Do yellow-billed magpies respond variably to West Nile risk over space and time? A geographically weighted regression approach

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Introduction

Yellow-billed magpies are birds endemic to California's Central Valley that are especially vulnerable to West Nile virus (WNV)[1]. While prior research has linked the presence of WNV to declines in magpie populations, less is known about if that relationship exhibits spatial variation. Understanding spatial patterns may point to environmental or ecological factors that mediate vulnerability and identify areas where magpies are more resilient or more at risk.

Aim

This project explores whether the effect of WNV risk on magpie abundance varies across space and whether that spatial pattern has shifted in recent years.

Methodology

Study Area

The US. Geological Survey (USGS) conducts surveys for birds along fixed-distance routes across California. Our units for spatial analysis are the routes along which yellow-billed magpies are spotted. These routes vary in location and terrain, making them good for detecting variation.

Data Sources

Yearly magpie abundance data along a route come from the North American Breeding Bird Survey (BBS) conducted by USGS.

WNV risk from 2009 to the present is measured using VectorSurv's estimated risk index. The index is derived from raster maps that display estimated WNV risk across California based on trap data and further modeling[2].

We also incorporate precipitation data from PRISM into our model[3]. While other covariates such as land cover and temperature were considered, only precipitation improved model fit and was retained in our final model.

Data Processing

Our analysis is limited to years for which risk index data were available. For each route, we create a 3-km buffer and calculate the mean risk index from the previous year within the buffer. Mean yearly precipitation data from the prior year were similarly averaged with the buffer for each period.

Finally, we split the data into two time frames (2010-2015 and 2016 to 2023) based on creating balanced sample sizes, sum up magpie counts with each time frame per route, and average the risk index and precipitation covariate per route. These aggregated values were then used in **geographically weighted regression.**

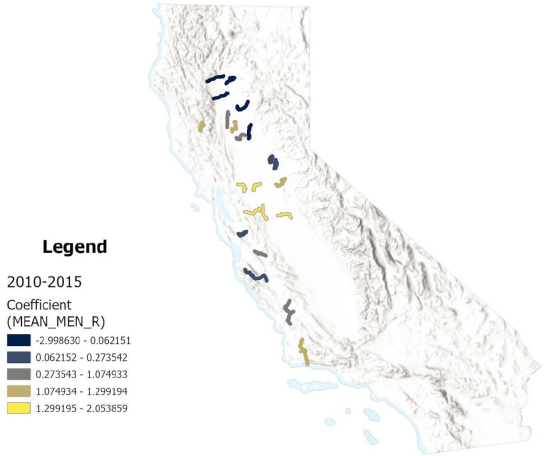
The Model

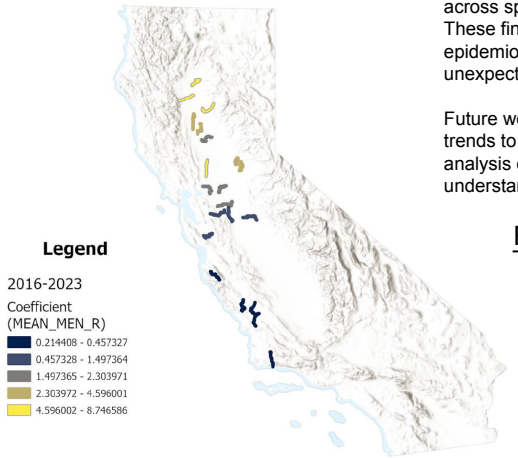
Geographically Weighted Regression (GWR) is a spatial method that fits local regression (defined by some number of neighbors, determined by ArcGIS's 'golden search') at each route, allowing the coefficient for WNV risk to change depending on location. This approach helps reveal spatial trends that would be masked by a single, global estimate.

Model diagnostics show that GWR improves fit, with local models explaining far more deviance that global models.

	2010-2015	2016-2023
Number of routes	21	25
Number of neighbors	8	9
Deviance explained (global)	.01	.06
Deviance explained (local)	**.84**	**.83**

We run GWR separately for the two time periods, with magpie abundance as the outcome and mean lagged WNV risk as the primary predictor. Coefficient surfaces are divided into quintiles to help compare the changes in variation from one period to another.





Results

In the 2010–2015 period, coefficients ranged from –2.99 to 2.05, whereas the 2016-2023 coefficients range from 0.21 to 8.75. While this may suggest a possible change in how WNV risk relates to magpie counts over time, we treat these results as descriptive patterns rather than evidence of any sort of causal relationship.

The spatial distribution of coefficient values reveals a shift in the relative sensitivity of some routes to WNV risk. For instance, several northern routes that previously showed strong negative associations with WNV risk ranked among the strongest positive associations in the later period, suggesting a potential reversal in the spatial pattern of risk sensitivity.

This reversal in rank-order may hint at localized ecological changes or evolving magpie responses over time.

Discussion and Conclusion

Limitations

This analysis is highly exploratory and non-causal. Limitations include data sparsity (limited bird counts for some years and routes, missing risk data), the exclusion of potentially important covariates form the model, and the use of mean values across years for predictors that may smooth over short-term variability.

Discussion

This project is meant to be hypothesis-generating rather than conclusive. By mapping how the association between WNV risk and magpie abundance varies across space and time, we can start to ask more targeted ecological questions. These findings can help prioritize areas for more in-depth ecological or epidemiological fieldwork, especially in routes that stand out as having flipped unexpectedly.

Future work could include incorporating finer-scale habitat data or linking these trends to mosquito abundance and bird survival data. Ultimately, this kind of spatial analysis can be a stepping stone towards a more complete ecological understanding.

References

Analyses conducted in R and ArcGIS.

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2. VectorSurv. (2024). Risk Surface Methodology. Retrieved from https://vectorsurv.org/docs/tools/risk_surface_methodology/

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