Novel Spatial Methods for Predicting Centers of Endemism of Andean Birds

Métodos Novedosos para Predecir los Centros de Endemismo para las Aves Andinas

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Introduction

Centers of endemism have long interested evolutionary biologists, biogeographers, and conservationists. Until recently, however, methods used to delimit centers of endemism for birds have been more qualitative than quantitative. One important element needed to identify centers of endemism is an accurate depiction of the current distributions of component species. Areas rich in endemism are frequently poor in ornithological survey effort, leading to incomplete knowledge of avian distributions. Here we apply new spatial techniques for accurate assessment of the distributions of poorly-known species to identify centers of endemism in the central Andes of South America. We compare these results with those of past analyses of avian centers of endemism and use outputs of the models to help identify areas for future surveys.

Methods

<u>Species selection</u>.—We selected all 72 montane bird species endemic to the area below treeline on the east slope of the Andes in Peru and Bolivia (Fig. 1).

<u>Distribution Modeling</u>.—We used **Maximum Entropy** (MaxEnt, Phillips et al. 2006, software available at www.cs.princeton.edu/~schapire/maxent) to model species distributions. This algorithm has proven to be especially effective for modeling species with small samples of known localities, as is typically the case with endemic species (Elith et al. 2006). Like many other distribution algorithms, MaxEnt uses information about the environment where a species is known to occur to predict all areas where it is likely to occur.

Fig. 1. Study area in the central Andes.

One species, the Scarlet-banded Barbet (*Capito wallacei*), is known from a single locality and therefore impossible model with MaxEnt. For this species, we used the area between 1000 and 1687 m elevation (the recorded elevational range) on the isolated mountain where the species occurs (O'Neill et al. 1998).

For locality information, we georeferenced museum specimen data from natural history collections in the project area and in the US (Fig. 2; see Acknowledgments for list of collections). We also included locality data provided in the literature and unpublished data from scientists working in the region. Once compiled, we subjected the locality data to review by ornithologists familiar with the study area (see Acknowledgments for list).

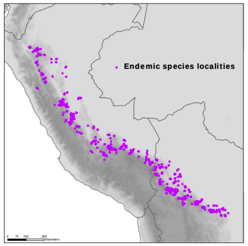

Fig. 2. Localities of specimens/ observations used in the study.

We selected three kinds of **environmental data** for the models: three STRM topographic variables (slope, elevation, and topographic exposure) (available at srtm.csi.cgiar.org); five uncorrelated climate variables from the WorldClim data set (www.worldclim.org): Mean Temperature diurnal range, isothermality, precipitation of wettest month, precipitation of driest month, precipitation seasonality; and the Enhanced Vegetation Index from the MODIS data set as a variable reflecting current land cover. Because the locality information often has a spatial error of up to several km, we experimented with models using the fine-scale MODIS data, MODIS data averaged across a 2 km-radius moving window, and MODIS data averaged across a 5 km-radius moving window.

After running models, we sought **feedback from ornithologists** familiar with the species to select the models that most accurately depicted each species' range. Distribution models tend to predict species' occurrences in areas with suitable habitat but not currently occupied by the species due to barriers to dispersal, interspecific competition, or other factors.

Results

Distribution Maps

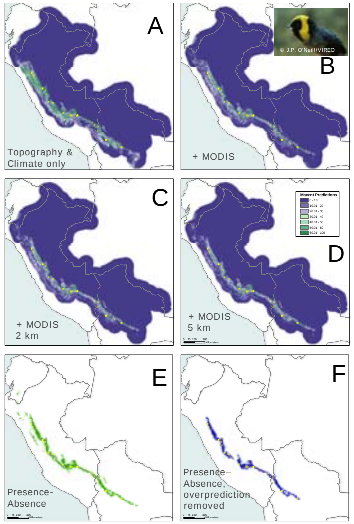

Fig. 3. Sample model output for the Golden-collared Tanager (*Iridosornis jelskii*). **A** Output for model using topographic and climate data; **B** As in A, but with MODIS data; **C** As in A, but with MODIS data generalized to 2 km moving window; **D** As in A, but with MODIS data generalized to 5 km; **E** Presence-Absence map generated from D; **F** As in E, but with areas of overprediction removed.

Centers of Endemism

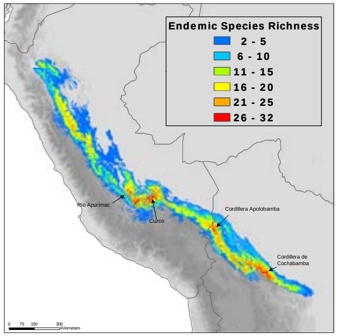

Fig. 4. Endemic **species richness** map showing especially high concentrations of avian endemism near Cuzco and the area north of the Río Apurímac in Peru, on the Cordillera Apolobamba and the Cordillera de Cochabamba in Bolivia.

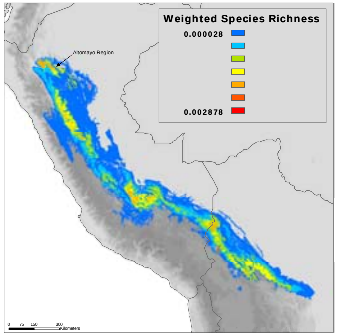

Fig. 5. Map of **weighted endemism** (the sum of the inverse of the range size of each species occurring in a grid cell) highlights the Altomayo region of San Martín Department, Peru as well as Cuzco and the Cordillera Apolobamba. Here the Cordillera de Cochabamba is less important as an area for narrow endemics.

Comparisons with Previous Analyses

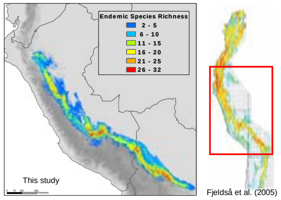

Fig. 6. An analysis by Fjeldså et al. (2005) closely matches our results except for the southwest slope of the Cordillera de Vilcabamba and the Cordillera Apolobamba.

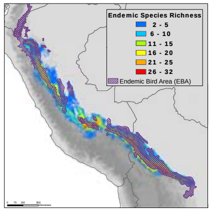

Fig. 7. Areas recognized as Endemic Bird Areas (Stattersfield 1998) for the central Andes closely match the centers of endemism identified in this study. Major differences are areas near Cuzco and some lower-elevation cordilleras east of the major ridge of the Andes in central Peru.

Areas for Future Surveys

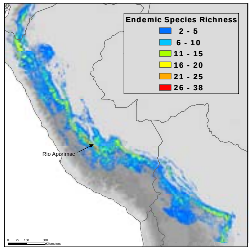

Fig. 8. Map of areas of overprediction highlights the hills southwest of the Río Apurímac in Ayacucho Department as most interesting for future surveys. To date, few ornithologists have explored this remote area.

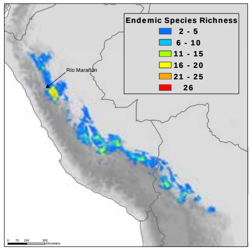

Fig. 9. Portions of predicted ranges that are > 50 km from existing collecting localities for the corresponding species. This analysis indicates that the region east of the Río Marañón in La Libertad and San Martín Departments is understudied.

Conclusions

- Distribution modeling can produce highly detailed distribution maps useful for both testing biogeographical hypotheses and for informing conservation decisions.
- Modeled distribution maps can help overcome the biases of traditional analyses caused by limited field surveys. In contrast to previous studies, this analysis flags the importance of the southwest slope of the Cordillera de Vilcabamba, an area poorly surveyed by ornithologists.
- Creative analysis of the results of distribution models can have useful side benefits, such as pointing to areas where future surveys would be most fruitful.

Acknowledgements

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References

Elith, J., Graham, C.H., and the NCEAS Species Distribution Modelling Group (2006). Novel methods improve predictions of species' distributions from occurrence data. Ecography 9: 129–151.

Fjeldsa°, J., Alvarez, M.D., Lazcano, J. M. and Leon, B. 2005. Illicit Crops and Armed Conflict as Constraints on Biodiversity Conservation in the Andes Region. Ambio 34: 205-211.

O'Neill, D. F. Lane, A. W. Kratter, A. P. Capparella, and C. Fox Joo. 2000. A striking new species of barbet (Capitoninae: *Capito*) from the eastern Andes of Peru. Auk 117:569-577.

Phillips, S.J., Anderson, R.P. and Schapire, R.E. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling 190: 231-259.

Stattersfield, J.A., Crosby, M.J., Long, A.J., and Wege, D.C. 1998. Endemic Bird Areas of the World: Priorities for Biodiversity Conservation. The Burlington Press Ltd., Cambridge, U.K.