Climate's Impact on Bird Distributions in California

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Abstract

This study examines the effect of Earth's rising temperatures on the species distributions of *Hirundo rustica* (barn swallow), *Melozone crissalis* (California towhee), and *Piranga ludoviciana* (western tanager) in California between 1980 - 1997 and 1998 - 2017. We evaluated the change in bird distributions by applying spatial statistics to measure geographic distributions and to detect and analyze spatial clusters of bird counts[3]. In addition, we conducted a negative binomial regression to determine if monthly mean temperature[4] could predict bird counts. Results indicated a northward shift in species distributions between the two time intervals for all species. A comparison of barn swallow and western tanager hot spot analysis maps revealed spatial clusters of high bird counts between 1998 - 2017 north of California, suggesting a change in environmental conditions that enabled these areas to support the two species. Negative binomial regression results showed that increases in temperature would lead to increases in both barn swallow and California towhee counts. Barn swallows were the species most sensitive to temperature changes, as temperature was a statistically significant predictor variable only for barn swallows. Inclusion of additional explanatory climate variables into the negative binomial regression models may improve results.

Background

Study Period:
1980 - 1997
1998 - 2017

100 mile buffer around California to account for birds emigrating and immigrating (Figure 1)

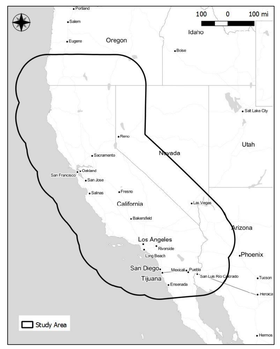

Figure 1: Study area

Species:
- *Hirundo rustica* (barn swallow)
- *Melozone crissalis* (California towhee)
- *Piranga ludoviciana* (western Tanager)

Data:
- Climate Forecast System Reanalysis (CFSR) monthly mean surface temperature (tas) reanalysis dataset[4]
- Crowd-sourced eBird bird sightings dataset[3]

Objectives

- Analyze change in geographic distributions of species between 1980 - 1997 and 1998 - 2017
- Identify spatial clusters of bird counts between 1980 - 1997 and 1998 - 2017
- Establish empirical relations between explanatory monthly mean surface temperature variable and bird counts

Methodology

Measuring Geographic Distribution:

Mean Center ⇨ Standard Deviational Ellipse (SDE)

Cluster Analysis:

Spatial Autocorrelation (Moran's I) ⇨ Hot Spot Analysis (Getis Ord Gi*)

Regression Analysis:

Rarefy samples using Moran's I ⇨ Extract temperatures from polygons intersecting bird observations ⇨ Negative Binomial Regression

Results

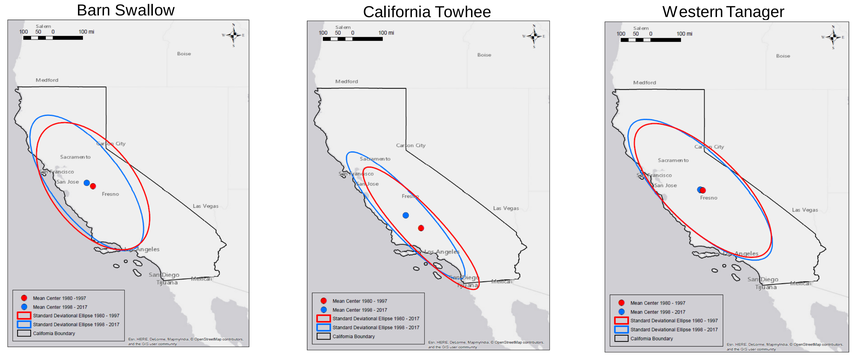

Figure 2: Geographic Distributions 1980 - 2017
Between 1980 - 1997 and 1998 - 2017, mean centers moved north, and SDEs elongated for all species.

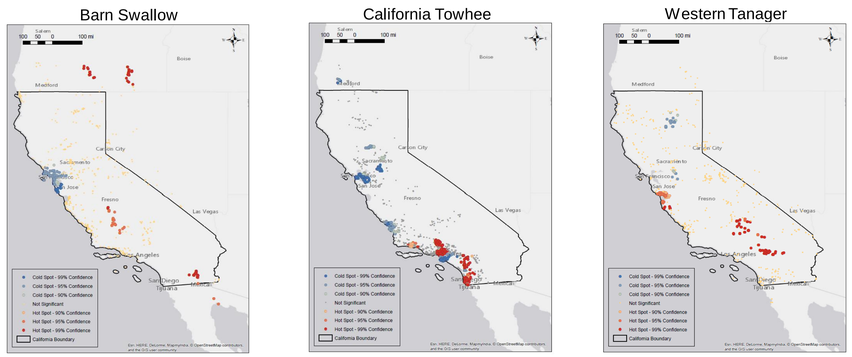

Figure 3: Hot Spot Analysis 1980 - 1997
Many significant hot and cold spots were located near major cities.

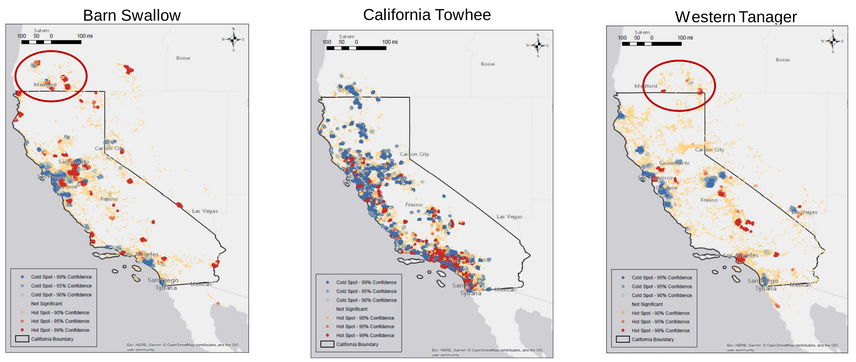

Figure 4: Hot Spot Analysis 1998 - 2017
New barn swallow and western tanager hot spots emerged north of California (shown by ellipses).

Results (continued)

	Coef.	Std. Err.	z	Pr(>|z|)
Intercept	-17.17	4.36	-3.93	8.34×10^{-5}*
Temperature	0.066	0.015	4.41	1.05×10^{-5}*

Figure 5: Barn Swallow Negative Binomial Regression Results
For every one degree K increase, barn swallow count is expected to increase by a factor of 0.066.

	Coef.	Std. Err.	z	Pr(>|z|)
Intercept	-2.30	2.26	-1.019	0.31
Temperature	0.012	0.0079	1.54	0.12

Figure 6: California Towhee Negative Binomial Regression Results
For every one degree K increase, California towhee count is expected to increase by a factor of 0.012.

	Coef.	Std. Err.	z	Pr(>|z|)
Intercept	3.26	3.28	1.00	0.32
Temperature	-0.0082	0.011	-0.73	0.47

Figure 7: Western Tanager Negative Binomial Regression Results
For every one degree K increase, western tanager count is expected to decrease by a factor of 0.0082.

*statistically significant at $\alpha = 0.05$
Note: Bird sighting observations from June 2017 were omitted from regression analyses due to a gap in temperature data.

Conclusions

- Species distributions shifted northward (Figure 2), agreeing with previous studies focused in Great Britain[5] and east of the Rocky Mountains[6]
- Hot and cold spots were located in major cities across all species, which suggests oversampling in highly populated areas (Figure 3)
- Conditions north of California may be becoming more inhabitable for barn swallows and western tanagers (Figure 4)
- Barn swallows are most sensitive to change in temperature (Figure 5)
- Western tanager counts and temperature are inversely related (Figure 7)

References

[3]eBird Basic Dataset. Version: EBD_relNov-2017. Cornell Lab of Ornithology, Ithaca, New York. Nov 2017.
[4]Saha, S., Moorthi, S., Pan, H. L., Wu, X., Wang, J., Nadiga, S., ... & Liu, H. (2010). The NCEP climate forecast system reanalysis. *Bulletin of the American Meteorological Society*, *91*(8), 1015-1058.
[5]Thomas, C. D., & Lennon, J. J. (1999). Birds extend their ranges northwards. *Nature*, 399(6733), 213.
[6]Hitch, A. T., & Leberg, P. L. (2007). Breeding distributions of North American bird species moving north as a result of climate change. *Conservation Biology*, *21*(2), 534-539.

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For Additional Information
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