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ECOLOGÍA

Updated geographical distribution of the Sunbittern (*Eurypyga helias*: Eurypigidae)

Distribución geográfica actualizada del Ave del sol (*Eurypiga helias:* Eurypigidae)

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ABSTRACT

The Sunbittern (*Eurypyga helias*), despite having a wide distribution, is poorly studied and with few records in its area of distribution. Updating the distributions of species allows us to understand distributional patterns which are useful in ecology and conservation, especially for rare or threatened species. Given this situation for *E. helias* and the new records outside its historical range, here we present its updated distribution and a new record in the south of the Middle Magdalena Valley in Colombia. Using occurrences with preserved specimens and photographic records we build an Ecological Niche Model using the algorithm implemented in MaxEnt. The new record was found in the municipality of La Belleza, Santander in northern Colombia. Its range extends approximately 200 km south of its historical distribution. In Venezuela, it could reach the northern part near the foothills of the Cordilleras Central and Oriental. In Bolivia to the south over the Chiquitano Forest. In Central America, it extends to the lowlands near the Cordillera Central and the Cordillera Volcánica Central, and in North America to southern Mexico. The model suggests that tropical lowlands are more suitable for the species than cold temperate zones, also, the Middle Magdalena Valley is a suitable area, however, the species prefers forested and preserved areas. Some distribution patterns could be explained by different biogeographical barriers, but phylogeographical analyzes are needed to test this hypothesis.

Keywords: Sunbittern, MaxEnt, Ecological Niche Modeling, Distribution.

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RESUMEN

El Ave del sol (*Eurypyga helias*) a pesar de tener una amplia distribución, es poco estudiada y tiene pocos registros en su área de distribución. Actualizar las distribuciones de las especies permite entender los patrones distribucionales lo cual es útil en ecología y conservación, especialmente para especies amenazadas o raras. Dada esta situación de *E. helias* y los nuevos registros por fuera de su distribución histórica, presentamos su distribución actualizada y un nuevo registro para el sur del Valle del Magdalena Medio en Colombia. Usando registros con especímenes preservados y reportes fotográficos construimos un Modelo de Nicho Ecológico usando el algoritmo implementado en MaxEnt. El nuevo registro se encontró en el municipio de La Belleza, Santander en el norte de Colombia. Su ámbito se extiende aproximadamente 200 km al sur de su distribución histórica. En Venezuela podría llegar a la parte norte cerca de las estribaciones de las Cordilleras Central y Oriental. En Bolivia hacia el sur sobre el Bosque Chiquitano. En Centroamérica, se extiende a las tierras bajas cerca de la Cordillera Central y la Cordillera Volcánica Central, y en Norteamérica hasta el sur de México. El modelo sugiere que las tierras bajas tropicales son más adecuadas para la especie que las zonas templadas y frías, asimismo el Valle del Magdalena Medio es un área adecuada, sin embargo, la especie prefiere áreas boscosas y conservadas. Algunos patrones de distribución podrían explicarse por diferentes barreras biogeográficas, pero se necesitan análisis filogeográficos para testear esta hipótesis.

Palabras clave: Ave del Sol, MaxEnt, Modelado de Nicho Ecológico, distribución

INTRODUCTION

The Sunbittern (*Eurypyga Helias* Pallas, 1781) is a heron-like bird of tropical american regions and is the monotypic species of the family Eurypygidae and the order Eurypygiformes (Haffer 1975, Cracraft 2013). Unlike herons, the Sunbittern has shorter legs, a relatively long tail, and a sun-like pattern on each wing, visible when fully extended. This species is distributed from Guatemala to northern Brazil and is found mainly in the lowlands. However, it can also be found in the mountainous regions between 1500 – 1800 m. There are three recognized subspecies: The Northern Sunbittern (*E. helias major* Hartlaub, 1844) distributed in Central America, western Colombia, and western Ecuador (Blake 1977); The Amazonian Sunbittern (*E. helias helias* Pallas, 1781) with a cis-Andean distribution from Colombia to Southern Brazil (Haverschmidt 1968); and the Foothill Sunbittern (*E. helias meridionalis* Berlepsch and Stolzmann, 1902) distributed only in the slopes and foothills of the Andes of Peru (Schulenberg *et al.* 2007). Preferred habitats of the Sunbittern are those near rivers or bodies of water such as forested streams, rivers, and sandbars (Stiles and Skutch 1989, Ridgely and Gwynne 1992, Hilty 2003), where it feeds on frogs, fishes, and small crustaceans (Deignan 1936, Haverschmidt 1962, Stiles and Skutch 1989, Spaans *et al.* 2018). It also presents a wide distribution, with few records. Thus, little is known about its ecological history, population, and demography (Lyon and Fodgen 1989).

Ecological Niche Modeling (ENM) is an analysis that uses environmental variables and species distribution to predict and understand current distributional patterns (Elith and Leathwick 2009) which are very useful in ecology and conservation (Urbina-Cardona and Flores-Villela 2010), especially for threatened and poorly studied species (e.g., Fois *et al.* 2018). Because the Sunbittern is a poorly studied species and has been recorded outside of the historical range, here we present the updated distributional range in South and Central America based on Climatic Suitability Models and historical records. Also, we present the first verifiable record of *E. helias* in the southern Middle Magdalena Valley in Colombia.

MATERIALS AND METHODS

Using the Global Biodiversity Information Facility (www.gbif.org), eBird (www.ebird.org), and iNaturalist (www.inaturalist.org) databases, we downloaded the records for South and Central America. The dataset was split into two groups: records with a preserved specimen or verifiable photography (Verifiable records), and records without verifiable information, *i.e.,* human observation (non-verifiable records). Furthermore, the verifiable dataset was split into records inside and outside the current distribution given the IUCN (Birdlife International c2020).

We used the Maximum Entropy algorithm (Phillips *et al.* 2004, Phillips *et al.* 2006) implemented in MaxEnt v3.4.4 (Phillips *et al.* c2017) using the R packages *ENMeval* (Muscarella *et al.* 2014). We only used the verifiable records within the current IUCN distribution, including the new record of the Middle Magdalena Valley. We generated a grid with size cells 1 ° and gathered one record per cell to reduce the sampling bias (Beck *et al.* 2014). For the calibration area (hereafter, M area), using the selected occurrences, we created a Minimum Convex Polygon with a buffer of 2.5°. We used the bioclimatic variables from WorldClim 2 (Fick and Hijmans 2017), and the variables bio1 (Annual Mean Temperature), bio3 (Isothermality), bio4 (Temperature Seasonality), bio5 (Max Temperature of Warmest Month), bio6 (Min Temperature of Coldest Month), bio7 (Temperature Annual Range), bio10 (Mean Temperature of Warmest Quarter), bio11 (Mean Temperature of Coldest Quarter), bio12 (Annual Precipitation), bio13 (Precipitation of Wettest Month), and bio16 (Precipitation of Wettest Quarter) were selected based on a previous Jackknife analysis using MaxEnt v3.4.4 to reduce autocorrelation between variables. We only used bioclimatic variables with a resolution of 2.5 arcminutes due to the uncertainty of the records. We randomly sampled 50 000 points in the M area for the background data or pseudo-absences.

We evaluated the Linear (L), Quadratic (Q), Hinge (H), and Product (P) features in different combination models (L, LQ, LQH, LQHP, and H) using regularization multiplier values from 1 – 5 every 0.5. We implemented the "block" partitioning method for both test and background. This method divides the occurrences into four blocks and uses one block as testing data and the others as training, this procedure is repeated four times until each block was used as testing data, for further information see Muscarella *et al.* (2014). Additionally, we set the "clamp" option to avoid problems of novel climate conditions (Phillips *et al.* 2006). We then chose models with a Minimum Training Presence omission rate (avg.MTP) value of less than 0.05, and then selected the model with the lowest value of AICc. The selected model was then tested against a null model using the partial ROC analysis (Peterson *et al.* 2008) with the R package *dismo* (Hijmans *et al.* c2017). We predicted the suitability distribution over an area from central Mexico to northern Argentina using the Logistic output, which transforms the values into continuous probabilities with a range from 0 (unsuitable) to 1 (most suitable). Finally, we transformed the predicted probabilities to a Boolean map of 0's and 1's using a 10 % training omission rate as a threshold.

We considered the suitability values, the Boolean map, and the verifiable records to propose new range extensions. Thus, areas with high suitability values and verifiable records are presented as range extensions. The data and R-scripts used in this study are available at https://github.com/oleon12/Sunbittern. Also, an interactive map with the results is available at https://rpubs.com/oleon12/sunbittern.

RESULTS

The new record was acquired in the municipality of La Belleza, Santander, Colombia. The species was recorded in a riparian forest at the river La Tipa, at the Minero river basin near Cuchilla del Minero and Serranía de las Quinchas (74° 3' 55" N; 5° 57' 18" W), on August 8 of 2018, first observed by O.D.L.-A and D.M.-C. at 10:00 hours flying across the river, and then photographed by F.A.-G. approximately at 14:00 hours (Fig. 1a). This photography was uploaded by O.D.L.-A. to iNaturalist (https://www.inaturalist.org/observations/18360787) for it to be available as GBIF. Only one proximal record exists in the Middle Magdalena Valley's Serranía de las Quinchas but is a non-verifiable one.

The ecological niche model selected was LQHP, with a regularization multiplier of 3.5 (LQHP 3.5). This model had an avg.AUC of 0.64, an avg.MTP of 0.003, an AICc value of 6631.91 (ΔAICc = 0), and *P*-value of 0.000 for the partial ROC analysis. For this model, the climate variables that most contributed were the Annual Precipitation (bio12, ~ 49 %), and the Temperature Annual Range (bio7, ~ 34.2 %). The prediction of this model on South and Central America suggested that tropical lowlands are more suitable than temperate and cold areas for the species to occur (Fig. 1b). In contrast, the high elevations in the mountain systems in South and Central America, the dry area of the Caatinga, and the Cerrado in Brazil are not suitable for this species (Figs. 1b–c).

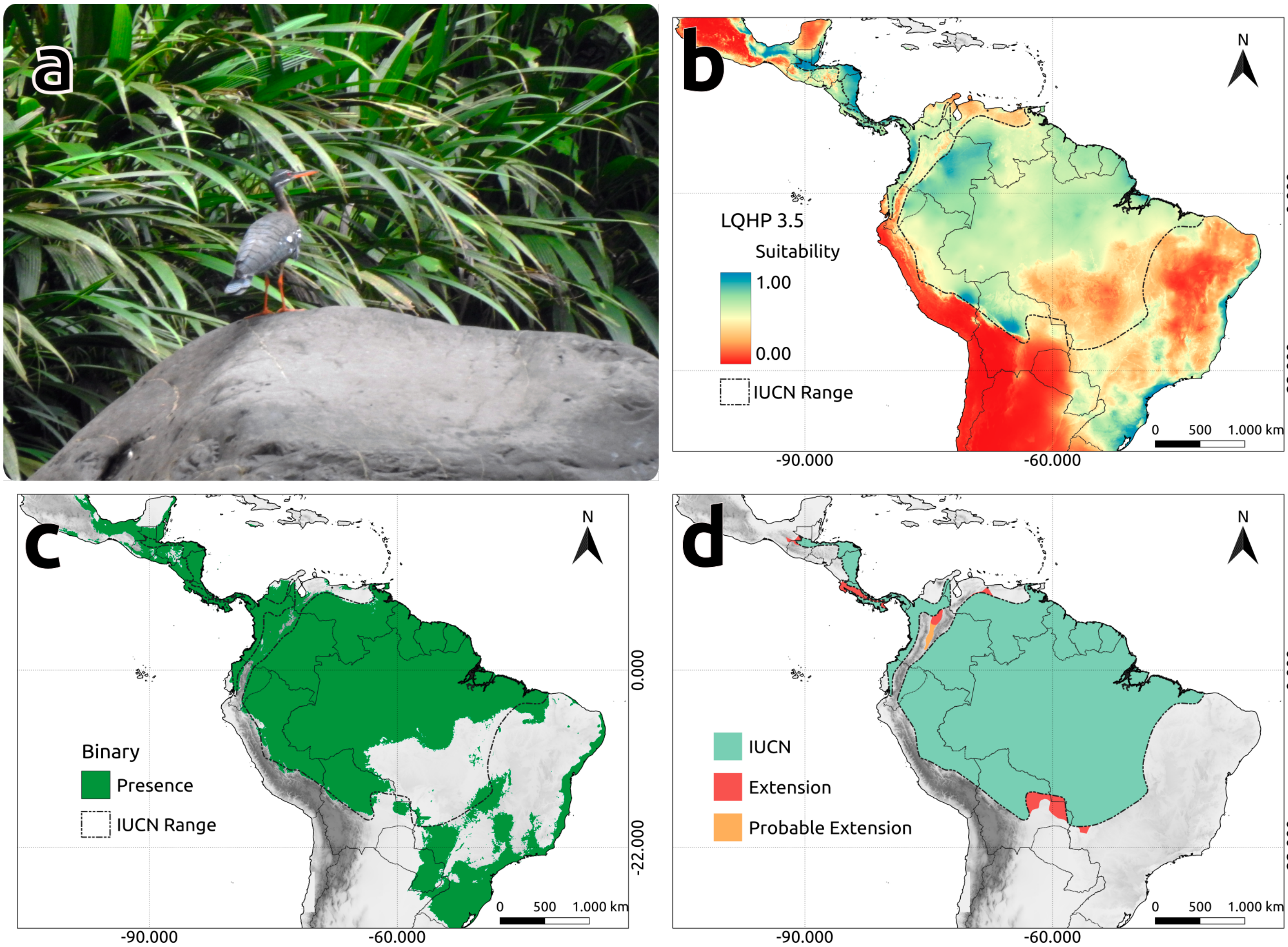

Figure 1. New record and suitability distribution under the LQHP 3.5 model. **a**. Photography of the individual found at La Tipa River, Santander, Colombia, **b**. The ecological niche model LQHP 3.5 with the suitability values, **c**. The binary output is based on the 10 % training omission threshold, **d**. The current distribution of *E. helias*, with the new and probable range extensions.

We propose an extension of approximately 200 km further south of its historical distribution, on an area of ~19.545.543 km², the southern limit of this area is the new record presented here. This area has high suitability values (Fig. 2a) and has a verifiable record (Fig. 2b). Southern to the new record, at the High Magdalena Valley in the Tolima and Huila departments we found also high suitability values (Fig. 2a), however, there are non-verifiable records for the species, so we propose this area as a Probable Extension area (Fig. 2b). In Venezuela, the range extends to the north of the country near the foothills of the Cordillera Central and Oriental (Fig. 1d), on an area of ~10.532.102 km². In Bolivia, the range extends on an area of ~111 345 782 km² to southeastern Amazonia, over the Chiquitano Forest with the Chaco region as its limit (Fig. 1d). In Central America, the range extends about 41.696.882 km² to the lowlands near the Cordillera Central (Panamá) and Cordillera Volcánica Central (Costa Rica) (Fig. 2b). Finally, in North America, the range extends about 9 626 739 km² to southern Mexico in the state of Chiapas, as suggested in previous works (Peterson and Chalif 1973).

DISCUSSION

In Colombia, there are two subspecies of *E. helias*, the Northern subspecies (*E. h. major*) and the Amazonia subspecies (*E. h. helias*). According to the data used in the present study, we found 323 records of *E. helias*, and only 3.4 % of these records belong to the *E. h. major* (Northern subspecies), and most of those records are found in the Pacific lowlands. The IUCN evaluates the species globally and does not take into account the subspecies, listing the species as Least Concern (LC) because the Area of Occupancy (AOO) is greater than 2000 km² and there are no

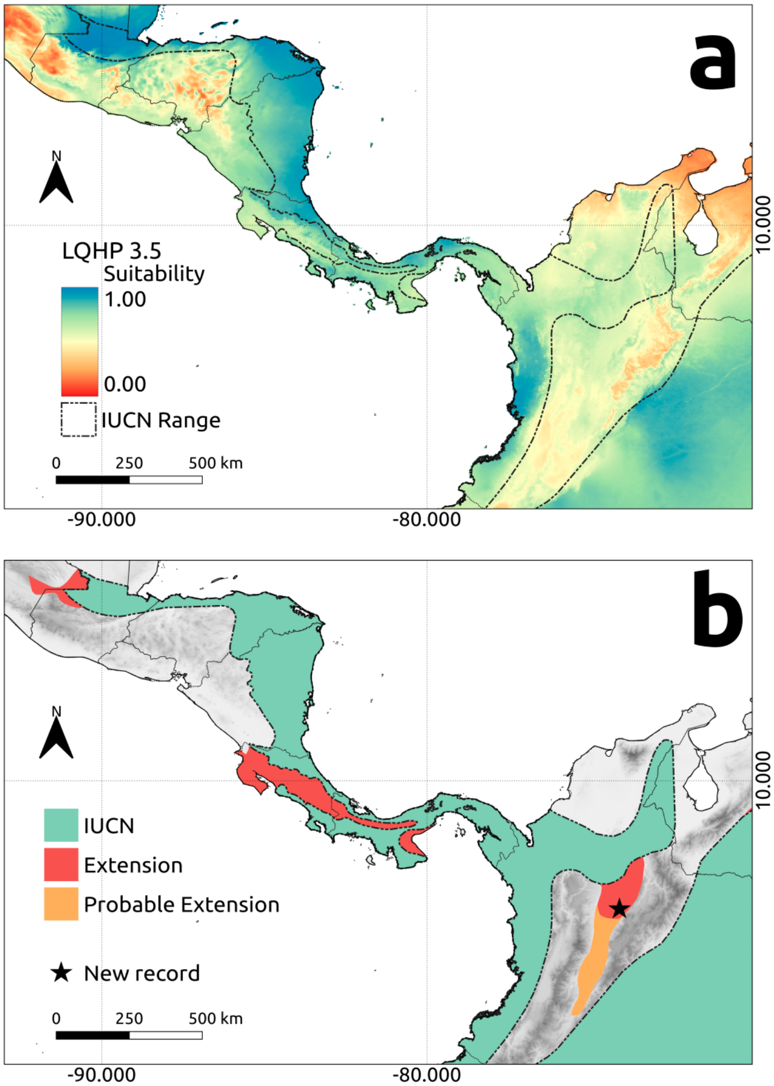

Figure 2. The ecological niche model for *E. helias* in Central America and the north of South America. **a**. The LQHP 3.5 model with the suitability values, **b**. Current distribution, with the new and probable range extensions, and the new record.

severely fragmented populations or have more than 10 locations. Given the data used here, the actual AOO for the species is 4596 km², however, the AOO for the total distribution of *E. h. major* is 728 km² and for the distribution in Colombia is only 44 km². Thus, it is necessary to evaluate the population sizes of *E. h. major* and at least evaluate the threatened status locally in Colombia.

The middle Magdalena Valley is a highly deforested area in Colombia, where about 76% of its natural areas were transformed into grassland (Etter *et al.* 2006), especially the areas near the Magdalena River, while the areas in the western foothills of the eastern cordillera are more forested (IDEAM c2015). Although the selected ecological model suggests that the entire Middle Magdalena Valley is a very suitable area for the Sunbittern, this species generally inhabits forested areas and forages near rivers (Stiles and Skutch 1989, Hilty 2003). Consequently, we consider that the species is more probable to occur in forested and conserved areas of the Middle Magdalena Valley, especially in areas, such as the Minero River basin, Cuchilla del Minero, and Serranía de las Quinchas. Furthermore, the western lowlands near the Serrania de Los Yariguies National Natural Park could be an important area for this species because it is a very forested area and is near to our own record (Fig. 2b), however, more field records and high-resolution analyses are needed to assert this hypothesis.

The climate variables that most contributed to the model were: Annual Precipitation and Temperature Annual Range. Thus, the areas with high precipitation above ~700 mm and low variation between annual maximum and minimum temperature are the most suitable for *E. helias*, which is in concordance with its historical distribution, the new range extensions, and the possible range extension (Fig. 1). The Caribbean and Pacific lowlands in Central America are highly suitable for *E. helias* (Fig. 2a). The species is distributed and has records in the coastal lowlands in Panamá and Costa Rica (Slud 1964, Garrigues and Dean 2014). In contrast, the species is distributed only in the Caribbean lowlands from Nicaragua to México (Fig. 2b). This interesting distributional pattern is shared by other species (e.g., *Cyanerpes lucidus* P. L. Sclater & Salvin, 1859; *Henicorhina leucosticta* Cabanis, 1847; *Harpia harpyja* Linnaeus, 1758). The presence of the Cocicolba lake and the Nicaraguan depression could be a possible explanation for the pattern found, as they are known to act as a biogeographic barrier for other species (Bonaccorso *et al*. 2008, Torres-Morales 2019). However, it is necessary to carry out phylogeographic and systematic analyses to evaluate this hypothesis. The model also indicated that the Alto Paraná Atlantic Forest and Uruguayan Savanna areas are very suitable for this species (Fig. 1b). However, two regions (Cerrado and Caatinga) between Alto Paraná Atlantic Forest and Uruguayan Savanna, and its current known distribution may act as barriers against its colonization. The Caatinga and Cerrado are dry regions, especially the Caatinga which is a desert, and these two regions presented the lowest suitability values (Fig. 1b). Although these two regions can be natural barriers, it is necessary for further studies and analysis to evaluate other variables like historical biogeographic events or biotic interactions that could explain the actual distributional pattern of the *E. helias*.

The range extensions proposed here depend mainly on the quality of the information posted in different platforms like iNaturalist and eBird, which are useful tools in landscape and macroecology studies (Dickinson *et al*. 2012, Van der Wal *et al*. 2015). We follow strict quality control criteria, however, it is necessary to improve and curate that type of information to obtain the most accurate and robust results. Human observations should be uploaded along with verifiable information, such as photographs and/or song records, which could be reviewed and improved by a specialist to avoid identification errors.

The Sunbittern prefers conserved and forested areas, and the most suitable areas for the species to occur are those in tropical lowlands with high temperature and precipitation conditions. The areas proposed here as the new and possible range extensions meet these requirements. Furthermore, the use of verifiable information is essential to make reliable biological inferences. It is necessary to collect more verifiable information in order to carry out phylogenetic and biogeographic studies, which help clarify the historical patterns of this species. Given the rarity of the subspecies *E. helias major* in Colombia and its small AOO, the record presented here indicates the general importance of the study area (La Tipa river) for future conservation strategies.

AUTHORS CONTRIBUTIONS

ODLA and DMC recorded the specimen and FGA photographed it. ODLA and KAMC performed the Ecological Niche Model analysis and elaborated the maps and figures. All the authors contributed to the preparation and critical revision of the manuscript

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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