A Study of Climate Change and the Effect on Bird Biodiversity in the Midwest and Great Plains

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Abstract

Climate change is one of the most political current events that involve every being on Earth. Climate change is an accepted explanation by scientists to be the cause of many earth-alternating phenomena, and can be seen and tested over time by monitoring these phenomena. The temperature increase allows birds to migrate to the United States and an increase in insect populations allow them to survive in areas that the carrying capacity used to be lower. To test what is affecting the amount of species entering the Midwest and Great Plains the change in the variables of agricultural land, pesticide treated acres, natural habitat, and temperature from the 1960s and today was compared. No factor was shown to have a significant effect on the amount of bird species but that is because only 30% of the change was tested for. There were correlations between certain variables but nothing on how much that affects the species counts. There can be many research topics that come from this study based on climate change and birds.

Introduction

Urbanization

Natural resources have been depleted to support the growth and industrialization of people everywhere. One of the fastest and advanced urbanization processes is the mega country of the United States. Humans have the ability to chop down trees and build houses/buildings. Establishing life for humans involves destruction of other species habitats and continuing development has negatively impacted the few natural habitats that are left. It is predicted by 2050, 7 out of 10 people will live in urban settings (Climate Change). Urbanization is thought of as only building but it also includes any form of destruction of natural habitat to help support urban growth, which includes
producing food. Based on the World Bank’s 2011-2015 survey 44.3% of the land in the United States is used for agriculture (World Bank 2016). In many parts of the United States agriculture has become most of the land cover instead of the natural forests and wetlands that were once there. This has affected birds by destroying natural food sources and forcing them to adapt to whatever food is available. Feeders in residential areas are nice for a small amount of birds but most birds find food in agriculture. The increasing amount of agriculture fields provides food for birds during their migration.

Agriculture

Agriculture in the United States has seen dramatic growth in the last 50 years. The difference from 1950 to 2000 includes the average yield increased from 39 bushels per acre to 153 bushels per acre, and farmers averaged a 12% increase in overall productivity on a single farm from 1950 to 2000 (America’s Private Land 1997). Crop yield is predicted to continually increase with advancements in technology and crop care. Figure 1 shows predictions within the upcoming decades and what is predicted to increase the amount of yield.

**Figure 1**: shows predictions made by FarmingFirst.org, a website dedicated to the expansion of sustainable agricultural practices. The prediction is global but agriculture is a large part of the United States labor and economy.
With increased yields and productivity farmland is taking over native landscapes. Almost ⅔ of the lower 48 states are involved in farmland or ranching, with only 5% being protected as road-less wilderness, which is native habitat for birds (Imhoff 2004). Changing areas into farmland causes habitat destruction, fragmentation, displacement of native species, and introduction of invasive species, adaptation, and pollution to aquatic and terrestrial ecosystems.

**Pesticides**

One of the biggest inventions in agricultural history is the chemical pesticide. Pesticides were created to protect plants from a targeted pest. The first modern day pesticide was created in India in the 1950s and has helped launch the agriculture and the economy of the crowded country (Aktar 2015). One of the major benefits of the introduction of pesticides is found in developing countries that might not have the best quality of soil or growing conditions. In Indian, middle ground, they grow rice and puddles from rain showers invite weeds to grow and take nutrients from the crops (Aktar 2015). Pulling the weeds is a labor intense activity that pesticides have been able to put a stop to. In the United States pesticides are used to increase crop yield by protecting against insects and diseases. Banning the use of pesticides across commercial farms would put farmers and consumers in jeopardy. Farms rely on pesticides to produce crops that are grocery store ready and that the consumer wants to buy. The consumers want healthy products that are good for their families and refuse to buy diseased or misshapen product. Pest carry diseases like the Fusarium Wilt. The wilt affects cotton and makes leaves have an obvious droop, turn yellow in color, and eventually attack the whole vascular system of the plant killing it (Cotton-Fusarium Wilt 2006). Corn also has a plethora of diseases that affect yield and if eaten by a consumer could cause illness. The Head Smut Fungus attacks corn ears and tassels by replacing them with brown spores that have a stringy appearance (Corn-Head Smut 2008). These are just diseases that directly affect
the plant and are dangerous for human consumption, pesticides also include insecticides that kill insects that can carry diseases. With the benefits of pesticides there has been a lot of trial and error throughout agricultural history. Cornell entomologist, David Pimentel, tested that only 0.1% of pesticides reach pests, leaving 99.9% to affect the environment (Pesticides 2015). This high runoff rate can be due to many errors in application or dosage. Pesticide abuse can best be seen in the era of DDT. DDT was a popular choice amongst farmers because of how effective it was and how cheap it was. The heavy use of DDT proved dangerous and fatal as made famous by Rachel Carson’s Silent Spring. While some pesticides have been banned many have not and are still being commercially used the same way DDT was.

Pesticides also have a major impact on the economy. In 2007 877 million pounds of pesticides were applied to cropland in the United States, and that cost around $7.9 million (Osteen 2012). This is a multi-million dollar business that affects almost every American and still has a bad reputation because of its history and the lack of knowledge of what is actually being applied to food.

Climate Change

Anthropogenic climate change has been on the social agenda since the 1980s and has more recently become a culturally hot topic in developed countries. There is a minority of people who do not believe in anthropogenic climate change and most people acknowledge it and want to figure solutions to reverse the damage. The problem with communicating climate change is educating the public of what the truth is and not supporting propaganda denying the effects of climate change. Unfortunately 95% of what the media report about is quoted from politicians or other media sources and not from scientific research or expert advice (Greenfield 2013). This means that what is presented to the public can be skewed by political bias or other unsupported evidence. It is difficult for people to grasp the idea of earth-wide change because the causes are invisible and the impacts are spread out over time. The public likes to live in the
now and not think about the externalities of their actions and how they affect the environment.

The scale of change is not limited to small or large but instead location. There are large-scale events that involve many people, glaciers melting, ocean temperatures warming, sea levels rising but many changes happen on much smaller scales. As climate temperatures rise warmer lake temperatures are affecting the Great Lakes. The warming water can be linked to the growth of blue-green algae that changes the ecosystem for microorganisms (Pryor et.al. 2014). Blue-green algae, or cyanobacteria, are known to deplete oxygen in a body of water, produce toxins, and reduce light penetration which all effects the food chain in the lakes (Pryor et.al. 2014).

Seasons are also affected by climate change in temperate climates seasons are warmer longer and hotter than ever before (Weiss et.al. 2009). This increase in warmth welcomes longer periods of migration for birds. Birds are able to migrate at a slower rate and more birds do not have to travel as far south to survive winter. With this change come problems with urbanization, food sources, native species and habitats, and introducing the side effects of pesticide use to their diets.

Growing seasons have been increasing because of warming temperatures. The EPA states that a growing season is the period between the last frost of spring and the first frost of fall (Climate Change Indicators in The United States 2015). Each plant has a slightly different growing season based on location and type of plant. Some plants naturally take longer to grow than others, but the EPA has come out with an average that accounts for all plants.
Figure 2: is labeled as figure one from a different report, but is referred as figure 2 in this paper and shows the difference in length of the growing season in the contiguous 48 states compared with a long-term average. For each year, the line represents the number of days shorter or longer than average. The line was smoothed using an 11-year moving average. Choosing a different long-term average for comparison would not change the shape of the data over time (EPA 2015).

Figure 2 shows that the current growing season is around 10 days longer than the long-term average. Extra days can have an enormous effect on the delicate balance of life in the agricultural ecosystem.

Changes Effecting Birds

Climate change affects bird food sources and pesticide use by increasing the insect population in agricultural land. The insects and pathogen insects that live off cropland have increased their lifecycles producing more generations during a season (Petzoldt, Seaman). Insects are cold-blooded organisms, whose body temperature is based on the environment they live in. The United States is a temperate climate that is seeing temperature increases yearly between seasons. This increase is allowing insects to live longer and reproduce more. During a regular growing season females produce on average 200 offspring a week, the increased growing season allows insects to be present for more weeks in a year (Pimentel 1993). The insect population affects bird biodiversity in two
ways; one being increase in food supply and two an increase in pesticide use. As mentioned before bird’s diets usually consist of insects, or plants they can find during migration (farmland crops). Birds migrate to find food and survive during cooler months; food is now becoming available sooner along migration routes, which results in changes and redirection of routes (Moore 2011). There are three migration flyway zones in the United States; starting in the west they go Pacific, Central, Mississippi, and Atlantic across the country (Figure 3). Each Flyway has different species migrating along it. Birds are stopping migration routes in the U.S. because of the temperature increase making climates warmer and increasing food availability.

The increase of insects also means the increase of pesticides. Scientists hypothesized that insects will increase their geographic range, which means farmers, will have more and different pests to manage (Petzoldt, Seaman). The application of insecticide will become a greater expense to the farmer and in returns affects the consumers of plants by ingesting more chemicals and paying more for the crops. This will continue the amount of money being put into pesticides market and doing nothing for the education of the people.

Specialists become a problem as more birds try to survive in one area. Birds that are good at adapting to humans are going to be able to adjust faster than birds that are more distant to humans and only eat certain foods. In a study comparing doves with other birds in competitive habitats where there was plenty of food sources available, found that birds such as the rock pigeon and house sparrow were able to find food faster than doves and other passive birds (Bonter et.al. 2010.) The collared doves were not aggressive enough to eat before the more aggressive species. In a site that there is not enough food this means that

![North American Migration Flyways](image)
the doves would suffer loss, but they did not because of the excess of food available. This study supports that human development has increased the resources available for migratory birds. Birds who are aggressive and will eat anything are able to move in fast, while other birds take more time but still survive due to the increase of food. Native birds like the collared dove have to adapt their niche to incoming birds that are surviving off the same food (Bonter et al. 2010).

Through this study I would like to answer the question are there more birds migrating through the United States than in decades past? What can be affecting their migration in the U.S.? I predict that change in agricultural land and temperature average will have the largest impact on the amount of bird species found during migration.

**Methods**

**Data Collection**

States have been selected out of the Midwest and Great Plains. The states are Ohio, Illinois, Indiana, Wisconsin, Kansas, Nebraska, North Dakota, South Dakota, Iowa, and Missouri. Every data set produced data from the years 1964 and 2012. Change between each of the years was calculated and the change was used for statistical analysis.

Temperature data came from the U.S. Climate database. This data is the average of every year based on everyday during a year.

The USDA produces a census of agriculture every 4 years, that collects data related to farming in the states. This census is county based for every state and gives out information such as net income, irrigation, livestock, crops, and machinery and equipment (USDA Census). This dataset gave information for both amount of acres of agricultural land and amount of acres treated with
pesticides totally in the state. All types of farms were grouped into one category and all types of pesticides are also grouped into one count of how many acres.

The USDA/ ERS (economic research service) produced land cover data for every state. Using the forest use data it is possible to calculate how much natural habitat is left for bird species to share. This census dates back until 1945 and records acres of forest area in each state. The study includes all acres of city, state, and national parks, as well as unincorporated forests. The most recent data available for this dataset was 2007; this year will take the place of 2012. All forest types are totaled and lumped together to create one type of land cover.

The United States Geologic Survey conducts the North American Bird Breeding Survey every year since 1966. The survey was started after the concern of super chemicals like DDT was having a negative impact on wildlife. Trained avian identifiers collected data along roadside survey routes. Each route was 24.5 miles long, the surveyor stopped every .5 miles for three minutes. At each stop all birds seen or heard were recorded for a .25-mile radius. The survey would start around 90 minutes after local sunrise and took 5 hours to complete. There are around 4100 routes nationwide. For this study the summary of each state will be used versus every route. Also for this study the names of all the species migrating is not completely revealed due to the nature of this study is to examine biodiversity not specific species. Non-breeding birds are described as migrating to breeding grounds instead of non-migrating birds that breed where they live year round.

Mapping

ArcMap 10.3 was used to create images showing the difference in between the years 1964 and 2012. The variables used for the maps are species change and pesticide treated acres change. The data was normalized by square foot so larger states would not show a larger change just because they are bigger.
Statistics

To test which of the variables is having the most significant effect on the number of species found in each state a multiple regression was run. A multiple regression will produce results on what is affecting the dependent variable. Change in species diversity was set to be the dependent variable and the change in agricultural acres, pesticide treated acres, forest acres, and temperatures were independent variables. Separate t-tests were also done to see if there was any correlation between individual variables and not weighted by their effect on species diversity.

Results

Data Collection

The data collected shows many differences between all years collected in every variable collected. Looking at bird species counts (figure 4) there has been an increase in every state from 1964 to 2012. Unfortunately not all states analyzed had data from 1964, so for more accurate results 1982 was included. Every state except Iowa and Nebraska had an increase in species counts, and the difference is very small. The states with the largest increase across all years are Illinois, Wisconsin, and South Dakota. Choosing to look at Wisconsin close up in figure 4, we can see that there is over a 20 species increase from 1982 to 2012 and a total increase of over 40 species increase from 1964 to 2012.
Temperature has been proven to be warming from previous studies but to show that it is happening in all climates the average temperature line from 1950 to 2015 is shown in figure 5. While there are no 10-degree changes yet it is apparent that there is a gradual increase.

The change in pesticide acres is what is important to this study. The graph in figure 6 shows that every state had increases from 1964 to 2012 in amount of acres treated with pesticides. In 1982 was included in this graph to keep consistency with the bird species graph. Even from 1982 some states had a significant increase in amount of acres. Many states had a significant increase in acres treat but the state with the biggest change is Iowa.

**Figure 4:** Represents all 10 states in the study and the amount of species recorded during the USGS North American Bird Breeding Survey from the years 1964, 1982, and 2012. The second graph shows Wisconsin records as a clearer visual of the separate years.

**Figure 5:** Presents data provided by the U.S. Climate dataset. The temperature is presented in degrees Fahrenheit from 1950 to 2015.
Statistics

The multiple regression ran provided many usefully values. Looking at table 1 shows the beta values that are the standardized b values, which determine the t-value when trying to graph a regression. The t-value tells how significant something is based on its distance from zero, and those results are turned into more readable significant p-values. The p-values resulted in none of the tested variables of change significantly impacting the change in bird species recorded. What is useful from the multiple regression is the R^2 value. This value tells how much of the change outcome comes from the variables tested. The R^2 value is .297, so only 30% of the change in species counts comes from the four variables. That leaves 70% of change to come from an untested variable.

**Table 1:** Results from the multiple regression providing the Beta, t, and significant p-values of the variables tested. The R^2 value is also given. Constant represents would is significant if there was no change

<table>
<thead>
<tr>
<th></th>
<th>R^2 = .297</th>
<th>Beta</th>
<th>t</th>
<th>Sig.</th>
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<td>.620</td>
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<td>.686</td>
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<td>.913</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>-.088</td>
<td>-.229</td>
<td>.828</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 6:** Presents data from the USGS Agricultural Survey on how many acres per state were treated with all types of pesticides. Years represented are 1964, 1982, and 2012.
To test if there were any correlations between individual variables separate t-tests were run (table 2). The tests show that there is a correlation between Δ in species and Δ in forest acres, Δ in species and Δ in agricultural acres, Δ in agricultural acres and Δ in forest acres. The strongest correlation is between the change in agricultural acres and the change in forest acres with a p-value of .000. The weakest correlation is between change in temperature and change in amount of pesticide treated acres, having a p-value of .452.

**Table 2:** Provides the t-test correlations, this is not weighting the variables instead saying the changes between the two variables are correlated some how.

<table>
<thead>
<tr>
<th></th>
<th>Species</th>
<th>Forest</th>
<th>Pesticide</th>
<th>Agriculture</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
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<td>.071</td>
<td>.266</td>
<td>.071</td>
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<tr>
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<td>.434</td>
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<td>Pesticide</td>
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<td>Temperature</td>
<td>.305</td>
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<td>.452</td>
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</table>

**Discussion**

**Data Findings**

Increases in species counts from 1964 to 2012 are hard to analyze because not all states had data for 1964. To make the data more accurate the year 1982 was be included to show change from a shorter period of time. Using the state of Wisconsin as a closer up example shows that the gradual raising the bar pattern and how drastic the change is. Showing Wisconsin’s temperature average proves that even in bitter Wisconsin the surface temperature is slowly
increasing, this counters what politicians or the media might broadcast. When confusing statements are said about how is it getting warmer but we still have a lot of snow in the winters portrays a misunderstanding of climate and surface temperatures, there can be more severe weather but does not account for overall surface temperature (Denchak 2016). Temperature is an average and the extremes do not affect the average over the whole year. Figure 6 shows that the amount of acres treated with pesticides are dramatically increasing. This is the basis for the entire study, pesticides are increasing and becoming part of the diet of more bird species migrating and living in the United States. Testing what variable had the greatest impact in the amount of species surviving was the goal and the statistics to figure it out was done.

**Change is happening**

No variables tested were statistically significant in the change of species found in each state between 1964 and 2012. From Figure 4 we saw that species are increasing and from figure 7 a visual representation of the change just from 1982-2012 in shown in shades of green. Both of these figures show that almost every state has had an increase in species found during migration. The most important calculation provided is the $R^2$ value. The value is .297 and that can be converted into a percentage of how much the variables tested effected the change in species. The four variables only had a 30% effect on the change in species counts. This leaves 70% of the outcome to be affected by an untested variable. Having such a low percentage from the results can explain the low significance, and raises more questions than answers.
While the regression (Table 1) did not show what is affecting the species, there can be connections made from the separate t-tests. The tests show that there is a correlation between $\Delta$ in species and $\Delta$ in forest acres, $\Delta$ in species and $\Delta$ in agricultural acres, $\Delta$ in agricultural acres and $\Delta$ in forest acres. The most important correlation is between $\Delta$ in species and $\Delta$ in agricultural acres. The correlation here is saying that as agriculture land is increasing so is the amount of bird species. It does not state that the agricultural change is having any effect on the birds but that they are both increasing together. While this cannot support this study it does prove that the change in agricultural land affects other factors in the ecosystem, possibly like species richness.

Stepping back and looking at the figures once more it is obvious that more species are being introduced into the states tested and other areas of the United States. This means that there are more birds looking from survival then travelling through migration. Due to increased food sources from insects and longer

**Figure 7:** the product of ArcMap showing the visual difference in the data between the years tested. The data is normalized by square foot to take any size comparison away.
growing seasons from increasing surface temperatures, birds are extending their stay (Moore 2011). The problem is not the there are more birds it is that the birds diet has had to adapt to agricultural food, insects and seeds. Looking at Figure 6 it is easy to see that there has been a dramatic increase in amount of pesticides used between 1964-2012. The biggest increase in change is in most of the states from the study but almost every state has had an increase. This means farmers are turning to chemicals to treat their crops, instead of other natural methods that are more labor intensive and expensive. While pesticides are easier on the farmer, they have dangerous health effects when ingested. Birds are increasing the amounts of pesticide in their diets, which has been proven to cause harm to them. For example a study done on raptors showed that due to a high-chemical diet eggshells became thinner and would be crushed under the weight of the nester, as well as shorter life spans and lower birth rates were observed (Bendraz et. al.1989). The introduction of increasing pesticides can cause major harm to individual bird species' populations.

While it is shown that there are more bird species that does not necessarily mean there are more birds. More species are being introduced to the dangers of pesticides and the effect can be fatal. So individually species might be suffering from decreasing populations because they are not adept to digest chemicals. The point of this study to look at birds as an indicator for change, and show what could be building up to effect humans over a longer period of time. Birds reproduce and respond to their environment faster than humans. Looking at what is happening to the birds can be used to predict what could be happening to humans who are eating out of the same agricultural fields. Humans today are consuming the highest amounts of pesticides than ever before, and it does not matter if it is organic or commercial (US Center of Disease and Prevention 2009). Human studies take a long time but if we use what is happening to other species, like birds, we can predict what is helping us, but more importantly what is hurting us.
Climate change is the overarching theme of this study because of how it changes the environment. Climate is changing and how the United States chooses to deal with it is to continually decrease natural habitats and increase pesticide use which can have negative effects on the surrounding life, birds or humans. How people react to climate change needs to change, it needs to be looked at in a serious manner before major loss to ecosystems takes place. This is also not a problem that is going away. Temperature is predicted to continue warming from 2.5° to 10° over the next century (Projections of Future Change in Climate 2007). In figure 8 there are multiple scenarios that are shown based on the speed of warming. All predicted outcomes are increasing over the next century. Due to the lack of knowledge about climate change the general public does not know the effect of their habits on the environment. People feel that they do not need to change their ways because they do not notice the changes in their backyard but if a surface temperature were to reach 10° that would cause many changes. Natural disasters would increase from more severe weather and health would decrease due to dirtier air. Also animal extinctions take place due to the hotter temperature and higher sea levels (Denchak 2016). Growing seasons will also continually get longer as there are less frost days. That will continue to support more species adventuring into the country.

This is a precursor study saying that change is happening, and can spur more research. One of the next steps could be to add more variables to the multiple regression. Some future variables should be change in insect population

![Graph showing temperature increase over the next century with various scenarios.](image.png)

**Figure 8**: shows the predicted ranges of temperature increase over the next century. Each color is a different scenario that the IPCC made up. The takeaway is that all lines are increasing.
(food source), change in impermeable surface (cities and towns), and any other change in climate data that is available. The results showed that only 30% of the change was represented in the four variables tested, leaving 70% open to other unknown variables. Another step could be to study the whole country. This study only looked at a small area but data from the entire country could provide new insight because every state has different crops and different birds migrating over. I focused on the Mississippi Flyway; there are three more that have different birds who could be affected by different factors. What this study is useful for is the study of individual species and how they are affected by all these changes. With individually studies it is possible to draw conclusions on the health of the species, especially if they have are new to migrating or living in the U.S. This study is proving that there is a change but not successfully figuring out why.

**Conclusion**

This is a long-term study of how the Midwest and Great Plains are trying to keep up with changing habitats and how that is affecting birds and in return how it could affect humans. While data mining for the numbers it is easy to get lost in the fact that millions of miles are being used for agriculture, which use to be natural forests and habitats. Anthropogenic climate change is not broadcasted to make the public care, but if things do not change soon there is a looming threat of extinction of many species and ecosystems that the people of today take for granted.
Works Cited


