RANGE FORECASTING OF AN ENDANGERED ISLAND ENDEMIC BIRD SPECIES USING ENSEMBLE SPECIES DISTRIBUTION MODELING

Isabella Pauline Quijano[1,2], Mary Joyce Flores[1,2] and Chito Patiño[1]
[1]Central Visayas Center for Environmental Informatics, University of the Philippines Cebu, Gorordo Ave., Lahug, Cebu City, 6000, Philippines
Email: ilquijano@up.edu.ph; clpatino@up.edu.ph
[2]Department of Biology and Environmental Science, College of Science, University of the Philippines Cebu, Gorordo Ave., Lahug, Cebu City, 6000, Philippines
Email: mlflores2@up.edu.ph

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ABSTRACT: Habitat and wildlife conservation is becoming more difficult to practice due to increasing human population growth, environmental degradation, and climate change. Fortunately, emerging developments in species mapping have become valuable conservation tools in predicting biological diversity trends and identifying important conservation areas. This study aimed to map the present and future distributions of an endangered endemic bird considered as Cebu Island's flagship species, the black shama (Copsychus cebuensis). Since the black shama's survival is constantly threatened by habitat loss and fragmentation, exacerbated by climate change, consensus range forecasting might help us better understand the suitability of different habitat zones for this endangered species. We developed species distribution models for the black shama which were projected in the current and future scenarios. Future projections were modeled from two 2070 representative concentration pathway (RCP) climate scenarios, with RCP 4.5 as the 'best-case scenario' and 8.5 as the 'worst-case scenario'. Land cover correction was also considered for the future scenarios to restrict projections onto intact habitats. Results showed localized extirpations of the species in the future scenarios with the remaining species populations concentrated near the key biodiversity areas. Future projections also exhibited an inclination of the species towards the south of the island, and occupying a lesser land area compared to the present distribution. With these results, we discussed recommendations for strategic management including opportunities for protected area expansion, potential habitat corridors, and reintroduction areas for protecting the species' metapopulation.

INTRODUCTION

Habitat and wildlife conservation is becoming more difficult to practice due to increasing human population growth, environmental degradation, and climate change. Fortunately, emerging developments in species mapping have become valuable conservation tools in predicting biological diversity trends and identifying important conservation areas.

Birds are bioindicators, which means that researchers may use them to assess the health of their ecosystem. Other species rely on them, which is why they are so essential in biodiversity conservation priorities and among other things, they aid in environmental balance, seed distribution, insect control, and pollination (Clout & Hay, 1989). Furthermore, because they are easily distinguishable, they are key species in assessing the state of their surrounding environment (Mac Nally et al., 2004). Many birds, especially island endemics, are sensitive to even the slightest changes in their environment. Once they find a habitat unsuitable, they leave in search of new territories, and in the worst-case scenario, they may become extinct (Sodhi et al., 2011). Generally, bird communities and their distribution are highly vulnerable to changes in the environment. These include changes in climate, temperature, rainfall, suitable habitat, abundant vegetation cover, and food availability (Goncalves et al., 2017). Furthermore, avians, being consumers, are highly sensitive to changes in the trophic levels below them, particularly in the population dynamics of producers.

Conversely, birds that can tolerate changes in their environment can also be used as indicators of a degraded forest (Canterbury et al., 2000). One such example is the Cebu black shama (*Copsychus cebuensis*), an elusive species that favors forested areas, but have since adapted to disturbed habitats such as scrublands, plantations, and bamboo groves (Kennedy et al., 2000). This study heretofore, aims to map the present and future distributions of the black shama. Since the black shama's survival is constantly threatened by habitat loss and fragmentation, exacerbated by climate change, consensus range forecasting might help us better understand the suitability of different habitat zones for this endangered species. Furthermore, finding the range of this particular bird is critical for the active management of its conservation and for mitigating the threats to its habitat.

In this study, we model the current distribution of the black shama as well as project it in the best and worst case greenhouse gas representative concentration pathway (RCPs) climate scenarios for 2070. To prevent reduce the temporal mismatches between species occurrence and land cover by inaccurately assigning species-habitat associations, we also utilize a corrected land cover dataset for the future scenarios which classifies the current land uses into suitable habitats for the species.

MATERIALS AND METHODS

Study Area

The study area is the island of Cebu (Fig. 1), which is located in the Philippines' central region. With a land area of 4,944 km2, it is the country's ninth biggest island, with six component cities and 44 municipalities. Five terrestrial Key Biodiversity Areas (KBAs) exist on Cebu Island, the largest of which is a protected landscape (Table 1). The IUCN Red List defines a KBA as a bounded site that makes a substantial contribution to world biodiversity. The geology of the area is dominated by ancient rocks such as limestone, conglomerate, shale, sandstone, and basalt. It has a climate with an annual mean temperature of 26.8°C to 29.4°C and a mean annual precipitation of 1,638 mm. (Supsup et al. 2016, Garces et al 2017).

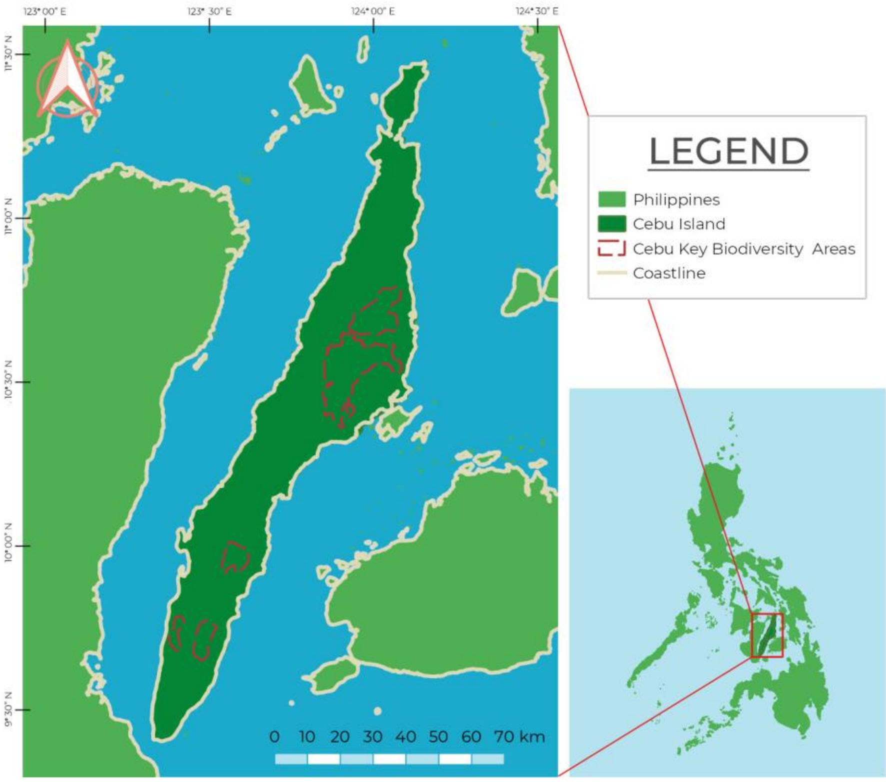

Figure 1. Island of Cebu with its key biodiversity areas relative to the Philippines

Species Distribution Modeling

The species distribution modeling program in the R open-source environment, 'sdm' by Naimi and Araujo (2016) was used to create the species distribution maps. Data pre-processing included clipping, reclassifying, projecting the necessary materials, and, most notably, translating thematic/environmental layers from vector and raster data to ASCII in a GIS context.

The maps were created using an ensemble prediction of a species' presence/absence, which entailed calculating a species' ecological niche based on the contribution of various environmental factors. These biotic and abiotic environmental variables are those that would potentially influence the movement of our modeled species. The occurrence datasets of the cebu black shama, serving as response variables, utilized presence data which were gathered by the Cebu Technological University – Argao NICER Project (data collected between April-July 2018) and from the Global Biodiversity Information Facility (GBIF), an open-source occurrence dataset. We used several layers of abiotic environmental factors sourced from the Worlclim climate dataset (Hijmans et al, 2015), geology, land cover, elevation, and elevation-derived datasets for the predictor variables, which offered landscape-level data to assess the target species' ecological tolerances. These variables are listed in table 2 with their corresponding descriptions below.

Land Cover Correction

Due to the risk of temporal mismatches when using land cover as a predictor variable in future projections, as well as the necessity to account for habitat degradation caused by anthropogenic land use, the distribution models were made using land cover correction to restrict projections onto intact habitats. This was accomplished by masking areas of unsuitable land cover through reclassifying the 2015 land cover dataset from the country's Department of Environment and Natural Resources into suitable or unsuitable types. Table 3 shows the ten different land cover categories in the island and their suitability for the black shama which can be seen in the accompanying figure 2. For the reclassification, anthropogenic land use types such as plantations, croplands, or built-up regions were judged unsuitable while natural land cover types with intact habitat was considered suitable (Pang et al, 2019).

Table 1. Land Cover Suitability

Land Cover	***Suitability***
Open Forest	Suitable
Brush/ Shrubland	Suitable
Mangrove Forest	Unsuitable
Grassland	Unsuitable
Inland Water	Unsuitable
Fishpond	Unsuitable
Annual Crop	Unsuitable
Perrenial Crop	Unsuitable
Built Up	Unsuitable
Open/ Barren	Unsuitable

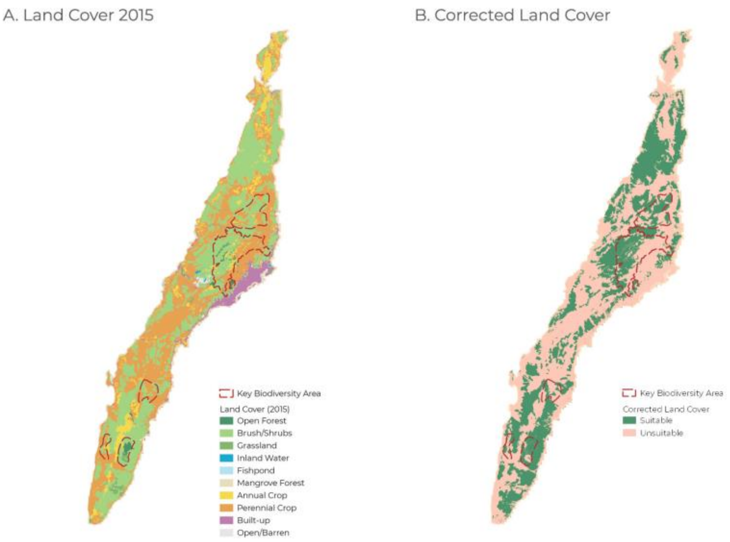

Figure 2. Corrected Land Cover

Climate Variables

Bioclimatic variables were obtained from Worldclim 1.4 (Hijmans et al, 2005) at a resolution of 30 arc seconds, which served as the basis for the species current range predictions. Subsequently, we did a pairwise analysis to eliminate out strongly linked variables by running a Pearson's correlation analysis ($|r|>0.75$). Through this, we retained the climate variables: Bio 4, Bio 7, Bio 9, Bio 13, Bio 18, Bio 19.

Table 2. Environmental factors considered for the species distribution modeling.

Environmental Layers	*Variable*
Elevation	LiDAR elevation dataset from Cebu Province
Slope	Elevation-derived dataset
Aspect	Elevation-derived dataset
Geology	Geology Dataset from the Department of Agriculture
LCC	Land cover suitability
WorldClim Climate Dataset	
Bio 4	Temperature Seasonality (standard deviation *100)
Bio 7	Temperature Annual Range (BIO5-BIO6)
Bio 9	Mean Temperature of Driest Quarter
Bio 13	Precipitation of Wettest Month
Bio 18	Precipitation of Warmest Quarter

Bio 19	Precipitation of Coldest Quarter

Future projections for modeling the effects of climate change were modeled from two 2070 representative concentration pathway (RCP) climate scenarios. According to the future climate scenarios, global annual greenhouse gas (GHG) emissions would peak in 2040 and then decline considerably for RCP 4.5, or will continue to increase until 2070 for RCP 8.5, reflecting a "best-case" and "worst-case" scenario, respectively. In the Philippines, climate change is predicted to increase mean temperatures by 0.9–1.9°C (RCP 4.5) and 1.2–2.3°C (RCP 8.5) with more extremes and variations, as well as increase mean precipitation with more frequent and intense severe rain events (Pang et al, 2019). The climate projections used for the study as shown in table 3 below, was an ensemble of IPPC5 climate projections of different global climate models (GCMs) from the CMIP5 dataset at 30 second spatial resolution, these GCMs, calibrated after the worldclim 1.4 dataset by Hijmans et al (2005), are listed in table 3 below.

Table 3. Global climate models (GCMs) used for the study

Code	***GCM***	
CN	CNRM_CM5	Centre National de Recherches Météorologiques, Climate Model version 5
HG	HadGEM2-CC	Hadley Centre Global Environment Model version 2 CC
MP	MPI-ESM-LR	Max Planck Institute for Meteorology Earth System Model LR
AC	ACCESS1-0	Australian Community Climate and Earth System Simulator, ACCESS 1-0
HE	HadGEM2-ES	Hadley Centre Global Environment Model version 2 ES
CC	CCSM4	Community Climate System Model version 4
MI	MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology Earth System Model Chemistry

Model Evaluation

The model evaluation used for the study was the bundled evaluation package, and was done to select model parameters that enabled the most efficient model performance. Models were clamped to training conditions to avoid extrapolation uncertainty. Thirty per cent of the occurrence data points were randomly held back for model calibration and the model was trained on the remaining seventy percent of the occurrence data. The resultant model performed well under cross validation and evaluation statistics. In the final model, the AUC-ROC value was 0.953 for the present climate conditions and 0.936 and 0.923 for the RCP 4.5 and RCP 8.5 future climate conditions which indicates high predictive ability for all models.

RESULTS AND DISCUSSION

The results showed rather disheartening results, with the species range rapidly declining with increased temperatures in 2070. Results showed localized extirpations of the species in the future scenarios with the remaining species populations concentrated near the key biodiversity areas and migrating to the coastlines. Future projections also exhibited an inclination of the species towards the south of the island, and occupying a lesser land area compared to the present distribution. The resulting range predictions can be seen in the subsequent figure 3.

The current distributions of the species are seen to be highly concentrated within the boundaries of the key biodiversity areas (marked with red dashed boundaries in figure 3 below) and more prominently in the southern KBAs with high probability of occurrence in the forested mountain ranges between the south-eastern KBAs. This can be attributed to the existing parcels of forest corridors in the area and can be validated through their greater abundance in field observation within these KBAs. The northern areas have practically no ranges of the species which can be attributed to the lower elevations in the area with higher annual temperatures. Similar observations of the current ranges can be seen in the future climate scenarios albeit with lesser degrees of probability.

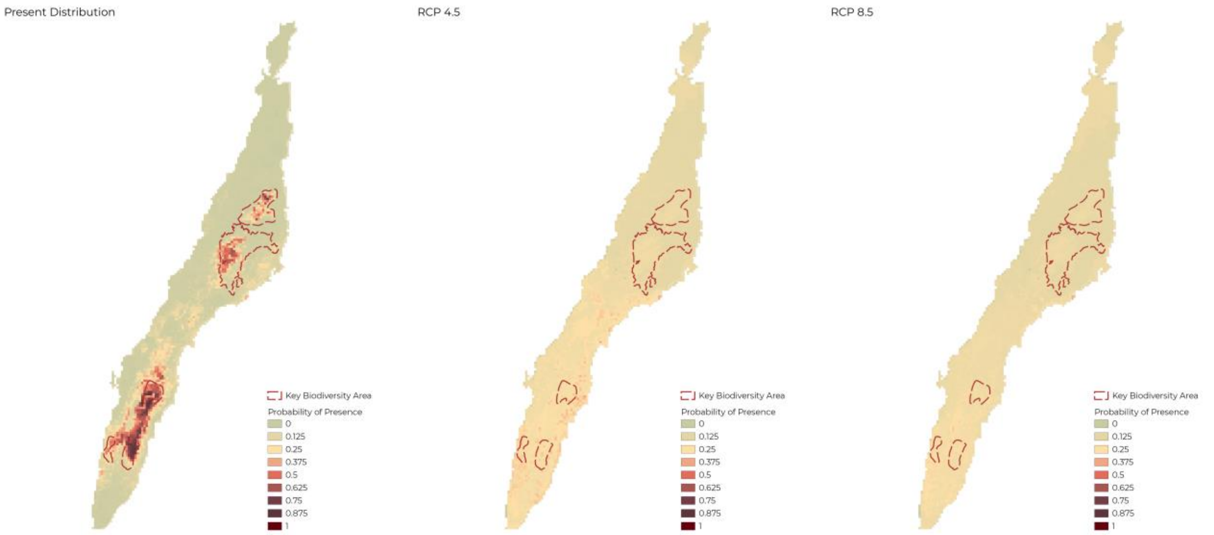

Figure 3. Black Shama ranged distribution in the current climate conditions compared with the RCP 4.5 and RCP 8.5 range predictions

Fortunately, albeit the species ranges being more minimal compared to the current ranges at higher probabilities, we can still see 50-75% probabilities of the species speckled in the southern parts of the island. Seen more evidently in the best-case scenario of RCP 4.5, species probabilities can be visible within the key biodiversity area boundaries across the island with higher probabilities seen towards the mountain ranges in the central-south of the island. The same can be observed for RCP 8.5 albeit having lesser distribution probabilities in the middle-eastern portion of the island and with lesser specks of ranges dispersed.

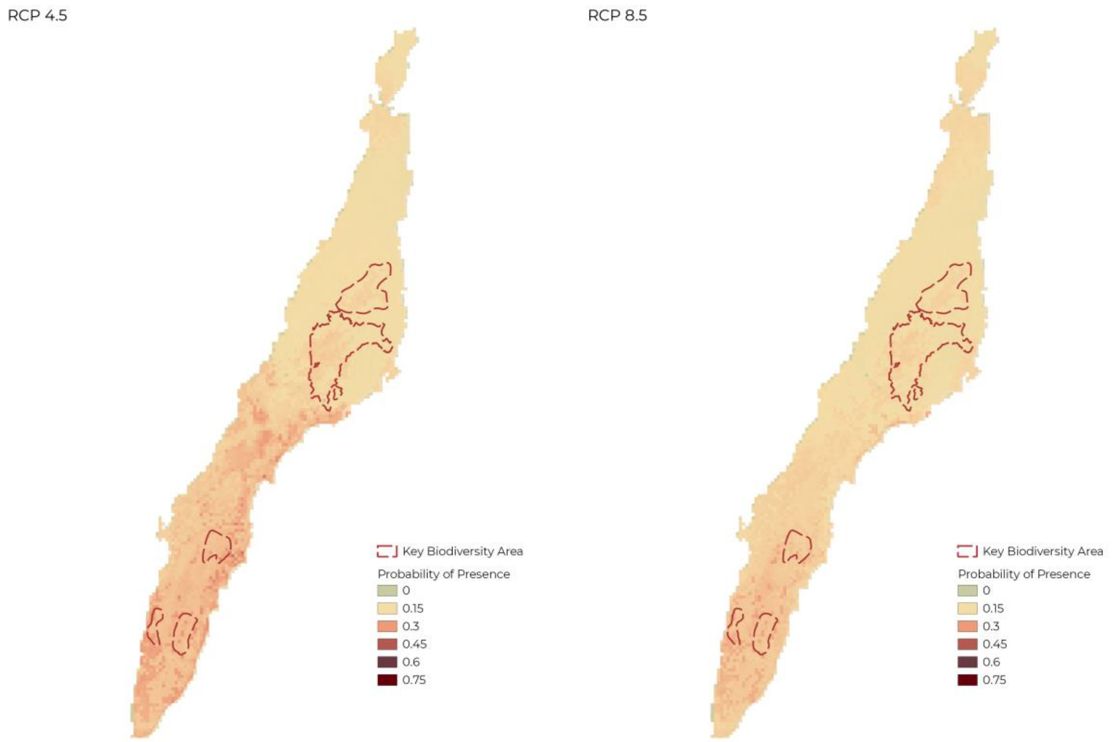

Figure 4. Comparing the future climate range distributions for RCP 4.5 and RCP 8.5 predictions

Here, we demonstrate how readily available environmental variables can be used to develop SDMs that describe the range distribution of an island endemic bird species – the Cebu Black Shama. The model trained on field occurrence data from across Cebu island, successfully developed models for current and future climate scenarios. With the garnered information from the results, these could be used to refine management plans for the active management of this threatened endemic species based on its projected geographic distribution.

As observed in the current climate projections, the ranges of the shama are greater and have have higher probabilities in the southern KBAs, these ranges serves as opportunities for protected area expansion especially for the areas between the south-eastern KBAs with patches of forest corridors that can be reinforced with more environmental activities. These areas could be projected to be biological refugia to the modeled species as well as other local endemic species based on the observed current and climate projections on its suitability. Prioritizing conservation activities in these biologically important areas, which serve as the remaining bastions of high biodiversity in the island, is critical, particularly those deemed as potential refugia for the threatened endemic species. Efforts to repair and extend the island's denuded forests should be continued not only for the conservation of these important species but more importantly to assist these ecosystems perform their critical services like regulating roles, such as reducing floods and increasing water recharge.

Another notable observation discerned from the predicted ranges is the lack of a continuous distribution over a large area. Consistent with the current projections and observed field datasets, populations of the black shama are restricted to the remaining forest patches in the highlands in the middle of the lanceolate island. Metapopulations of the species can be distinctly seen in the KBAs throughout the island, which provides them the last tracts of remaining suitable habitat. Using the environmental factors of the species ranges to build management plans to accommodate transitions through a changing landscape can successfully promote proactive rather than reactive management. Furthermore, characteristics such as trophic rewilding, nursery establishment, and reintroduction of the species into neighboring forest areas might be investigated further to improve the species' chances of survival. We urge protected area managers and conservation researchers and organizations to use species distribution models to discover characteristics that may be adjusted to change the suitability of managed lands to wildlife populations while still maintaining the required ecosystem services. With ecosystems worldwide increasingly affected by human-induced global change rapidly affecting ecosystems throughout the world, including over-exploitation of living systems, increased temperature, eutrophication, and the spread of alien species, culminating in an ecological emergency, scientific and evidence-based solutions must be made in earnest.

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