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Association Between June Very Warm Conditions and Annual Abundance of American Robin, Tree Swallow, Barn Swallow, and Mourning Dove, 1980-2019

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Abstract. Unusually warm conditions may influence breeding-season bird populations, but responses can vary among species. This study examined whether the percentage of the contiguous United States classified by the National Oceanic and Atmospheric Administration as "Very Warm" in June was associated with annual abundance indices for the American Robin, Tree Swallow, Barn Swallow, and Mourning Dove from 1980 to 2019. June temperature data were paired by year with model-based annual abundance indices from the North American Breeding Bird Survey. For each species, Pearson correlation and simple linear regression were used to evaluate the direction and strength of the association. The American Robin showed a weak positive correlation ($r = 0.232$, $R^2 = 0.054$, $p = 0.150$), whereas the Tree Swallow showed virtually no linear relationship ($r = -0.051$, $R^2 = 0.003$, $p = 0.753$). The Mourning Dove showed a weak negative, non-significant association ($r = -0.281$, $R^2 = 0.079$, $p = 0.079$). The Barn Swallow had the strongest negative relationship and was the only species with a statistically significant result ($r = -0.356$, $R^2 = 0.127$, $p = 0.024$). The findings indicate that broad-scale unusually warm June conditions were not associated with a uniform abundance response across the four species. The modest explanatory power of the models also suggests that habitat, precipitation, food availability, migration, and other ecological factors should be considered in future analyses.

Keywords: Climate change, Bird abundance, Extreme temperature, Breeding Bird Survey, Pearson correlation

1. Introduction

Climate change is raising average temperatures and making extreme heat events more frequent and more intense. Extreme heat events are increasing of concern in North America and many researchers expect heatwaves to become more frequent, longer and more extreme as temperatures continue to rise [1]. These changes may have significant ecological consequences, as animals need to adapt to both gradual warming and episodes of extreme heat.

Birds can regulate their body temperature. But heat in the environment still makes them very weak and at risk. High temperatures during the breeding season can make heat stress worse and cause more water loss. They can also change how much food is available. They can change the

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conditions that eggs and young birds face. Also, bird populations in North America have changed a lot over the long term. Rosenberg et al. estimated that nearly three billion birds disappeared from North America between 1970 and 2017. Many species that used to be common also declined [2]. These big changes show why we need to know if climate conditions are linked to changes in bird populations.

Earlier research suggests that temperature can affect bird populations in several ways. Koenig and Liebhold found that population changes in many common North American bird species became more alike across different areas over time. Maximum air temperature also became more alike [3]. This pattern suggests that large-scale temperature conditions may play a part in population changes across large areas. But abundance changes do not go in the same direction for every species. This shows that birds can respond in different ways to the same broad climate changes.

Temperature can also affect birds by changing when and where they breed. Neate-Clegg et al. found that North American landbirds changed their breeding latitude, elevation, and breeding timing when temperatures changed [4]. The size of these changes was different among species. Changes in breeding timing were often larger than changes in latitude or elevation. These differences show that similar temperature changes do not always cause the same biological response in different species.

The effects of unusually high temperatures may be most important during reproduction. Taff and Shipley looked at more than 300,000 breeding records from 24 North American bird species. They found that heatwave exposure was linked to lower relative breeding success in several species [5]. Work on single species gives more evidence for body-level effects. In Tree Swallows, more frequent extreme heat during early breeding was linked to lower hemoglobin and hematocrit levels in young birds. This suggests poorer body condition [6]. So high temperatures may affect birds directly through body stress. They may also affect birds indirectly through breeding conditions and food availability.

Previous research has looked at changes in bird distributions, breeding timing, reproductive success, and body responses. But fewer studies have compared long-term abundance patterns across many common species using the same large-scale measure of unusually warm conditions. This gap is important. Differences in feeding ecology, breeding behavior, migration, and heat tolerance may cause responses that differ by species even when climate exposure is similar.

Recent studies across the continent support the importance of responses that differ by species to warming. Viana and Chase reported a growing disconnect between bird abundance or distribution patterns and changing climate across North America [7]. Youngflesh et al. found broad body-shape changes linked to temperature in North American landbirds. They also found big differences among species [8]. Martins et al. found northward shifts in the best latitude for abundance for many North American bird species. They showed that the size of change differed with heat-related and ecological traits [9]. These findings suggest that temperature is an important ecological driver. But it does not produce the same response in every species.

This study focuses on four common breeding birds: the American Robin (Turdus migratorius), Tree Swallow (Tachycineta bicolor), Barn Swallow (Hirundo rustica), and Mourning Dove (Zenaida macroura). We used yearly abundance measures from 1980 to 2019. These came from the North American Breeding Bird Survey and its model-based analysis results [10, 11]. For June temperature conditions, we used the percentage of the contiguous United States that the National Oceanic and Atmospheric Administration classified as "Very Warm." This label means that temperature conditions adjusted to a common scale fell within the highest 10% of their historical range [12]. The goal was to find out if unusually warm June conditions were linked to similar or different yearly abundance patterns among the four species.

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2. Methods

2.1. Data sources

This study used secondary data from the North American Breeding Bird Survey (BBS) and the National Oceanic and Atmospheric Administration (NOAA) U.S. Percentage Areas dataset. The BBS monitors breeding bird populations across the United States and Canada using standardized roadside survey routes. In recent decades, approximately 3,000 routes have been surveyed annually, providing a large long-term dataset for monitoring North American bird populations [10].

Raw counts from individual survey routes were not used directly. Bird abundance was obtained from the BBS Core Annual Indices, which provide model-based annual estimates derived from the original survey observations. The analysis dataset includes annual abundance indices and population-change estimates for hundreds of North American bird species [11].

The selected species were the American Robin (Turdus migratorius), Tree Swallow (Tachycineta bicolor), Barn Swallow (Hirundo rustica), and Mourning Dove (Zenaida macroura). These species were selected because they are common within the BBS Core survey area, have complete annual abundance indices for the study period, and represent different ecological characteristics. The study period was restricted to 1980-2019, providing 40 annual observations for each species.

Temperature data were obtained from NOAA National Centers for Environmental Information. The U.S. Percentage Areas product reports the percentage of the contiguous United States experiencing unusually warm, cold, wet, or dry conditions. A climate division is classified as "Very Warm" when its standardized temperature value is above the 90th percentile of its historical distribution [12]. For each year from 1980 to 2019, the percentage of the contiguous United States classified as "Very Warm" in June was recorded. June was selected because it closely corresponds to the main BBS survey period and the breeding season of the selected species.

2.2. Variables

The study included one climate exposure variable and four species-specific abundance outcomes. Table 1 summarizes the variables, data sources, units, and study period. The independent variable was the percentage of the contiguous United States classified as "Very Warm" in June. The dependent variable was the BBS annual abundance index for each bird species, which represents relative annual abundance rather than an exact population count.

Table 1. Variables used in the study

Variable	Data source	Representation	Unit	Time period
"Very Warm" area	NOAA NCEI	Percentage of the contiguous U.S. above the 90th percentile of its historical temperature distribution	%	1980-2019
American Robin abundance	USGS BBS	Annual model-based abundance index	Index	1980-2019
Tree Swallow abundance	USGS BBS	Annual model-based abundance index	Index	1980-2019

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Table 1. (continued)

Barn Swallow abundance	USGS BBS	Annual model-based abundance index	Index	1980-2019
Mourning Dove abundance	USGS BBS	Annual model-based abundance index	Index	1980-2019

Several design choices were kept constant to make comparisons among species more reliable. The study period was fixed at 1980-2019 for all four species, only June temperature data were used, and the geographic exposure measure was consistently defined for the contiguous United States. Abundance indices for all four species came from the same BBS Core analysis, reducing differences that could arise from using different survey designs or abundance estimators.

Some environmental and biological factors could not be controlled directly because the study used long-term observational data. Precipitation can influence water and food availability, while habitat change can alter nesting sites and food resources. Migration conditions may affect the number of Tree Swallows and Barn Swallows returning to breeding areas, and human activity can influence species in different ways. These factors were treated as potential sources of unmeasured variation when interpreting the observed climate-abundance associations.

2.3. Statistical analysis

The relationship between June "Very Warm" area and annual bird abundance was examined separately for each species. Because both variables were continuous and the research question focused on whether they changed together over time, Pearson's correlation coefficient (r) was used to measure the strength and direction of the linear association.

Scatter plots were used to inspect the overall data pattern and assess whether a linear relationship was reasonable. A simple linear regression line was then fitted for each species, and the coefficient of determination (R^2) was reported to describe the proportion of variation in annual abundance associated with variation in June "Very Warm" area within the fitted linear model. Statistical significance was evaluated at alpha = 0.05. Interpretation considered statistical significance together with the direction and magnitude of r and R^2. The same analytical approach was applied to all four species to support direct comparison.

3. Results

3.1. Data processing

The NOAA and BBS datasets were filtered to include only 1980-2019. From the NOAA dataset, the percentage of the contiguous United States classified as "Very Warm" in June was selected. From the BBS Core Annual Indices, the annual abundance indices for the American Robin, Tree Swallow, Barn Swallow, and Mourning Dove were extracted. The datasets were then matched by year, producing 40 paired observations for each species.

An extract of the processed dataset is shown in Table 2. The processed data were subsequently used for Pearson correlation and simple linear regression analyses for each species.

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Table 2. Extract of processed June temperature and annual bird abundance data

Year	June "Very Warm" area (%)	American Robin	Tree Swallow	Barn Swallow	Mourning Dove
1980	13.12	26.24	2.95	19.51	42.51
1981	24.56	26.48	3.00	19.12	44.09
1982	1.61	26.93	3.09	19.41	42.91
1983	0.21	27.52	3.00	19.11	40.29
1984	0.97	27.81	3.03	19.26	38.65
...	...	...	...	...	...
2017	20.39	27.69	3.00	13.24	34.06
2018	43.04	26.94	2.84	13.00	33.32
2019	5.22	26.23	2.69	12.39	32.02

3.2. Statistical results

Pearson's correlation coefficient was calculated separately for each species, and simple linear regression was used to obtain R^2. A p value below 0.05 was treated as statistically significant. The statistical results differed among the four species. The American Robin showed a weak positive correlation, whereas the Tree Swallow, Barn Swallow, and Mourning Dove showed negative correlations of different strengths. Table 3 summarizes the main results.

Table 3. Correlation and regression results for June "Very Warm" area and annual abundance

Species	Pearson's r	R^2	p value	Significance
American Robin	0.232	0.054	0.150	Not significant
Tree Swallow	-0.051	0.003	0.753	Not significant
Barn Swallow	-0.356	0.127	0.024	Significant
Mourning Dove	-0.281	0.079	0.079	Not significant

Among the four species, the Barn Swallow showed the strongest negative correlation and was the only species with a statistically significant relationship. The Tree Swallow showed the weakest association, with an r value closest to zero. The following species-specific subsections present the corresponding scatter plots and regression patterns.

3.3. American Robin

The American Robin showed a weak positive relationship between June "Very Warm" area and annual abundance. The Pearson correlation coefficient was $r = 0.232$, indicating that abundance tended to increase slightly as the percentage of the United States experiencing "Very Warm" conditions increased. The regression model produced $R^2 = 0.054$, so approximately 5.4% of the variation in annual American Robin abundance was associated with variation in June "Very Warm" area within the fitted linear model. The p value was 0.150, which was above the significance

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threshold of 0.05; therefore, the observed relationship was not statistically significant. Figure 1 shows the scatter plot and fitted regression line.

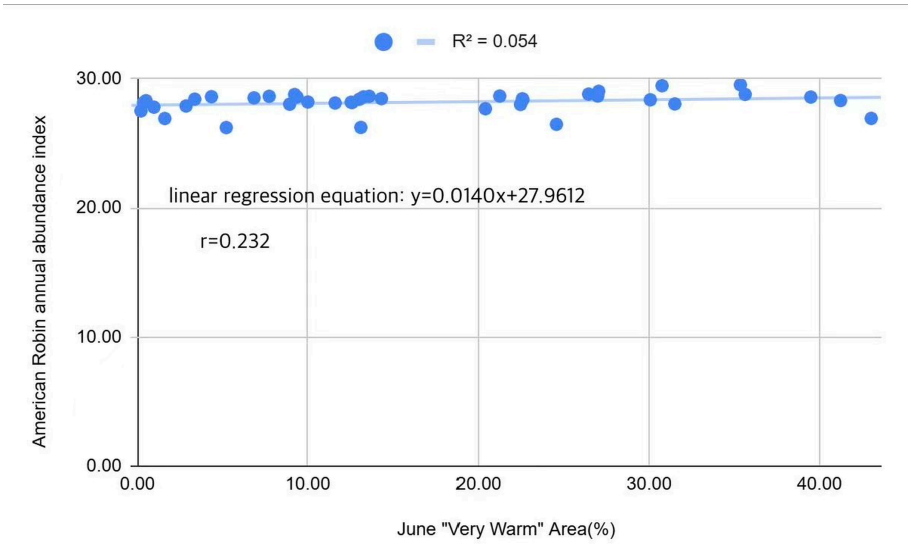


Figure 1. Relationship between June "Very Warm" area and American Robin annual abundance index, 1980-2019 (picture credit: original)

3.4. Tree Swallow

The Tree Swallow showed an extremely weak negative trend. The Pearson correlation coefficient was r = -0.051, indicating almost no linear relationship between June "Very Warm" area and annual abundance. The regression model produced $R^2 = 0.003$, so only about 0.3% of the variation in Tree Swallow abundance was associated with the June temperature indicator. The data points were widely distributed around the fitted line, with no clear increase or decrease in abundance as unusually warm conditions became more widespread. The p value was 0.753, which was well above 0.05, and the relationship was not statistically significant. Figure 2 presents the observed pattern.

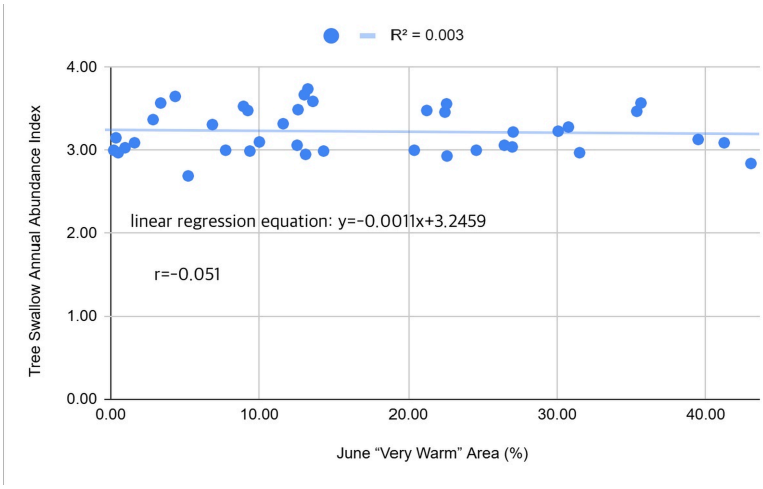


Figure 2. Relationship between June "Very Warm" area and Tree Swallow annual abundance index, 1980-2019 (picture credit: original)

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3.5. Barn Swallow

The Barn Swallow showed the strongest negative association among the four species. The Pearson correlation coefficient was r = -0.356, indicating lower annual abundance in years when a larger percentage of the contiguous United States experienced "Very Warm" June conditions. The regression model produced $R^2 = 0.127$, meaning that approximately 12.7% of the variation in Barn Swallow annual abundance was associated with variation in the June temperature indicator. Although most annual variation remained unexplained, this was the largest R^2 among the species examined. The p value was 0.024, which was below 0.05, making the negative relationship statistically significant. Figure 3 shows the corresponding scatter plot and regression line.

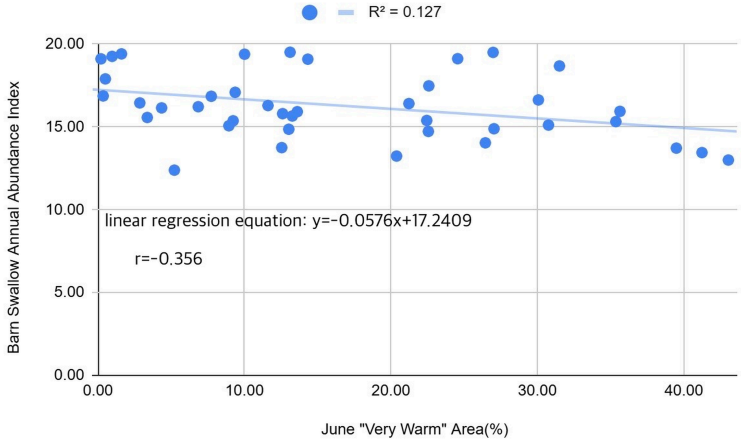


Figure 3. Relationship between June "Very Warm" area and Barn Swallow annual abundance index, 1980-2019 (picture credit: original)

3.6. Mourning Dove

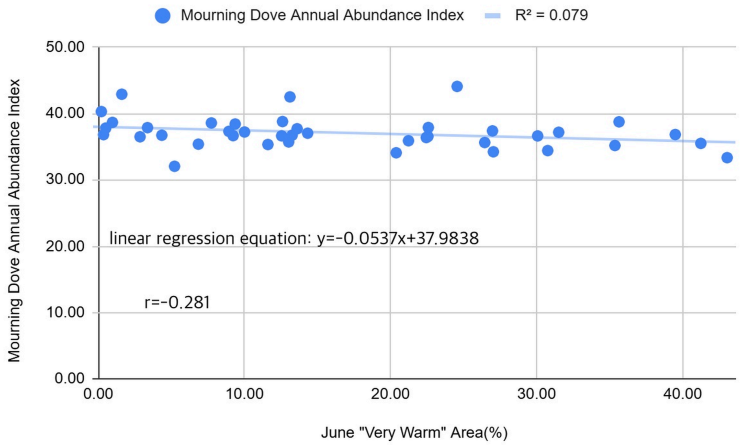


Figure 4. Relationship between June "Very Warm" area and Mourning Dove annual abundance index, 1980-2019 (picture credit: original)

The Mourning Dove showed a weak negative trend, with a Pearson correlation coefficient of r = -0.281. The regression model produced $R^2 = 0.079$, indicating that approximately 7.9% of the

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variation in annual Mourning Dove abundance was associated with variation in June "Very Warm" area within the fitted linear model. The p value was 0.079, which was above the significance threshold of 0.05. The negative relationship was therefore not statistically significant. Figure 4 shows that abundance generally declined as the warm-area percentage increased, but the scatter around the regression line was substantial and the observed association remained weak.

4. Conclusion

This study looked at the link between unusually warm June conditions and yearly abundance measures for four common North American bird species from 1980 to 2019. The results did not show the same response across species. The American Robin had a weak positive relationship with June "Very Warm" area. The Tree Swallow showed almost no link. The Mourning Dove showed a weak negative relationship. It was not significant. The Barn Swallow had the strongest negative link. It was the only species with a significant relationship. These different patterns show that broad-scale warm conditions were linked to bird abundance in different ways for different species, not in the same way for all species.

For the Barn Swallow too, June "Very Warm" area explained only 12.7% of the change in yearly abundance. The numbers were smaller for the other species. These small values show that one broad-scale temperature indicator cannot explain most year-to-year changes in bird abundance. Long-term population patterns likely come from many processes that act together. These include rain, habitat change, food availability, migration conditions, breeding ecology, and human activity. The use of a national temperature measure may also hide regional differences. Local breeding populations may face conditions that are very different from the average pattern across the contiguous United States.

The results show why it is important to study species separately when looking at ecological responses to unusual warmth. Differences in diet, nesting behavior, migration strategy, habitat use, and body tolerance can cause different population responses under similar climate conditions. The four species analyzed here show this point clearly. One species had a significant negative link. Two had negative links that were not significant, and the links were different in size. One had a weak positive link. This variation warns against treating one climate exposure as having the same population effect across broad groups of birds.

Future work could expand the analysis by adding rain, habitat and land-use change, food availability, and regional climate conditions in models with many variables. Regional analyses could better match local temperature exposure with the populations sampled by BBS routes. More methods could also account for long-term time trends and time-related patterns. These may affect simple year-by-year links. These extensions would help find out whether the Barn Swallow result stays strong after adjusting for other environmental factors. They would also help find out whether more local climate measures reveal relationships that are hidden at the national scale.

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