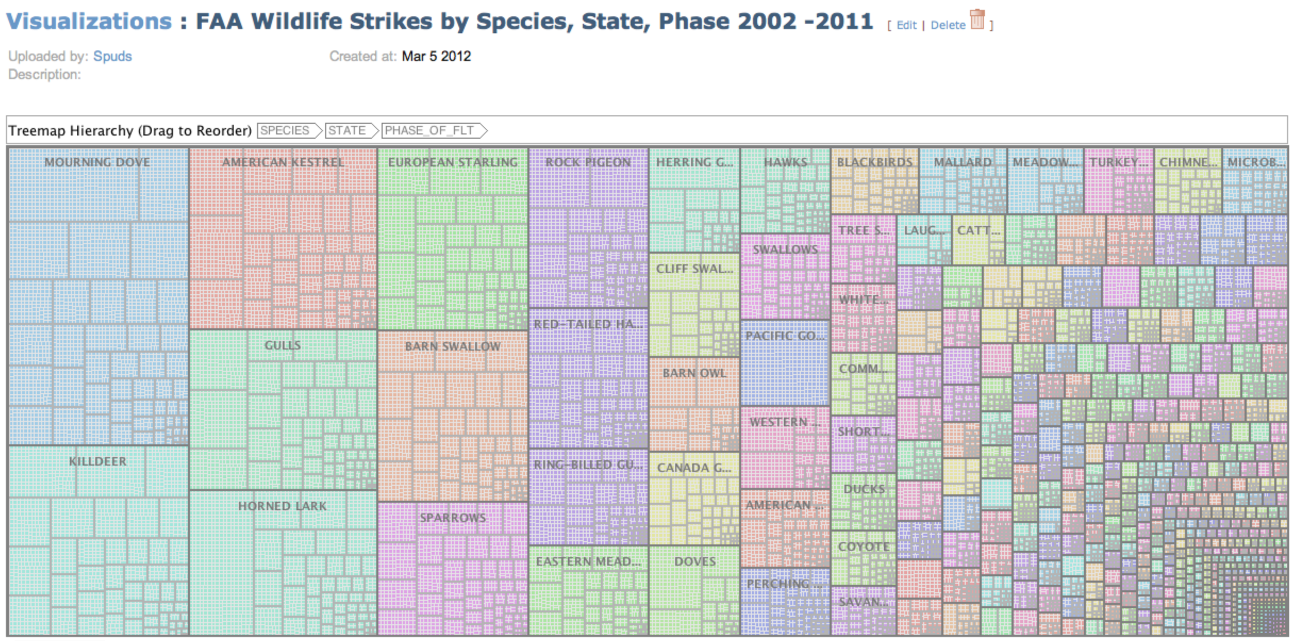

Fig.4. Treemap visualization using Many Eyes. Displays strikes by Species, State and Phase of Flight.

2.3.1 Horned Lark in Colorado

According to eBird, the Horned Lark is common to America's driest and most barren terrain. Additionally, they breed in wide open areas including beaches, deserts, vast agricultural fields, shortgrass prairies, arctic and alpine, tundra and airports [7]. The eBird site offers a helpful animated occurrence map of the horned lark which can be seen at http://ebird.org/content/ebird/about/occurrence-maps/horned-lark.

In order to further explore our finding of the high incidence of bird strikes in Colorado involving Horned Larks, we used Tableau to provide further analysis of the data. We first ran a query in Tableau to determine if most of the instances could be attributed to a particular airport. In Figure 8, Appendix A we can clearly see that Denver International Airport (DIA) had the most Horned Lark bird strike events, far exceeding any of the other Colorado airports.

According to the FAA's report over 70 percent of bird strikes happen at or below 500 feet [1]. These are usually near and around airports. Those bird strikes that happen at higher altitudes may be more closely associated with bird migration. In order to rule out if what was happening to Horned Larks in Colorado was related to bird migration we created a bar chart of the average height of the incidents involving Horned Larks at DIA. This resulted in an average of 28 feet confirming that it was associated with the airport. This result can be seen in Figure 10, Appendix A.

Lastly, we wanted to find out what other species had been reported out of DIA. In Tableau another Bar Chart was created to visualize this data. The results showed that while there were many other species reported out of DIA, the number of incidents involving the Horned Lark far exceeded any other species. The Horned Lark was reported 521 times for DIA followed by the Mourning Dove which was reported 219 times. This result can be seen in Figure 9, Appendix A.

Based on these findings it is clear the Denver International Airport has a real problem with Horned Larks. According to the FAA, federally obligated airports should be implementing mitigation plans to address this situation [1]. Some examples would include building a habitat area for the birds a certain number of miles away from the airport. We did not find any concrete evidence that any such activities were taking place at DIA.

Our analysis of the Horned Lark bird strikes in Colorado is an example of the insight that can be gained from good information visualizations.

2.4 Phase of Flight and Time of Day

In order to understand whether bird strike incidents are related to the wildlife around airports or bird migration, we used Tableau to visualize the phase of flight. As Figure 11, Appendix A clearly demonstrates, most bird strikes happen on Approach, followed by Take-off run and Landing Roll. This would indicate that most bird strikes happen around airports at a lower altitude. Interestingly, this visualization also shows that most incidents happen during the day and night. Dawn and dusk incidents are low. ***Which raises the question, from a bird strike perspective is it truly safer to fly during dawn or dusk, or are these numbers simply low due to a reduced number of flight availabilities during these times?*** While the data set does not allow us to answer this question, it would be important to research since this could be misleading if not properly interpreted. We must keep in mind that our data set only contains data from reported incidents. In order to answer this question we would need to look at data about the overall number of flights that take place at the various times of day. In reviewing the FAA databases publicly available none seem to contain the statistics we would need in order to draw a definitive conclusion on the safety of dawn and dusk.

2.5 Airports

Viewing the data, we initially thought that there was a connection between coastal areas and the impact of weather on incident occurrence. However, this theory was not supported by the data. Dallas is not on the coast and it had a significant amount of strikes in relation to the Forth Worth airport. We refocused on the species count at the specified airports and connected that data into the problem. We found that there are specific types of wildlife associated with these airports. Dallas appears to be directly impacted by the Mourning Dove while Pensacola and Sacramento are affected by Gulls. Figure 12, Appendix A depicts the species type, precipitation and associated airport at incident occurrence.

As shown by Figure 12, Appendix A precipitation and species type are related in that incidents occur during the seasons of increment weather and species migration. Using Tableau to create the displayed visualizations enabled us to find these connections and create new questions about the data. After the initial association between species, airports and weather we wanted to identify which species were affecting flight routes. Migration patterns and time of day were used to filter the data to consider this question.

2.6 Bird Migration and Traits

Using Tableau, the frequency of strikes for the Barn Swallow and the European Starling were considered by month. These two birds were selected from the previously identified top percentage of bird strike species. They were considered by month in order to analyze the data for any bird strike frequency trends by generating a Polygon visualization in Tableau for Month and Species. As seen in Figure 5, there was a strong increase beginning April-June for both species, peaking in July-August, and the decrease ending by October-November.

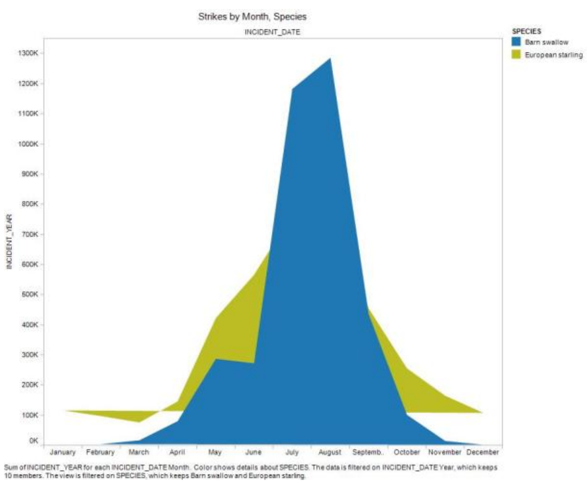

Fig.5. Strikes by month and species

2.6.1 Migration

We can see that the most frequent bird strikes occur during the spring/summer months, which indicates a potential connection with migration patterns. ***Specifically, are the bird strikes reaching these highs due to migrations happening during those months?***

According to Cornell University, "More than 650 species of birds nest in North America. Some are permanent residents and live in the same area year-round. The majority of the species, however, are migratory" [8]. Considering the two selected species we can see that both begin climbing during the spring season and peak during the summer season. ***Is this due to migration patterns or another habitat oriented reason?***

The Barn Swallow is a long distance migrating bird that flies from its North American breeding grounds to winter in Central and South America. The southbound migration begins in June in the southern regions and as late as July in the northern areas. Furthermore, the return route begins as early as January in the southwest and as late as May in the upper northern areas [9]. This is consistent with the data that indicates the high strike period begins by the end of the return to the breeding sites, and the lows begin towards the end of the breeding season as they leave. The Barn Swallow migration range can be viewed in Figure 1.

In contrast, the European Starling is only considered to be partially migratory with variances occurring by region and individual even birds. For example, many of the European Starlings are estimated to simply move into valleys or more urban areas during the winter rather than traveling [10]. As seen in Figure 1 they are considered to live year round in one general North American region.

2.6.2 Traits

In determining whether bird strike incidents are related to bird migration or birds in the vicinity of an airport it is import to consider the height at which bird strikes tend to take place. Using Tableau we created a scatterplot visualization of the maximum height by species and year which can be seen in Figure 13, Appendix A. As we can see the results are varied with most occurring at the lowest altitudes, but some also occurred at higher altitudes indicating a potential correlation with bird migration.

The results indicated that there was only a single Barn Swallow strike above the 10,000 while half of the European Starling strikes are above 12,000 feet. However, also of note are the feeding and lifestyle traits of the Barn Swallows and European Starlings. According to allaboutbirds.org, Barn Swallows generally feed while flying just above ground or water level at 100-10,000 feet. Additionally, they generally reside in areas that are wide open such as fields, parks, meadows, ponds, and along the coast. Nests are built upon structures such as inside or on buildings, bridges, barns, etc. Whereas the European Starling are most likely to be found living in a wide range of areas, including, lawns, fields, sidewalks, and parking lots. Furthermore, they tend to perch and live on very high areas such as wires, trees, and buildings. This is consistent with data that indicates that they feed around fields and other wide open areas in large flocks [11].

This information is generally consistent with the generated data. As a species, the European Starling is more often found flying at higher altitudes during daily activities and is only partially migratory. On the other hand, the Barn Swallow migrates great distances and generally stays below 10,000 feet. The data tells us that the Barn Swallow is much more likely to be struck during the migration season, whereas the European Starling is more like to be hit at higher altitudes. Both variables are consistent with the trend of higher altitude bird strikes. Consequently, we can hypothesize that bird strike frequencies are impacted by both migration and species traits.

3 DISCUSSIONS

The most surprising results we have found included the location of the most incidents, time of day for those incidents and the specific timeframes where incidents are in great numbers. For instance, the ASO [12] southern region has the most incidents and it covers Alabama, Florida, Georgia, South Carolina, and Puerto Rico. This presented new questions on climate and types of species that dwell in warmer areas. However, some species that we thought were linked to the southern region are in fact spread throughout the US.

Our project has confirmed our hypothesis that there is a correlation between weather and the migration time fame. The results created more questions than they solved. Questions such as, what are the specific, consistent months when incidents increase? How can we specifically relate these months to match known bird patterns? What is the ratio of impact between migration and feeding/flight habits? Knowing this type of data would help connect the dots for creating safer flight routes.

Many of the field values were null or unknown. Thus, we have to be cognizant that lack of data can skew results. The FAA database is a voluntary courtesy, and not all incidents are reported in their entirety. Mapping bird migrations to neighboring countries such as Canada and Puerto Rico is an additional scenario that may help identify more patterns in migration routes. Despite the null values we were still able to demonstrate that with the use of the proper information visualization tools we can easily identify problems that need to be addressed.

We would have liked to explore additional mandated reporting databases in order to compare results. However, we feel that our end results are indeed insightful as they provide direct visualizations of the data contained in that FAA Wildlife Strike Database. Querying the data online provides a terse view of what is actually represented and one would have great difficulty putting the pieces together without some form of visualized aide.

4 CONCLUSIONS

Deciphering all the factors that contribute to wildlife strikes is an ongoing topic of research. We have used the information provided in the FAA Wildlife Strike Database to visualize some of these factors in order to connect some of these elements together. We found that weather is indeed a factor but we also found information that may lead to further studies of the migration path of certain species of birds. The goal is to be able to share the air space and decrease the number of incidents that may be the result of lack of data or lack of understanding the current collected data. Independent access to other sanctioned wildlife databases may prove to be an asset and may lead aviation personnel on a better path to safety. Wildlife strikes cost loss of life and millions of dollars in damage to equipment. Being able to pinpoint the factors listed in this project can be a great catalyst to decreasing the number of wildlife strikes in aviation.

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Appendix A

Bird Strikes by State

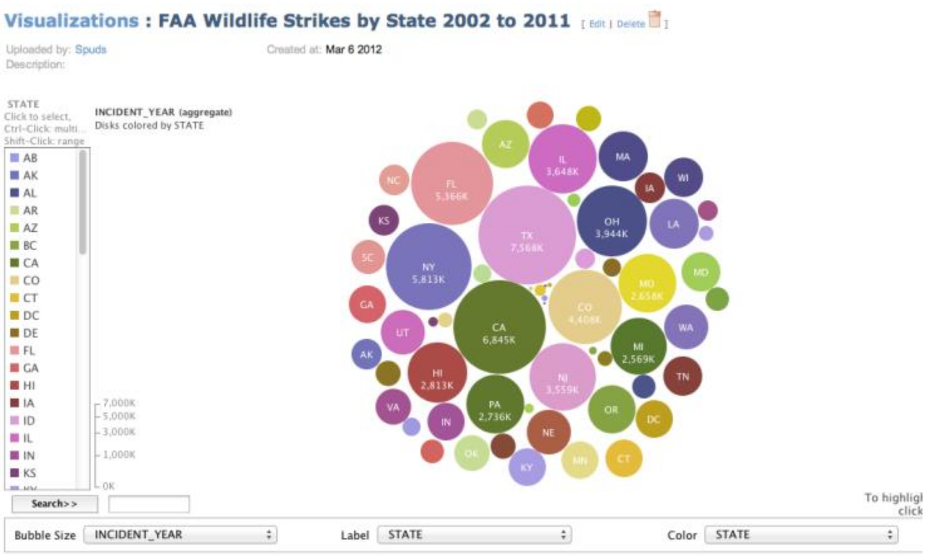


Fig.6. Bird Strikes by State using a Bubble Chart in Many Eyes. Null and unknown states and species excluded.

Bird Strikes by Weather and Region

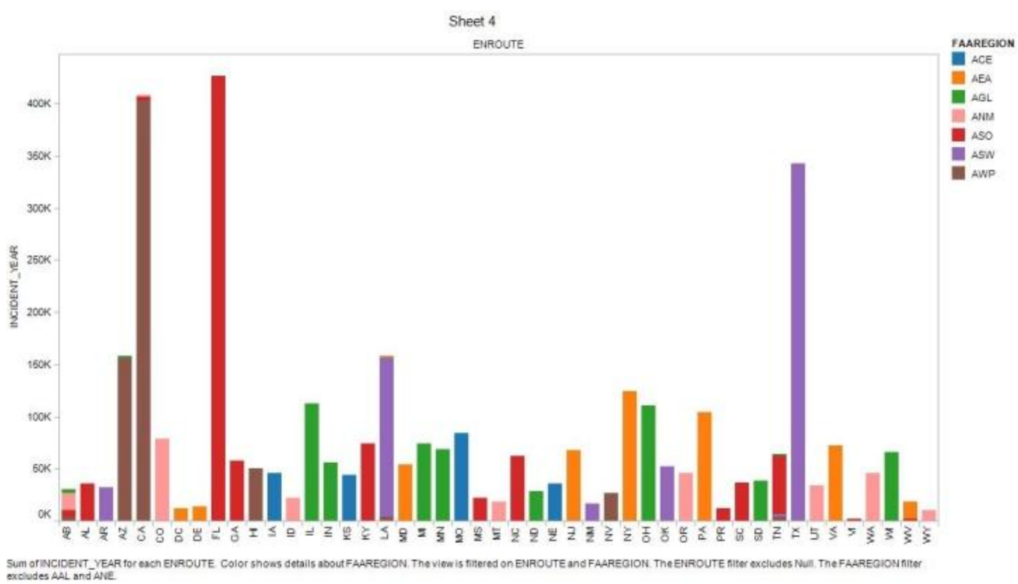
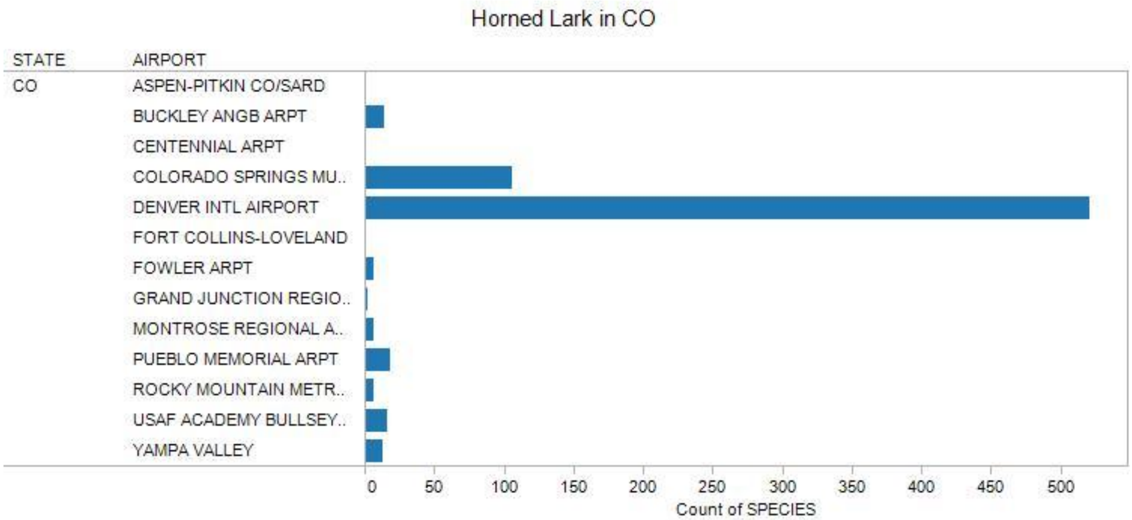


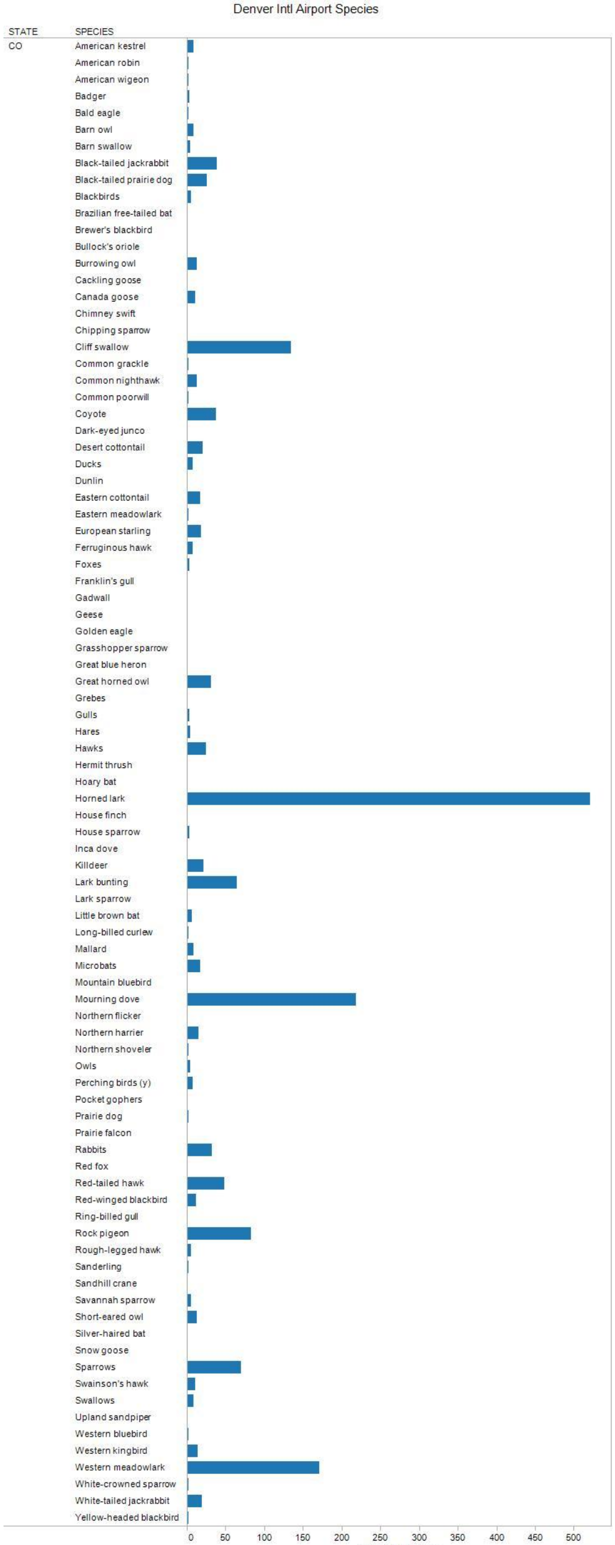
Fig.7. Tableau display of incidents by Region and State

Bird Strikes by Species – Horned Lark

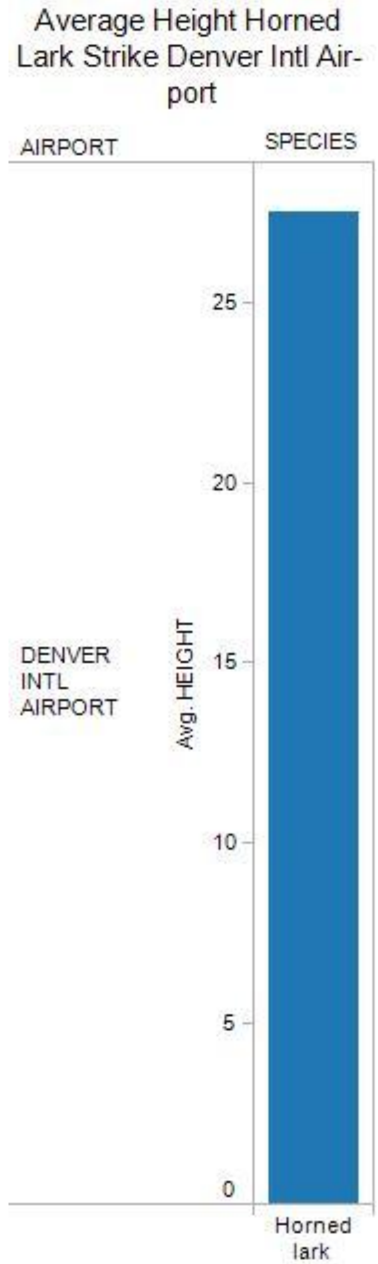


Count of SPECIES for each AIRPORT broken down by STATE. The data is filtered on SPECIES, which keeps Horned lark. The view is filtered on STATE, which keeps CO.

Fig.8. Tableau visualization of Horned Lark by Airport.



Count of AIRPORT for each SPECIES broken down by STATE. The data is filtered on AIRPORT, which keeps DENVER INTL AIRPORT. The view is filtered on STATE and SPECIES. The STATE filter keeps CO. The SPECIES filter has multiple members selected.



Average of HEIGHT for each SPECIES broken down by AIRPORT. The data is filtered on sum of HEIGHT and STATE. The sum of HEIGHT filter keeps all values. The STATE filter keeps CO. The view is filtered on SPECIES and AIRPORT. The SPECIES filter keeps Horned lark. The AIRPORT filter keeps DENVER INTL AIRPORT.

Fig.9. and Fig.10. Respectively, using Tableau we could visualize all of the species struck at DIA clearly showing that the Horned Lark was struck far more than any other species. We also viewed the height of the strikes.

Phase of Flight and Time of Day

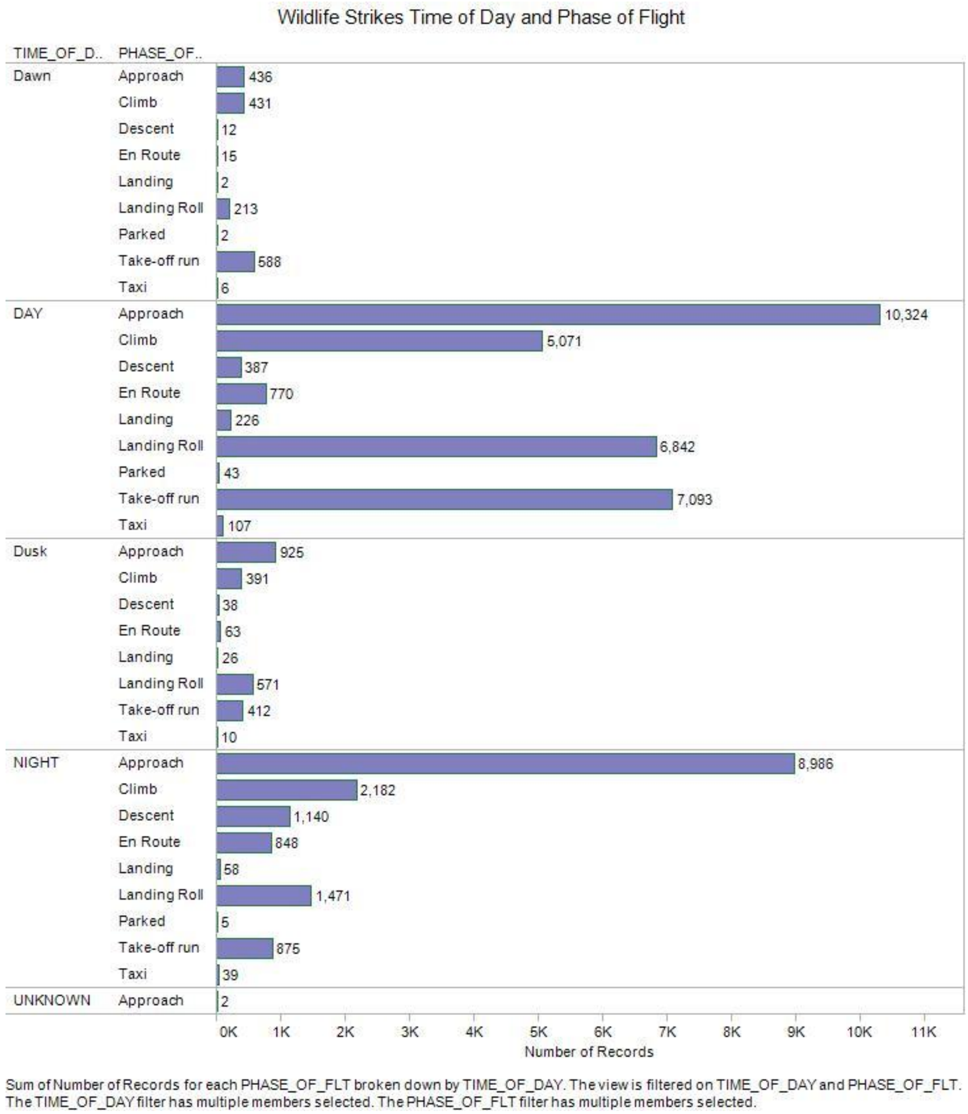


Fig.11. Tableau visualization of Time of Day and Phase of Flight. Using Tableau's quick filters, all nulls were excluded.

Airports

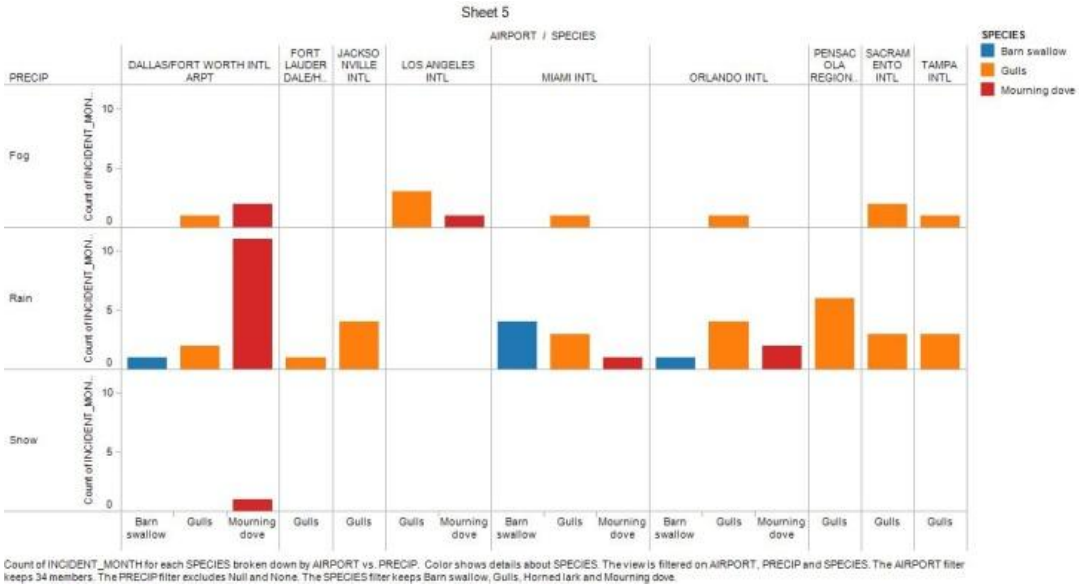


Fig.12. Tableau visualization of precipitation filtered by airport.

Bird Migration and Traits

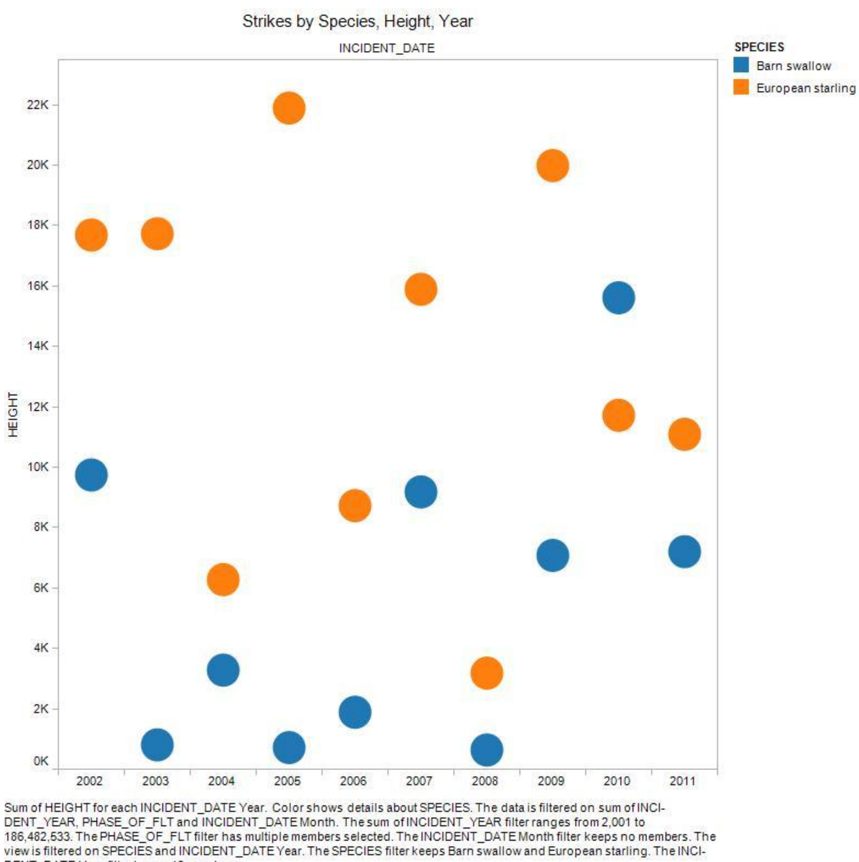


Fig.13. Tableau scatterplot visualization of height of strikes by species and year. Barn Swallow and European Starling are visualized here.

[1]