SCALING FOREST HABITAT SUITABILITY USING AN ENDANGERED SPECIES AS BIOINDICATOR

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ABSTRACT: Despite its biological significance, the role of forests in food security and sustainability is often overlooked. Forests are vital in providing ecosystem services and have contributed directly and indirectly to the livelihoods of an estimated one billion people globally. The continued degradation of forests prompts the need for timely and scientific approaches to guide conservation targets and policies. This study aimed to assess forest biodiversity and habitat quality through the habitat suitability model of the black shama (*Copsychus cebuensis*) as a biodiversity and environmental indicator for terrestrial biodiversity areas in Cebu Island, Philippines. A multi-criteria approach was explored using a predictive habitat suitability model based on Weights-of-Evidence method through the estimation of a set of environmental predictor variables from GIS and remotely-sensed data. With the use of Bayesian rules, evidence layers in the form of environmental variables were then combined in a weighted spatial overlay to produce a single map of probability and occurrence. The resulting map was divided into 3 ranges of suitability, 3 as highly suitable, 2 as moderately suitable, and 1 as not suitable. The majority of the island especially those in the key biodiversity areas are only classified as moderately suitable (76.8%). Highly suitable areas for the black shama are very limited (1.26%) which indicates the need to expand the priority areas and focus conservation in key biodiversity areas with lower habitat suitability indices. The suitability model can be used to locate and prioritize critical areas that will serve as basis for developing appropriate conservation plans throughout Cebu island.

INTRODUCTION

As vital sources in providing significant ecosystem services and functions, terrestrial forests are often overlooked. Regrettably, their significance is belatedly thought of; only when the rampant degradation becomes more apparent as their roles as a prime source for natural resources and in food security and sustainability are missed. As the need for these ecosystem services increases, more areas of forest ecosystems are converted to other land uses and fragmentation becomes more apparent. The continued degradation of forests, as well as the onset of climate change impacts, prompts the need for timely and scientific approaches to guide conservation targets and policies. Moreover, these conservation decisions must be assessed using a combination of expert knowledge and habitat models (Romero-Calcerrada, 2006).

For this study, we aim to identify a suitable site for threatened species through the use of the focal species concept by Lambeck (1997) which asserts that a certain species or group of species can effectively define environmental limits in their habitat for the protection of other species present in the area. The focal species fundamental to this study is the Cebu black shama (*Copsychus cebuensis*), a Cebu endemic bird species considered rare and endangered with a very small range and population in the highlands of Cebu's remaining terrestrial forests (Malaki et al., 2013). Several studies have focused on birds as bioindicators because they are easy to detect, their ecology is well studied and understood, and their links to the local flora and faunal community has been clearly demonstrated (Padoa-Schioppa et al., 2006; Egwumah, 2017). Using bird species is advantageous when used as bioindicators to appraise the health conditions of their environments since they are capable of taking flight should their habitat's environmental integrity fails to fulfill their functions and requirements.

Geospatial habitat suitability models have proven to be powerful tools in guiding several habitat restoration efforts by integrating different spatial information crucial to the species' requirements (Warren et al., 2016; Theuerkauf, 2019). Some advantages of using habitat suitability models in monitoring and maintaining progress in habitats include: (1) providing a consistent approach for monitoring the priority areas; (2) useful in identifying site-specific limitations when introducing species in certain areas; (3) can be used to track potential habitat goals and deficiencies over time; (4) can be modified to accommodate new information and changing conditions; and, (5) can guide policymakers and area managers to maximize cost-efficiency in the conservation and restoration efforts (Romero-Calcerrada, 2006, Theuerkauf, 2019).

METHODS

Study Area

Cebu Island (10.3167°N 123.7500°E), located in Central Philippines, is flanked by the Bohol islands in the east and Negros island in the west. It has a total land area of 4,468 km^2 and is characterized by its mostly limestone geology with vegetation on its hill zones and coastal plains (Supsup et al., 2016). The island is home to municipalities and component cities with the majority of the population residing in the coastal plains.

Historically, central Cebu's forests used to be covered by dense vegetation of hardwood timber trees like tindalo, molave, ipil, and narra but have since been slowly wiped out due to logging and 'kaingin' (slash-and-burn) activities (Bagarinao, 2010). The remaining strips of forest have since been declared key biodiversity areas to ensure the protection of the remaining biodiversity and the threatened endemic species on the island (Fig. 1).

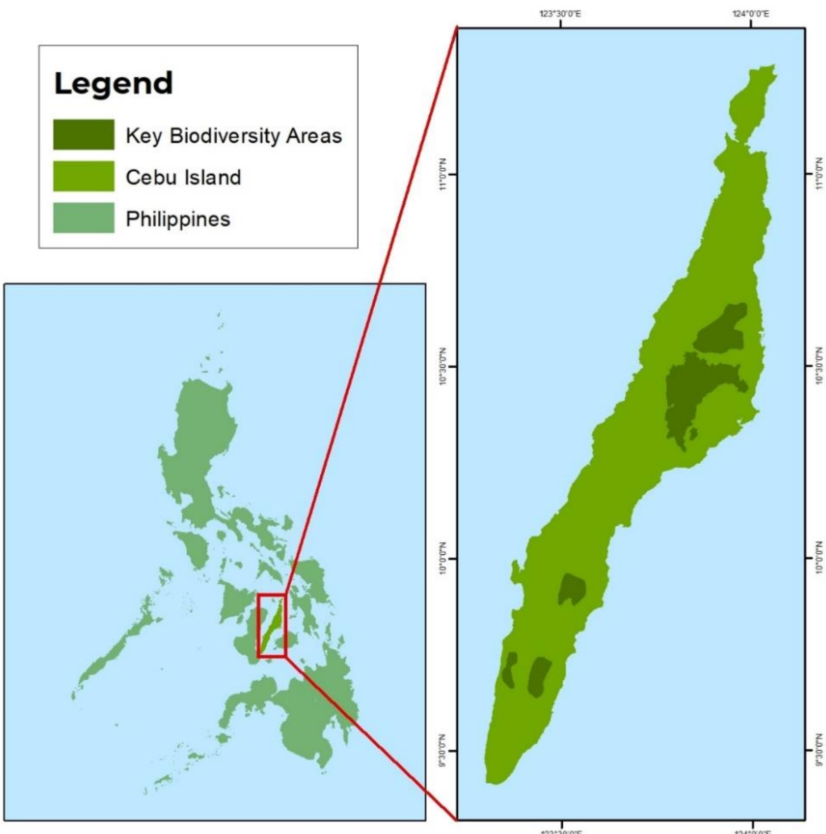

Figure 1. Cebu Island with the terrestrial key biodiversity areas in dark green.

Identification of Variables and Criteria

A multi-criteria approach was explored using a predictive habitat suitability model based on Weights-of-Evidence method through the estimation of a set of environmental predictor variables from GIS and remotely-sensed data. With the use of Bayesian rules, evidence layers in the form of environmental variables were obtained to produce the habitat suitability model for the study (Table 1). Different landscape variables were selected based on the publication by Malaki et al. (2018) on the factors affecting the spatial distribution of the black shama.

Table 1. Description of criteria for the habitat suitability analysis.

Criteria	***Description***
Elevation	Due to vegetation differences associated with elevation
Slope	Valley-bottom sites have higher relative humidity and a higher percentage of canopy cover preferred by the species and its diet
Canopy Cover	Species' sensitivity to forest edges and frequents areas with high percentage of canopy cover
Distance from Stream	Stream geomorphology affects insect influx which is the species' primary diet
Distance from Built-up Areas	Species is an interior forest species with a declining population when in proximity to built-up areas

Data Acquisition and Pre-processing

Various vector and raster datasets of different scales obtained from different sources (Table 2) were used to represent the variables identified as having a significant contribution to the shama's population. Some factors, largely vegetation structure variables, like canopy height, shrub cover, relative humidity, and light intensity outlined in Malaki et al.'s paper, were removed in the analysis due to the unavailability of geospatial datasets for the region.

Table 2. Sources of variable datasets used for the Habitat Suitability Analysis.

Criteria	***Source***
Elevation	IFSAR
Slope	Derived from Elevation Raster
Canopy Cover	Hansen Global Forest Change v1.7
Distance from Stream	Stream Centerlines from Project Digitization
Distance from Built-up Areas	CIESIN x Facebook Connectivity Lab 2015

The datasets acquired, mostly through open-source repositories, were chosen for having the highest resolution available as well as the most recent data. The obtained raw datasets are shown in Figure 2.

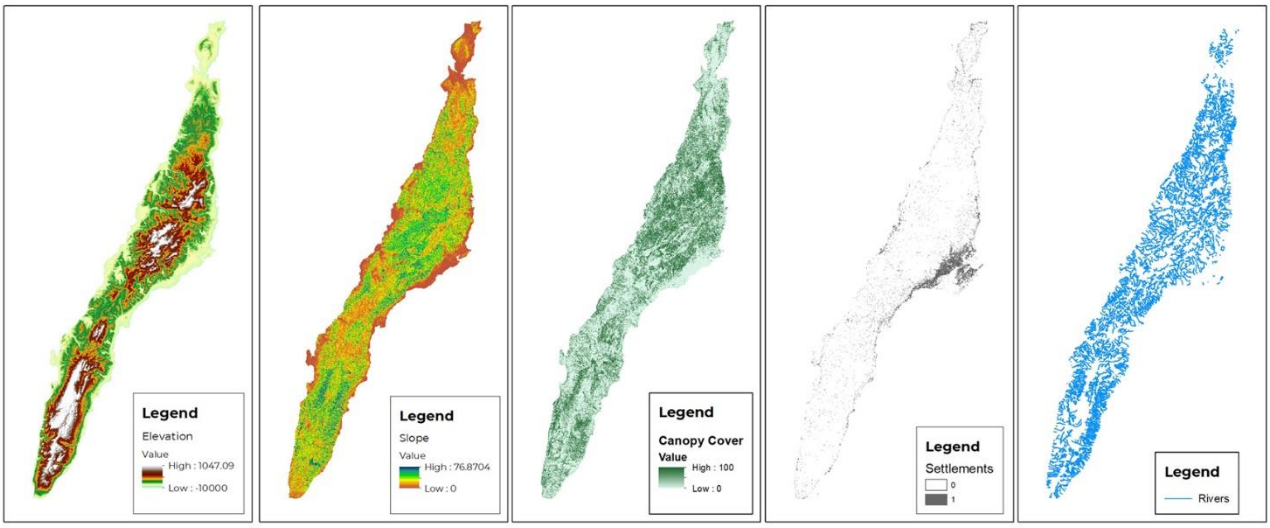

Figure 2. Datasets used for the Habitat Suitability Analysis.

These criteria were then combined in a weighted spatial overlay to produce a single map of probability. Each criterion was weighted based on their causal relation to the black shama's habitat (Table 3). The canopy cover layer was assigned the highest relative importance (weight of evidence) since it was found as the strongest predictor for black shama population density in Malaki et al.'s (2018) study.

Table 3. Environmental criterion used and their significance based on the reference study.

Criteria	***Weights***	***Basis***
Elevation	22%	Positive Significant Correlation
Slope	22%	Negative Highly Significant Correlation
Canopy Cover	39%	Positive Highly Significant Correlation
Distance from Stream	11%	Positive Correlation
Distance from Built-up Areas	6%	Negative Correlation

RESULTS AND DISCUSSION

The resulting maps (Fig. 3) show three ranges of suitability: 3 as highly suitable, 2 as moderately suitable, and 1 as not suitable. As illustrated, the majority of the island is moderately suitable for the black shama as a habitat while only 1% is highly suited for the species (Table 4). Consequently, the same pattern applies to the different key biodiversity areas (KBAs). The majority of the KBAs' extent is only moderately suitable. Meanwhile, areas with high suitability were minimal. Nugas forest shows a different profile with 15% of its extent as highly suitable and 5% as not suitable. Together these results show that there is a necessity to review conservation actions in the key biodiversity areas to improve areas with low suitability and expand highly suitable areas.

Table 4. Area of habitat suitability for Cebu island its key biodiversity areas (KBA)

Name of KBA	Not Suitable		Moderate		High		Total Area
	Area (KM^2)						
CCPL	34.41	11.77%	248.10	84.89%	9.74	3.33%	292.24
Mt Capayas KBA	11.75	8.63%	119.30	87.66%	5.05	3.71%	136.10
Mt Lanaya KBA	2.49	9.50%	21.80	83.17%	1.92	7.33%	26.22
Mt Lantoy KBA	6.80	12.85%	43.91	82.92%	2.24	4.23%	52.95
Nugas Forest	2.47	4.78%	41.60	80.58%	7.56	14.64%	51.62
Whole Island	**941.16**	**21.94%**	**3,294.95**	**76.80%**	**53.91**	**1.26%**	**4,290.03**

Finally, to confirm the accuracy of the output habitat suitability model, we superimposed 113 black shama occurrence points sourced from the Global Biodiversity Information Facility (GBIF, 2020), an open-source database, to validate if shama sightings were indeed in areas that are highly suitable to the species. The occurrence overlay results in 102 points within the bounds of moderately suitable habitats and 11 points on highly suitable habitats while no shama occurrence fell in unsuitable habitat which indicates that our produced model is within a degree of correctness.

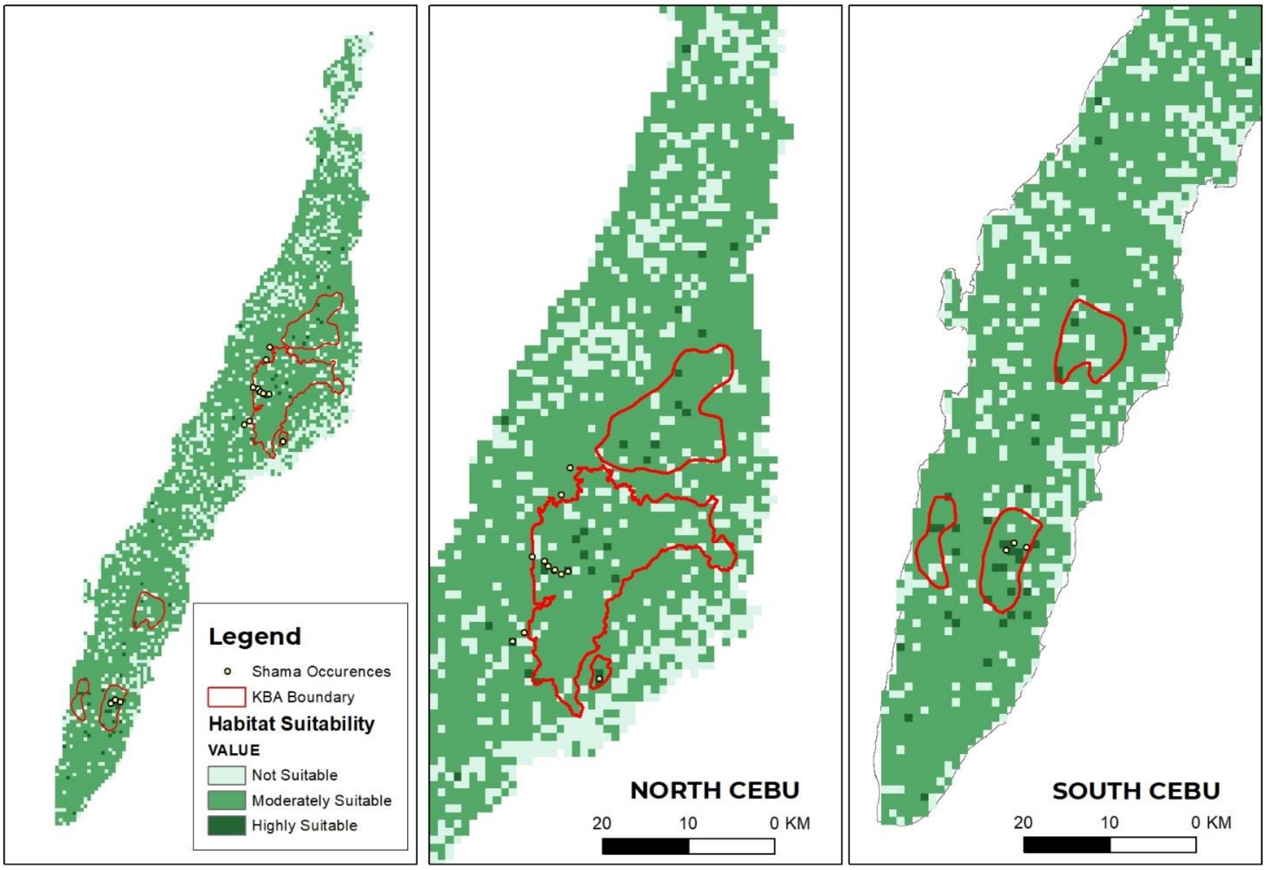

Figure 3. Validation through the overlay of black shama sightings from GBIF

It is evident in the resulting map that the highly suitable areas for the black shama are very scarce (1%) and inadequate to support an endemic species that ought to be protected. This supports previous biodiversity studies in Cebu which disclosed the fragmented and highly denuded strips of forests on the island due to extreme pressures from humans (Bagarinao, 2010; Malaki et al., 2013; Supsup et al., 2016).

SUMMARY AND CONCLUSION

To summarize, this study has assessed the habitat quality of Cebu Island by producing a habitat suitability model of the black shama habitat. In the produced model, the majority of the island especially those in the key biodiversity areas are only classified as moderately suitable (76.8%). Highly suitable areas for the black shama are very limited (1.26%) which indicates the need to expand the priority areas and focus conservation in key biodiversity areas with lower habitat suitability indices. Accordingly, the produced model demonstrates the use of the GIS weights-of-evidence methodology for rapid biodiversity assessment. This can provide decision-makers access to information about the current status of the local ecosystems using a focal species in the area. Similar modeling techniques and maps provide local policymakers and key stakeholders gain a rational basis for conservation and restoration decisions to develop appropriate conservation plans to incorporate impact on species' habitats.

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