Spatial Dynamics of the Red-Backed Shrike Annual Migration Cycle

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Abstract

The annual migration cycle of the red-backed shrike is an intercontinental pattern influenced by various environmental factors. Using geolocator data, this study employs indicator kriging to analyze migration stages across the species' range. The predictive models show distinct spatial patterns, aligning with observed data. A raster-based grid approach and a polygon-based border approach offer complementary perspectives. There are challenges with the autumn Sahel staging site, but the results provide valuable insights into migration patterns. The study contributes a baseline prediction map, facilitating future comparisons and offering a way to monitor potential shifts in migration patterns. This research expands understanding of red-backed shrike migration, particularly during changing environmental conditions and declining populations.

Introduction

The red-backed shrike (*Lanius collurio*) is a bird species that migrates from parts of Europe and Asia to southern Africa (Pearson & Lack, 1992). This annual migration is routed north to south through eastern Africa and occurs in late autumn and early winter, with a return in spring. The specific migration patterns are affected by factors such as food availability, climate conditions, weather, and available resting sites. Its diet consists primarily of large invertebrates, such as beetles and grasshoppers, as well as small vertebrates, such as lizards (Tryjanowski, Karg, & Karg, 2003). This food is also affected by climate and weather conditions.

While the red-backed shrike was last assessed as a least-concern species, its population is decreasing (BirdLife International, 2017). One concerning problem is that eastern Africa is undergoing a negative change in its drought patterns (Haile et al., 2020). Droughts are becoming more numerous, more intense, and longer. Additionally, the red-backed shrike once had a notable breeding presence in Great Britain, but since 1989 the bird has rarely been there

(Tryjanowski, Sparks, & Crick, 2006). It is currently a Red List species there and its numbers are declining through much of western Europe.

For these reasons, a baseline monitoring of the spatial patterns of the red-backed shrike is called for. The bird has a large enough population that allows for adequate sampling, but is seeing shifts in its habitat. As climate change progresses and land uses are transformed, the same baseline monitoring methods can be applied to see any shifts in this bird's behaviors. Additionally, the results can be compared against other changing factors that are not explicitly linked to the red-backed shrike. As various environmental elements change, references to various animal behaviors can be examined for cross-referencing. Specifically, studying the red-backed shrike allows for an analysis of an intercontinental migration pattern that crosses the changing environment of Africa.

Two similar studies have been done on red-backed shrikes using geolocators to analyze their migration route (Tøttrup et al., 2017; Pederson et. al, 2020). The 2017 study aims to determine the route optimization of the migration. It finds that there are four primary staging sites: the Balkan staging site, the Sahel staging site in autumn, the southern Africa staging site, and the Sahel staging site in spring. These are in addition to a more general migration stage as well as a breeding cycle. The 2020 study finds that the red-backed shrikes that breed in relatively northern latitudes tend to migrate with local seasonal vegetation phenology, while those at relatively southern latitudes do not exhibit this pattern. The data from the 2017 study is used here, and is available online at Movebank[1].

Methods

Geolocator data on red-backed shrikes, collected from April 2012 through May 2014, were utilized in the 2017 study (Tøttrup et al., 2017). The study's authors classified the 4,403

[1] https://www.movebank.org/cms/webapp?gwt_fragment=page%3Dstudies%2Cpath%3Dstudy225376313

location points into categories based on the previously mentioned stages of migration (Figure 1). There is some data available for 2015 and 2016 that was not used here, because migration stage classification had not been done on it.

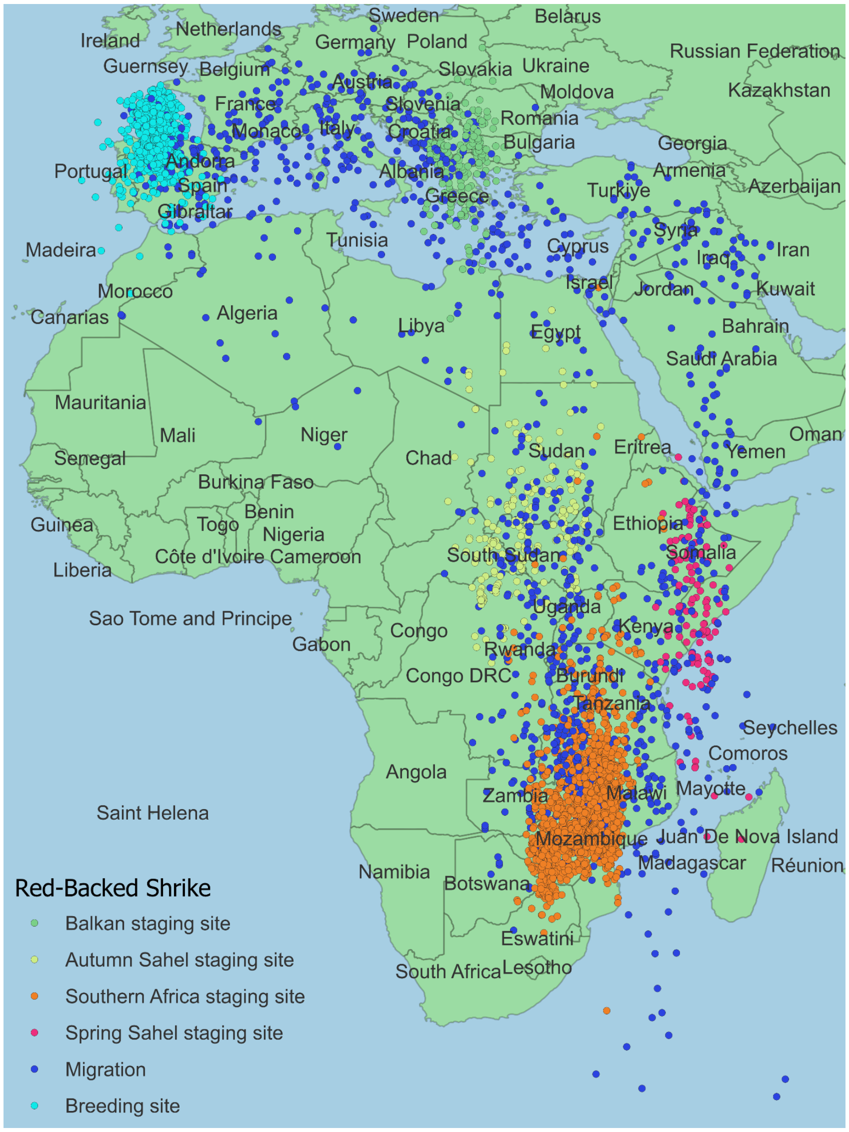
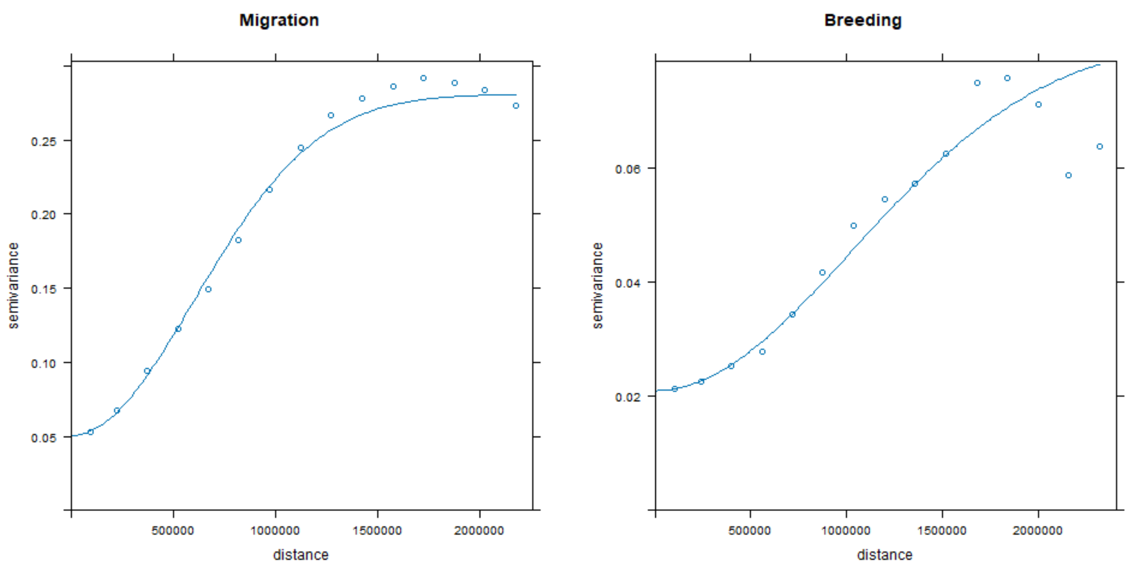


Figure 1: Point map showing the locations data was collected for during the study. Visually, it is suggested that there is a longitudinal difference in the Sahel staging sites, depending on whether it is spring (pink) or autumn (yellow).

This migration stage classification proved critical to the analysis of the data. In this instance, spatial clustering around high and low values would not work, since there is no ordinal ranking of migration stages. Instead, indicator kriging was deemed appropriate, as a prediction surface could be generated from the categorical variable of migration stage. This would allow comparisons of future analysis against this baseline to see if observations are in line with predictions. Additionally, future surfaces could be generated to determine any shift in predicted behaviors.



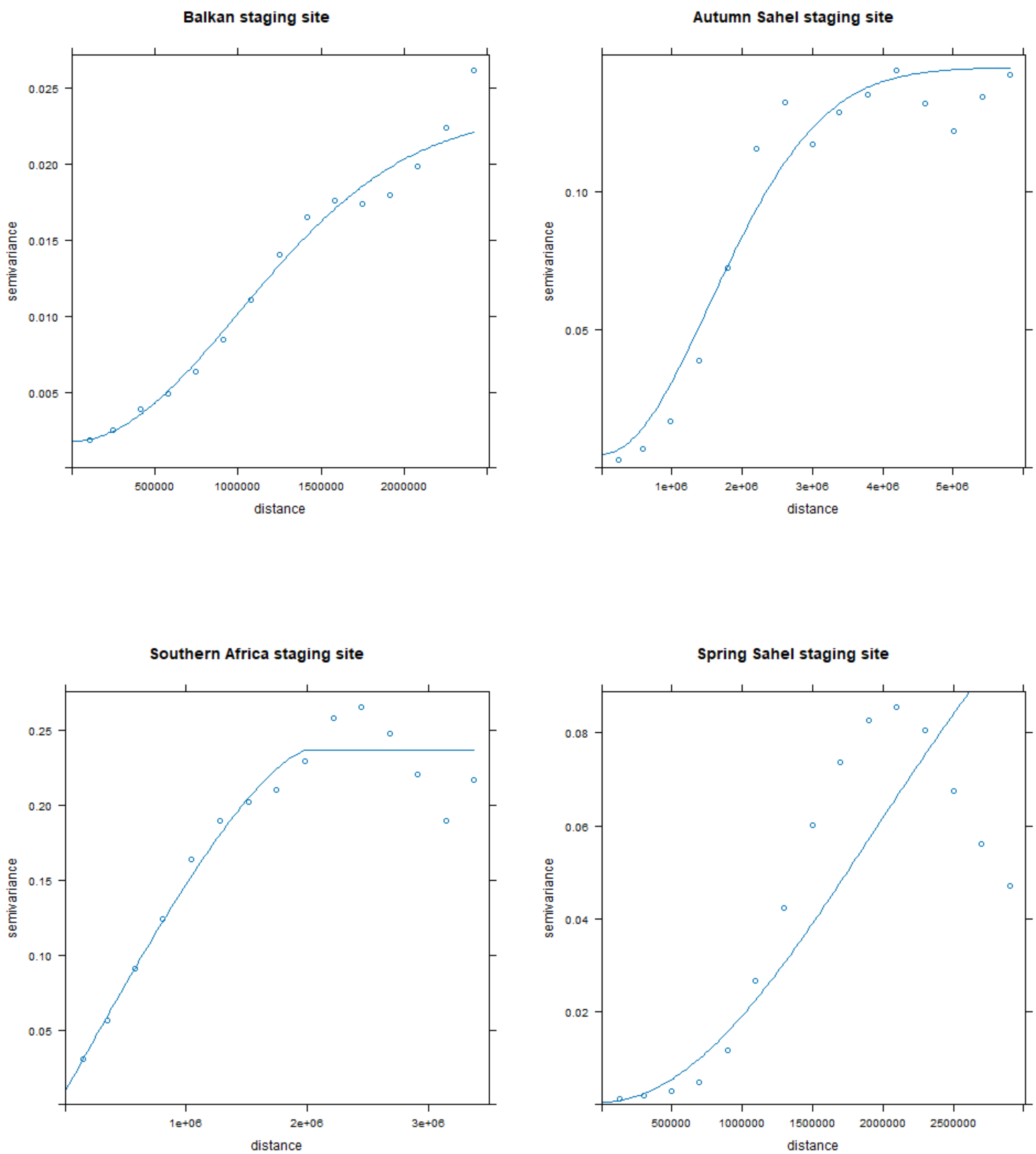


Figure 2: Variograms models used for indicator kriging. For the Southern Africa staging site, a fitted circular model was used. For the others, a fitted Gaussian model was used.

Once variograms (Figure 2) were generated, two main methods were used for indicator kriging. The first method was to interpolate over a prediction grid sized to match the minimum bounding rectangle of the study area. Cell sizes were set to 250 km as a compromise between resolution and processing speed. The second method was to interpolate over a polygon surface, where each polygon encompassed the national borders of the countries in this study area. The borders used were provided by ESRI[2] and were last updated on June 8, 2023. It's worth noting that the fitted variogram that was generated for the spring Sahel staging site does appear questionable. This model was fit from a Gaussian variogram with a partial sill of 0.1, a range of 1,400,000 m, a nugget of 0.001, and a cutoff of 3,000,000 m. This initial fit appeared adequate. Several other parameters and models were attempted, but none converged successfully.

In both the grid and national border cases, the individual prediction interpolations were combined into a single matrix. The maximum prediction value at each location was then used to generate a prediction surface. This shows the best prediction for the migration stage each location is related to.

Results

Both methods reveal spatial prediction patterns that align with the point data observations. Examining the grid first (Figure 3), the predicted breeding site areas are relatively confined to the Iberian Peninsula and the Bay of Biscay. The Balkan staging area prediction stretches from Greece to Ukraine, Belarus, and Poland, in a north-south direction. In southern Africa, a staging area is predicted from eastern South Africa to the Kenya-Uganda border. The autumn Sahel staging area is mostly predicted over much of Sudan, Chad, and the Central African Republic. The spring Sahel staging area is predicted over parts of Kenya, Ethiopia, and

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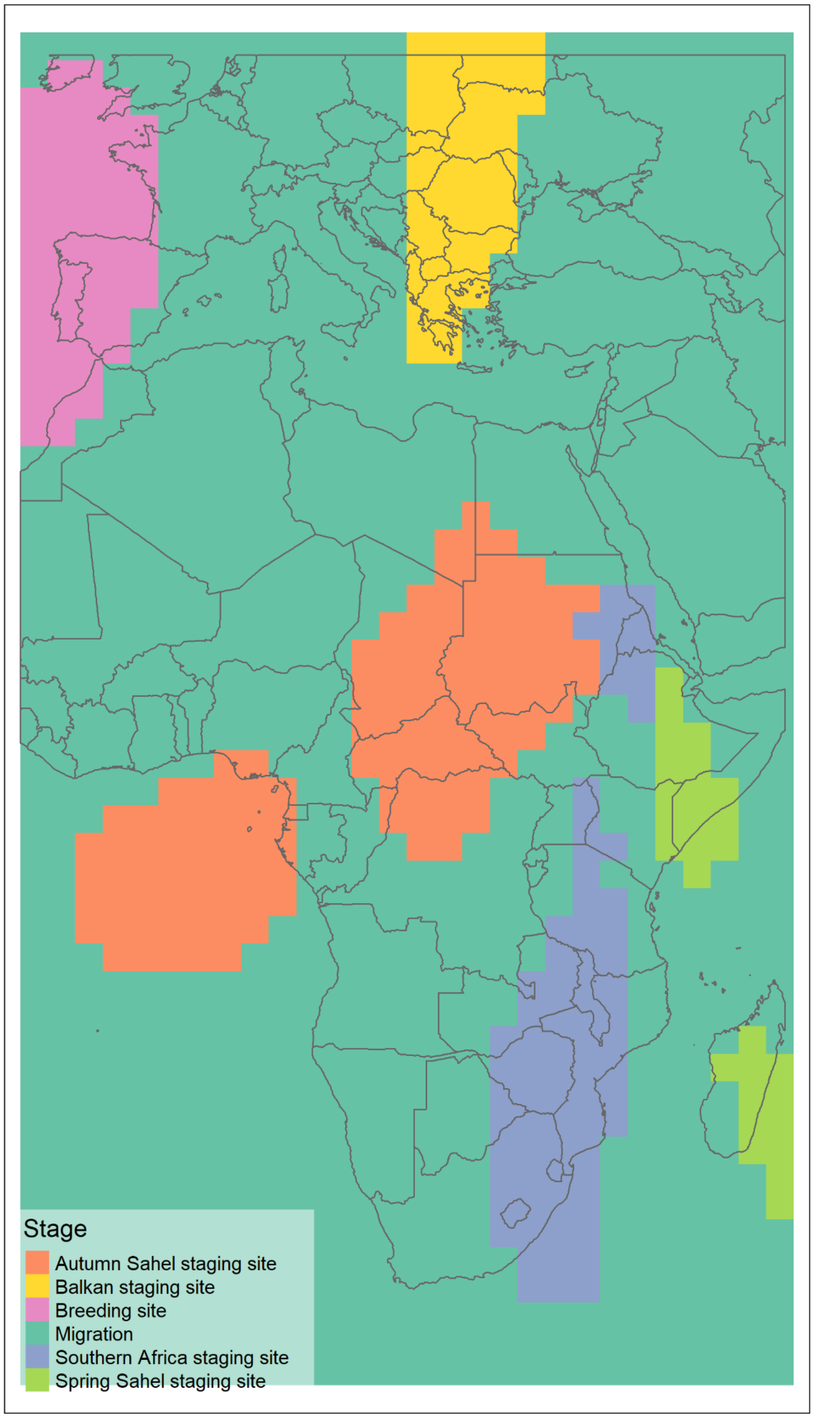
[2] https://hub.arcgis.com/datasets/esri::world-countries-generalized/about

Somalia, as well as Madagascar. This spring Sahel prediction appears to align with the observations, despite the appearance of the variogram used.



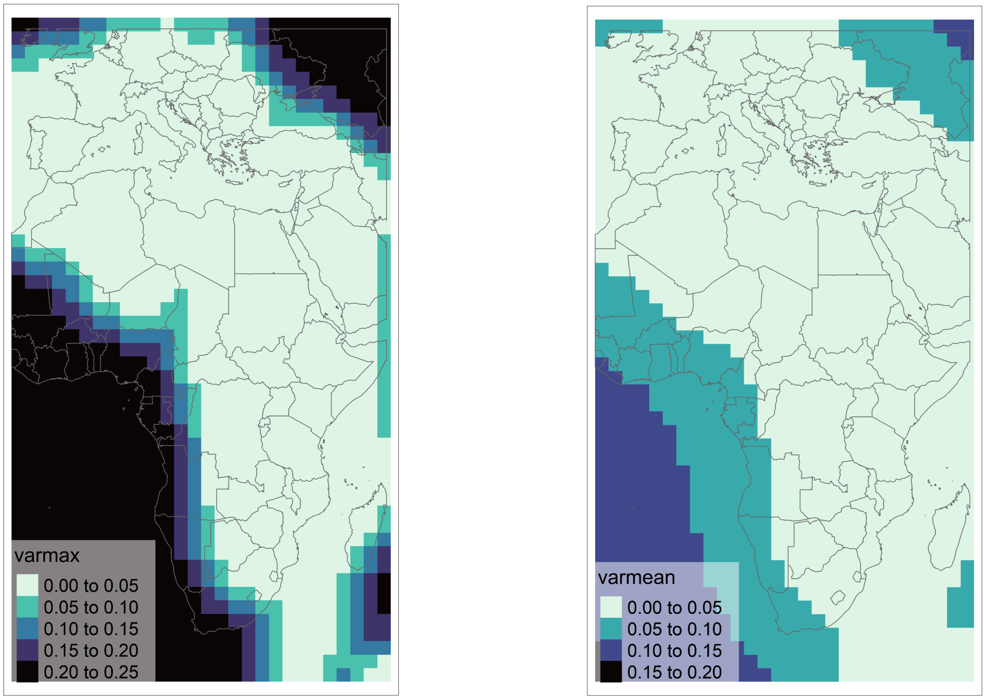


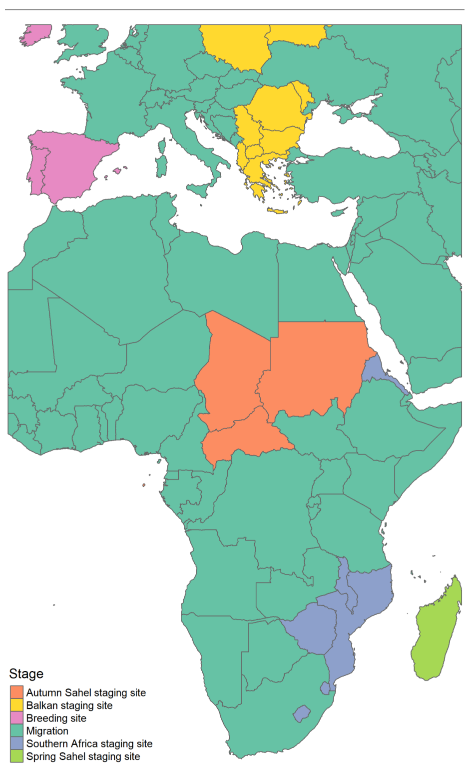
Figure 3: The kriging interpolation grid of the migration stages of the red-backed shrike, along with variance maps. On the left, the maximum variance from the subset of individual kriging interpolations at a location is shown. On the right, the mean of the variances is shown.

The autumn Sahel staging area does show a prediction to the west, over the Gulf of Guinea. The variance over that same area is relatively high compared to the other areas. The observed variogram model for this staging area does have a ping pong effect after a distance of about 3,000 km. The distance between the Chad-Sudan border to the coastline at the Nigeria-Cameroon border is roughly 2,000 km. Extending this line to 3,000 km puts a point in the Gulf of Guinea, generally near the center of this secondary prediction site. Another important factor to consider is the relative absence of the red-backed shrike in this area and its relative proximity to the observed staging site when compared to other regions in the study. While there is a relative absence of the species here, it is important to include its generated prediction.

There is no physical boundary that prevents the bird from entering any space in the study area, as it is free to roam.

A different approach to this interpolation is to run them over the bounds of each nation in the study area (Figure 4). This can allow a centralized approach for citizens and governments to effectively understand what is happening in their country. This can be useful for countries where there are multiple grid prediction stages. If a country's prediction "flips," it can be a sign that further exploration is needed.

Patterns in the interpolation and the variance are similar to those of the grid approach. However, some countries in the Balkans are predicted to be migration areas. Also, Madagascar is the only country predicted as a spring Sahel staging site. While this method is not as useful and robust as the grid method, it does provide a framework for countries predicted to be either an autumn Sahel staging site or a southern Africa staging site.



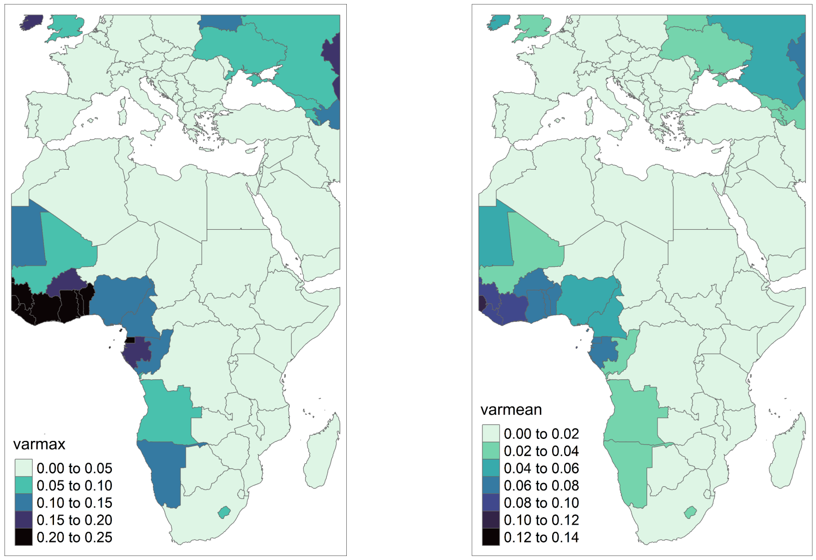


Figure 4: The kriging interpolation by country of the migration stages of the red-backed shrike, along with variance maps. On the left, the maximum variance from the subset of individual kriging interpolations for a country is shown. On the right, the mean of the variances is shown.

Discussion

Intercontinental migration patterns of the red-backed shrike can be understood using indicator kriging. A method and baseline prediction map have been generated, serving as a reference for future observations. Any changes in either the semivariances or kriging interpolations can be explored and hopefully understood.

Using a grid prediction method, a plot of the interpolations was made. This aligned with the observations from the source data, and the remaining variance was relatively low for most of the study area, except for the region around the Gulf of Guinea. Adding a covariate for the time-location within an annual cycle may prove useful. Also, a covariate representing species presence in an area could be explored. This may be useful in areas such as Ethiopia and Kenya, where observations of multiple stages are intermingled.

Existing methods for spatiotemporal analysis of the red-backed shrike's migration patterns can be both expanded upon and reframed in different contexts. Great work has been done, and the original study's data collection must be commended (Tøttrup et al., 2017; Pederson et. al, 2020). The analysis shown here can be paired with their efforts to monitor changing conditions.

Conclusion

This study uses geolocator data and indicator kriging to highlight distinct patterns across the migration cycle of the red-backed shrike. Despite challenges encountered in modeling the autumn Sahel staging site, there are important insights into migration behavior of the species. The baseline prediction map provides a reference point for future observations and allows for monitoring of shifts in migration patterns. This study adds an understanding of the migration pattern as environmental conditions change and the species' population declines. Further efforts and data collection are ideal for the ongoing analysis using these methods, hopefully adding more understanding to migration patterns as environmental factors change.

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