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Palawan Peacock Pheasant (*Polyplectron napoleonis*) Species Distribution Modeling: A Review of the Impact of Typhoon Rai/Odette on the Diversity and Distribution of an Endemic Bird Species

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Abstract

This study quantified the habitat requirements and, consequently, described the remaining suitable habitats through species distribution modeling of *Polyplectron napoleonis* within Cleopatra's Needle Forest Reserve and Puerto Princesa Subterranean River National Park after the onslaught of Typhoon Odette in the Palawan region. This was accomplished using MaxEnt software, a statistical machine-learning algorithm that creates niche models with presence-only (PO) data and surrounding environmental variables (Dudik et al., 2007; Merow et al., 2013). Previous studies have identified precipitation, elevation, and land cover as the top environmental variables influencing *tandikan* habitat suitability, as revealed by their percent contributions. There were earlier claims of the noticeable movement of habitat-suitable areas to the fringes and beyond Cleopatra's Needle Forest Reserve. The migration seems to be going towards highland forests. Two factors could be behind this migration: the *tandikan* are responding to climate change or avoiding human disturbance. As this species is known to have a high tolerance for temperature change, the latter could be the more plausible factor. For 2022, post-Odette, MaxEnt analysis revealed a shift of percent contributions with elevation and land cover classification outranking aspect and slope. Environmental layers were limited to four, as these were the only currently available data. This shift in percent contributions could be linked to the direct damage to forests brought by the Typhoon in December of 2021. The land cover map generated for this year has shown large areas of forests that were converted into non-forests. Conservation efforts, therefore, for the *tandikan*, a forest species, should be recalibrated in response to this current development. Further, measures to mitigate the impact of solid typhoons on forests should be reviewed and evaluated.

***Keywords*:** MaxEnt, species distribution modeling, Palawan Peacock Pheasant, endemic species

Background of the Study

Bioinformatics, the study of information processes in biotic systems, has become a significant tool in understanding the impact of climate change. Complex and large biological data sets could now be analyzed and simplified using algorithms and computational and statistical techniques, leading to the accurate and science-based formulation of policies and actions that could mitigate the alarming effects of the warming climate. In this study, bioinformatics was used to understand how a strong typhoon, a known consequence of a warming climate, has affected the habitat suitability of an endemic bird species in Palawan, the *tandikan*.

Palawan, a biodiversity-heavy region, is rarely hit by solid typhoons as it is conveniently situated in the western part of the country, shielding it from the Pacific Ocean, as does mainland Luzon to its right. In recent years, typhoons that make landfall significantly weaken before reaching Palawan. However, this was not the case for the super-typhoon *Rai* (local name Odette), which caused severe damage in the region in December 2021. It was even predicted that this is just the beginning of stronger typhoons entering the region due to climate change, a cumulative effect of deforestation, exploitation, and over-extraction of natural resources. Through MaxEnt software, a machine-learning tool, the impact of the typhoon on the diversity and distribution of an endemic bird species in Palawan, the Palawan peacock pheasant (*Polyplectron napoleonis)*, was empirically deduced using global data sets from the Global Biodiversity Information Facility (GBIF) and WorldClim.org.

The logo of Puerto Princesa was inspired by the Palawan peacock pheasant, a bird species endemic to the humid forests of Palawan Island in the southern Philippines. Surveys conducted in 1985 suggested that there were 13.8 males per km^2 in primary forest and 8.5 per km^2 in forests logged ten years before. However, subsequent research in 1988 found the density to be 18.12 individuals per km2. The population of this bird species is estimated to be less than 10,000 due to its sedentary nature and the fragmentation of its lowland habitats, which are prone to degradation and loss. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species identifies this bird species as vulnerable due to the dwindling of its known forest habitats (BirdLife, 2020).

The IUCN elucidates the criteria for classifying a taxon as vulnerable. They are the following: a) reduction in population size by 30-50% over the last ten years or three generations (whichever is longer), which could be directly observed as linked to the quality of habitat or decline in area of occupancy, b) geographic range with proof of severe fragmentation, extreme fluctuations, continuing decline, area, extent, and quality of habitat, as well as the number of its locations and mature individuals, c) population size that is estimated to be fewer than 10, 000 mature individuals and which could be attributed to an estimated continuing decline of at least 10% within ten years or three generations, d) population that is very small or restricted which could be attributed to a very restricted area of occupancy, and locations (5 or less) that may be prone to human pressure and uncertainties; and lastly, e) a quantitative analysis which shows the possibility of extinction in the wild of at least 10% within 100 years (IUCN Red List, 2016).

The *tandikan* is endemic to only one island in the Philippines, Palawan. There are five areas in Palawan with *tandikan* sightings, namely Mount Mantalingahan, Puerto Princesa Subterranean River Natural Park/ Cleopatra's Needle Forest Reserve, San Vicente- Taytay-Roxas forests and Victoria and Anepahan Ranges (BirdLife, 2023). It's percent of occurrence in all these five areas is described as either "present" or "frequent" by the IUCN as of 2001.

The study is limited to the Puerto Princesa Subterranean National Park and the Cleopatra's Needle Forest Reserve as these two sites have verified presence records available through the Center for Conservation Innovations, Ph. (CCIPH).

Statement of the Problem

This paper quantifies the habitat requirements and describes the remaining suitable habitats of *Polyplectron napoleonis* by constructing a species distribution model using the MaxEnt software. Environmental conditions and *tandikan* presence records in two sampling sites, the Cleopatra's Needle Forest Reserve and the Puerto Princesa Subterranean Park, were sourced from WorldClim.Org and Global Biodiversity Information Facility (GBIF) for the period 2021-2022. These two websites are globally acknowledged public ecological mapping and spatial modeling data sources.

The following research questions are formulated to meet the abovementioned goal:

1. What are the habitat requirements of *Polyplectron napoleonis* using known environmental records as predictors?
2. Where are the remaining suitable habitats of *Polyplectron napoleonis* based on climate and land cover changes?

Statement of Specific Objectives

Here are the research objectives:

1. Develop ecological models for *Polyplectron napoleonis* using floristic and environmental data from observed sites.
2. Create a predictive model for species distribution using bioclimatic variables and geo-referenced local observations.

Significance of the Study

Through the use of the bioinformatics tools, MaxEnt and QGIS, empirical knowledge on how a strong typhoon, a known consequence of a warming climate, impacts the species distribution of one endemic species, the Palawan peacock pheasant (local name is *tandikan*) could be produced. This endemic bird is found in Palawan, a biodiversity-rich region rarely hit by strong typhoons. As deforestation, over-extraction of natural resources, and exploitation of flora and fauna in the region continue, strong typhoons are predicted to pose an even more significant threat to its already threatened biodiversity.

Review of Related Literature

Polyplectron napoleonis' taxonomy, morphology, temperature tolerance, and diet were ascertained to understand the taxon in focus. Information on its breeding, known habitats, and requirements were likewise reviewed and linked to its vulnerability status. Further, as the approach used in quantifying habitat requirements and describing suitable habitats was through species distribution modeling, studies that used the same were presented.

Taxonomy

Polyplectron napoleonis was named by R. Lesson in 1831 based on a specimen painted in the hands of a descendant of Napoleon Bonaparte's marshals (Dickinson, 2001). Its name underwent several changes, with the subspecies name *napoleonis* remaining correct as it is the oldest. In 1832, it was renamed *Polyplectron emphanum Temminck*, but this was changed back to *Polyplectron napoleonis* (*Polyplectron napoleonis*, Lesson, 1831 in GBIF Secretariat, 2022). Its English names are Palawan peacock pheasant (*Polyplectron et al.*, 1831 in National Museum of Natural History, Smithsonian Institution, 2023), Palawan peacock-pheasant (*Polyplectron* *napoleonis*, Lesson, 1831 in Miller S, Rycroft S. Colaboraciones Americanas Sobre Aves. Scratchpads, n.d.) and Napoleon's peacock pheasant (BirdLife International, 2018). In the Philippines, its local name is *tandikan* (Melendres, n.d.).

The British Museum is said to have had a specimen collection before 1863, but its true origin remains unclear. In 1878, 1887, and 1888, Tweeddale, Whitehead, and Platen presented fresh specimens from Palawan showing Indian males with white superciliary narrow stripes, triangular white cheek patches, and white ear- coverts. The Menage Expedition of 1894 obtained additional specimens again in Palawan, affirming the same white facial markings earlier noted by Tweeddale, Whitehead, and Platen (Dickinson, 2001).

This bird is known by two names, *Polyplectron emphanum* or *Polyplectron napoleonis*. However, experts prefer the latter. It belongs to the Phylum Chordata, Class Aves, and Order Galliformes. Understanding the relationships between members of the Galliform phylogeny is important because 26% of its 290 species are at risk of extinction, compared to 12% of all bird species. However, recent studies have produced incongruent or unclear results.

This bird is a member of the Phasianidae family, which also includes turkeys, grouses, and partridges. The family has a complex genetic makeup due to its intricate matrilineal (mtDNA) genealogies based on nuclear DNA retrotransposable elements. This bird belongs to the Polyplectron genus and shares characteristics with seven other peacock pheasant species. These species are part of a larger clade that includes Argusianus, Pavo, and Afropavo. They are found across Southeast Asia and form a monophyletic group.

Morphology

The Palawan peacock pheasant is a stunning bird with a striking appearance. The male of this species has a mantle that features a beautiful blend of blue and green feathers, complemented by distinct black underparts. It boasts a unique and eye-catching black-and-white pattern on its face, further accentuating a long, pointed crest. The mantle and wing coverts of the male are metallic blue with purple reflections, while its back, rump, and tail are black with rusty brown spots. It also has two to three spurs on each leg.

In contrast, the female Palawan peacock pheasant is typically smaller and brown, with scattered buff markings and a brownish-white face and throat. It is smaller, with no spurs, and is mainly mottled brown with a brown crest that is not as visible as the male. Its face and throat are whitish, and its tail is much shorter than the male's, with faint ocelli on the feathers. Both sexes have black bills and brown feet (Coym, 2017; Palawan Peacock Pheasant, n.d.). On average, males measure 20 inches and weigh 21 ounces, while females measure 16 inches and weigh 18 ounces (Coym, 2017; Palawan peacock pheasant, n.d.).

The Palawan peacock pheasant is often considered the most beautiful peacock species, and it is easy to see why. The male's colorful plumage is a feature of sexual dimorphism, which refers to the differences in physical characteristics between males and females of the same species. The male's colorful feathers are used to attract a mate and are truly a sight to behold (Britannica, 2023; Durell et al., 2002; Woodland et al., 2001).

The lifespan of peacock pheasants in the wild is not yet known. However, in captivity, males have been recorded to live up to a maximum of 24.6 years, while females can live up to 21.8 years. These findings are from studies conducted by Coym (2017), Palawan et al., and Friends of the Rosamond Gifford Zoo Education Volunteers (2006).

Peacock pheasants may resemble peafowl, but they differ in the patterns on their feathers. These birds have different types of feathers, including tail feathers, tail coverts, flight feathers, wing coverts, and mantle feathers. The eight species of peacock pheasants have varied distributions of the size and color of these patterns on their feathers. These differences are mainly attributed to the mating and courtship display successes of male peacock pheasants, as noted by Johnsgard (1986).

Peacock pheasants have large, squarish wings, and their tails consist of 22-24 elongated feathers adorned with ocelli. According to Bush and Strobeck (2003), tails are crucial for peacock pheasants as they use them for sustained flight, socialization, and anti-predatory behaviors.

Demographic Distribution and Breeding Information

The Palawan peacock-pheasant is a small bird species. Males weigh an average of 436 g, while females weigh 322 g (Dunning, 2008, as cited by Brooks & Miranda, 2015). They are native to the rainforests of the Palawan Island Group, specifically the humid coastal lowland forest and deep forests. The species can be found in forest patches at Danlig in the north and in the Pagdanan Range (BirdLife, 2003).

It is a monogamous bird with several different vocalizations. Females make a prying sound to alert chicks to the presence of food, while males hiss to indicate courtship (Brooks & Miranda, 2015). The species has a clutch size of 2-4 eggs, with an average incubation period of 19-20 days (Enchanted Birds, n.d.). Male Palawan peacock pheasants reach sexual maturity at approximately one year of age but only begin breeding when they reach three years old and their full adult plumage has developed, a characteristic it shares with other peacocks. In contrast, females begin laying eggs at approximately two years old (Holmes, 2012). Nesting can occur both on the ground and above it, and the clutch typically consists of off-white eggs that are exclusively incubated by the female for 18-20 days (Glenn, 2006). Its chicks are born in a precocial or advanced state. This ability enables them to keep their bodies reasonably warm without heat from an incubating parent, in this case, the hen. These chicks can also feed themselves, but the hen will lead them towards food and protect them for several weeks. When it comes to keeping this species in captivity, it is recommended to house them individually. This is because having them in groups may make the males aggressive towards one another and even their young. It is suggested that demographic and genetic goals be set. Offspring are expected to remain within their natal group. Males and females with unknown pedigrees may breed together. These measures will help ensure the safety and well-being of this species in captivity.

Temperature tolerance, diets, and life expectancy

These birds can handle temperatures from 20 to 110 degrees Fahrenheit. They have heated sheds to stay warm and can be kept indoors on colder days. Wild Palawan peacock pheasants are folivores, or they prefer eating leaves, while those in captivity may also eat pellets and crickets. It is not known how long they live in the wild, but in captivity, they can live up to 15-24.6 years.

Habitat Associations and Requirements

Palawan peacock pheasants can be found in lowland, primary, and secondary forests up to 800 meters above sea level on flat, undulating terrain. However, records show they have also been spotted in forests above 1200 meters above sea level. Unfortunately, the widespread clearing of their lowland habitats has increasingly restricted their population to hill forests (Mallari, et al., 2011).

Lee et al. (2000) investigated the habitat preferences and population density of the Palawan peacock pheasant and found them in all types of forests. The study was conducted at five sites in Palawan: St. Paul Subterranean River National Park (SPSRNP), Panaguman Marofinas, Port Barton, Trident Narra, and Dumanguena, Aborlan. The researchers used multiple logistic regression to compare the differences between "positive" (pheasant recorded) and "negative" (pheasant not recorded) observations. This study considered eleven habitat factors to link the habitat conditions and requirements of *Polyplectron napoleonis* (Palawan peacock pheasant) with the presence of its species. These factors included mean gradient, percentage covers of vegetation at the canopy, mid-storey, shrubs, mean girth at breast height (gbh) of the two largest trees, number of fallen trees > 1.6 mgbh, number of trees of gbh < 0.8 m, number of trees of gbh > 0.2 m but < 0.8 m, number of saplings of gah < 0.2 m, and the number of palms > 2 m tall. This study seems to be the most recent in terms of modeling the distribution of the Palawan peacock pheasant.

Puerto Princesa Subterranean River National Park

The Puerto Princesa Subterranean River National Park plays a crucial role in the preservation of wildlife. Encompassing a diverse ecosystem spanning from the mountains to the sea and comprising eight distinct forest types, the park is renowned for its unique tree species and holds the distinction of being the largest and most significant limestone forest in Asia. Moreover, it boasts the longest navigable river, serving as a sanctuary for numerous at-risk plant and animal species (Acero, 2020). Its wet season is generally overcast, with the sky completely covered with clouds and with not much light. On the other hand, the dry season is windy, mostly cloudy, hot, and oppressive year-round. The temperature rarely drops below 73°F or rises above 92°F, with the year-round temperature typically varying from 76°F to 90°F (WeatherSpark, n.d.).

Cleopatra's Needle Forest Reserve

The Cleopatra's Needle Forest Reserve (CNFR), also known as the Cleopatra's Needle Critical Habitat (CNCH), is one of the country's oldest and most diverse forests. It is home to numerous endemic species and is of significant ecological and environmental importance. Therefore, it was declared a critical habitat for specific animal species (Ramos, 2019).

Unlay (2021) asserts that Cleopatra's Needle is the largest critical habitat in the country, spanning an impressive 41,350 hectares. It is the ancestral domain of the Batak, an indigenous group, and provides a habitat for a wide array of endemic species of flora and fauna, including the Palawan pangolin (*Manis culionensis*) and Palawan Forest turtle

(*Siebenrockiella leytensis*). Moreover, this area, as well as the entire province of Palawan, is teeming with diverse wildlife species, such as the Palawan hornbill (*Anthracoceros marchei*) and Palawan peacock pheasant (*Polyplectron napoleonis*).

Species Distribution Modelling

Species distribution models (SDMs) are utilized to predict the presence of a particular species by analyzing correlations between environmental variables and geo-localized species records. However, SDMs have limitations. For instance, they may fail to evaluate the relevance of variables before selecting them to fit their models, and they may not account for the fact that multiple variables, such as climate and land use, can drive species distribution at different spatial scales without respecting their operating scale.

To address these limitations, a three-step framework has been proposed. Firstly, SDMs select the most relevant climatic variables to predict a given species distribution at a continental scale. Secondly, species and area-specific habitat filters are created locally by characterizing the species-habitat relationships. Lastly, the two pieces of information are combined to refine climatic predictions according to habitat compatibility. This approach has been employed to integrate multiple drivers while maintaining their scale of effect, resulting in a potential range 55.9% smaller than predicted using the climatic model alone for the invasive species *Vespa velutina nigrithorax* (Asian hornet).

Trophic rewilding, also known as species reintroduction, aims to restore self-regulating and diverse ecosystems using species distribution modeling (SDM). Human-induced climate change poses a significant threat to global biodiversity and ecosystem functions, and SDM is considered a forward-looking approach to ecological restoration because it can provide detailed predictions of environmental suitability for species.

A study was conducted on *Swertia bimaculata* (double-spotted Swertia) in Darjeeling, Sikkim, Eastern Himalayas, using MaxEnt software for species distribution modeling. Future climate scenarios for 2050 and 2070 were postulated using geo-referenced data and bioclimatic variables. The study showed a low and sporadic species distribution within the study area. The habitat's size decreased from 869.48 to 0 km² in future climate scenarios, indicating the species' increased vulnerability to extinction.

Polyplectron napoleonis, also known as the Palawan peacock-pheasant, is an important endemic species found in the Palawan Islands in the Philippines. The species is known for its courtship and mating behaviors, which involve a flamboyant display of tail colors in males, similar to peacocks. Despite their fascinating characteristics, they are physiologically vulnerable due to their monogamous practices, limited egg hatching (up to 4 per season), and their preference for thriving in deep forests. Their lifespan and existence in the wild remain ambiguous as they are elusive birds. The forest habitats of these birds are threatened by deforestation and illegal logging. An assessment in Palawan, Philippines, suggests that these forest ecosystems are suitable for this bird group as they are folivores. The prevailing humid temperatures and overcast weather may not make them vulnerable, but extreme weather and temperature changes could pose a threat.

The researcher employed species distribution modeling with MaxEnt software to predict the species distribution of *Polyplectron napoleonis* and quantify its habitat requirements. By utilizing the most current floristic and geo-referenced data of its known habitats in Palawan, Philippines, potential remaining habitats are identified. This is crucial for protecting its current population and avoiding extinction. It is acknowledged that there are many challenges to overcome in managing and rehabilitating its natural habitats in Palawan.

Methodology

This study utilized a predictive modeling approach to determine species distribution based on the environmental conditions of known occurrence sites. This technique is crucial in analytical biology and has practical conservation and reserve planning applications. This method has been extensively researched and cited in various studies, such as Corsi et al. (1999), Peterson & Shaw (2003), Peterson et al. (1999), Scott et al. (2002), and Yom-Tov and Kadmon (1998) as cited by Sambale et al. (2012).

In extracting data from the research questions mapped, species distribution modeling (SDM) was performed using the maximum entropy algorithm (MaxEnt) software. Four bioclimatic variables in the two sampling sites in Palawan, namely Cleopatra's Needle Forest Reserve and the Puerto Princesa Subterranean River Park, were sourced from WorldClim.org for 2020-2022. These variables are elevation, slope, land cover, and aspect. These are suggested for determining species-habitat relationships in tropical environments (O'Donnell & Ignizio, 2012).

Honesty and ethics were observed in all activities related to this research, with consent sought from the Research Ethics Board of the

University. At the same time, the data gathered, methods, and results were without conflict of interest with any individual or institution.

Data Preparation

Following Supsup's (2014) methods, a predictive model was created to quantify the habitat requirements of *Polyplectron napoleonis*:

Species data of the Palawan peacock pheasant were obtained from the Global Biodiversity Information Facility (GBIF) and outlined to set the geographic coordinates where species have been recorded. Each record must be distinct, reliable, and accurate to avoid errors. Ribeiro et al. (2022) see data quality as dependent on the integrity of the risk status given to a species. The study magnified that the GBIF-provided data may provide an overestimation but could still be considered 66-75% accurate and 89-98% specific. Citizen science data, on the other hand, shows 51-62% accuracy (Bueno et al., 2017). From this same study, the correlation between globally referenced data and citizen science data is culled to be 72% out of 81 pairings analyzed. However, the positive correlation ascertained is said to be weak. These two (2) approaches in data gathering were considered in this study, with GBIF records providing the species presence identification and the CCIPH and SIBOL as local data sources. Twenty (20) presence records were used for the post-Odette SDM Scenario (2022).

Environmental variables in raster and vector formats were then identified from WorldClim.org, and the researcher used a raster grid as input.

Consequently, the species distribution models were initiated through MaxEnt. The researcher underwent two weeks of training on setting parameters for downloading data inputs, validating them using local data from CCIPH and SIBOL, and eventually using these same inputs using MaxEnt and QGIS software. The MaxEnt software could easily detect errors in the form of record duplicates. Biases and potential prejudices were identified and removed during the initial review and the final processing of the model.

MaxEnt Data Features and Validation

The MaxEnt output model algorithms use binary outputs, i.e., 0,1, which indicate the relative likelihood of species' presence or habitat suitability.

A model fit metric is generated to evaluate the fitness of data entered in the MaxEnt software, called the Area under the receiver-operator curve

(AUC). It is described as a “threshold-independent measure of predictive accuracy based only on the ranking of locations and is interpreted as the probability that a randomly chosen presence location is ranked higher than a randomly chosen background point (Merow et al., 2013).”

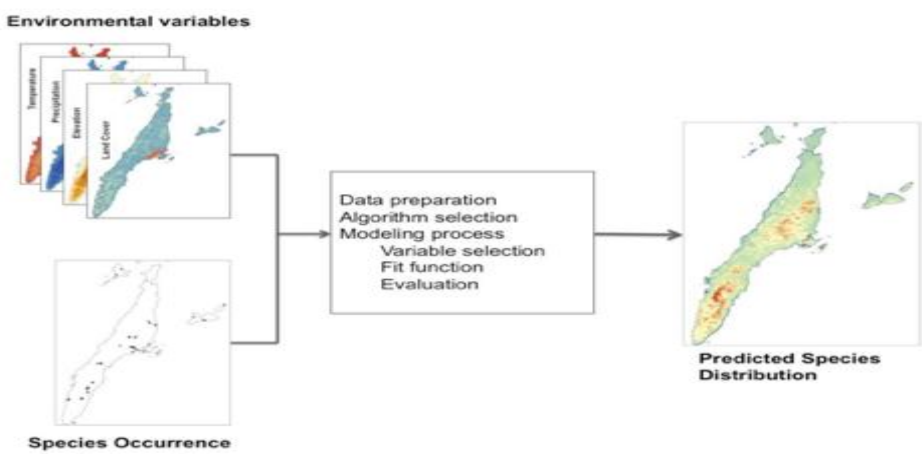
The MaxEnt output is summarized in a table where estimates of relative percent contributions of the environmental variables are placed. To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable or subtracted from it if the change to the absolute value of lambda is negative. For the second estimate, the values of that variable on training presence and background data are randomly permuted for each environmental variable in turn. Values shown are averages over replicate runs.

MaxEnt could also predict a variable’s permutation importance. Permutation predicts how many ways a particular set could be arranged (Hoang, 2014), while permutation importance directly measures variable importance by observing the effect on model accuracy of randomly shuffling each predictor variable (Parr et al., 2018). It provides a good foundation for understanding all the possible ways the variables could be arranged, called probability distribution, in the predicted model.

The researcher generated a predicted species distribution model for *tandikan*, guided by a systematic organization of environmental variables and species occurrence data and application of MaxEnt.

Figure 1.

Process illustration of species distribution modeling (Supsup, 2014)



The MaxEnt results were then subjected to interpretation. Using the same MaxEnt results as inputs, QGIS habitat suitability maps were generated. Consequently, NAMRIA maps for land cover and CCIPH-published reports were sourced and reviewed to interpret the data and arrive at an accurate and reliable interpretation of findings.

Results

Table 1.

Range thresholds of tandikan habitat requirements

Environmental layers	Range thresholds
1. Annual precipitation	1768-2195mm
2. Annual temperature	22-26°C
3. Diurnal range	8°C
4. Elevation	201-1235 masl
5. Isothermality	66-73%
6. Land cover	Closed forest, Open forest
7. Precipitation seasonality	65-67%
8. Slope	90% (42°)
9. Temperature seasonality	66-101%

According to BirdLife (2023), the *tandikan* data quality is poor to good. Exact values or range limits of their environmental requirements remain poorly known (Collar et al., 1994; BirdLife, 2001). One contribution of this study is an inference on the range thresholds of the *tandikan* habitat requirements as deduced from the QGIS generated habitat suitability models. Only the highly suitable habitats were used as reference for the ascertained values as summarized in Table 1.

These clarified range threshold estimates of nine environmental variables are essential in arriving at an empirical understanding of the MaxEnt SDM outputs and in eventually designing a *tandikan* habitat management plan.

Post- Rai/ Odette SDM Scenario (2022)

Typhoon Rai/ Odette struck Palawan in December of 2021, and a drastic change in land cover was observed. Fabro (2022) described the typhoon to have caused severe damage to protected areas, including Puerto Princesa Subterranean River National Park (PPSRNP), Cleopatra’s Needle

Critical Habitat, Malampaya Sound Protected Landscape and Seascape, and El Nido-Taytay Managed Resource Protected Area. The first two areas are the sampling sites used in this study. From this same report, it was said that more than 2200 trees were damaged on the park's fringes, and bird sightings were down by 90%.

A post-Rai/ Odette species distribution model was created to estimate the effect of the typhoon on the habitat requirements and habitat suitability of tandikan.

For the 2022 post-Odette MaxEnt model, only 20 presence records and four (4) environmental records were used, as they were the only currently available data. The average test AUC for the replicate runs is 0.775, and the standard deviation is 0.169, proving the data is valid.

Table 2.

Post- Odette 2022 summary of percent contributions and permutation importance of environmental variables as habitat requirements of Polyplectron napoleonis

Variable	Percent contribution	Permutation importance
Elevation	68.6	88.6
Land cover classification	22.4	10
Aspect	8.6	0
Slope	0.4	1.5

Table 2 estimates the relative contributions of the environmental variables to the Maxent model. The values shown are averages over replicate runs.

In the 2022 MaxEnt output, elevation was ranked first regarding percentage contribution and permutation importance. As a variable, it could heavily influence species presence and the result of the other variables or environmental layers within the predictive MaxEnt model. Land cover classification ranked second, with aspect and slope occupying the last two ranks. Ashoori et al. (2018), Zou et al. (2019), and Asgharzadeh et al. (2023) have clarified the positive correlation between elevation and species abundance, the influence of land cover changes in determining avian species range shift, and the role of human disturbance in initiating land cover changes. Zou et al. (2019) performed an N-mixture modeling to detect the abundance of three sympatric pheasant species, namely Cabot's Tragopan *Tragopan caboti*, Silver Pheasant *Lophura nycthemera*, and White-necklaced Partridge *Arborophila gingica*. They identified a positive correlation between elevation and species abundance, while Asgharzadeh et al. (2023) named climate and land cover changes as "critical drivers" of avian species range shift upon performing species distribution modeling of the common pheasant *Phasianus colchicus* along elevational gradients in Mazandaran province in Iran. The group ascertained the severity of the effects of climate and land cover changes at varying altitudes. It concluded that understanding land cover and climate change is essential in analyzing alterations in avian distribution. Before this discovery, Ashoori et al. (2018) had already noted the shift of the common pheasant to high-altitude areas in the same province. Also, they suggested vigilance against habitat loss caused by climate change and land cover changes.

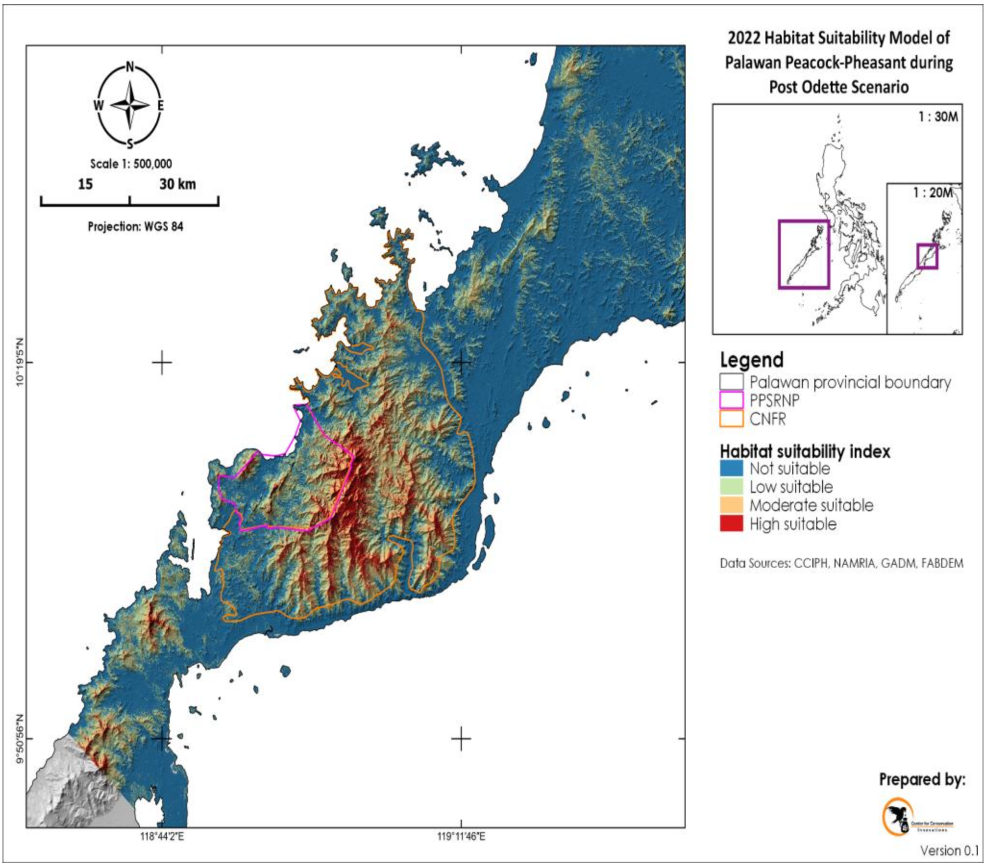
Elevation, aspect, slope, and land cover classification are generally associated with one another as elevation data, alongside the degree and direction of slope, is needed in adequately classifying land use and land cover. Further, absolute elevation identifies the types of vegetative growth and the degree and the slope direction within the land cover (Colvocoresses, 1981).

Land cover is seen to have a direct causal effect on ecological structure and function (Marland et al., 2003) as it influences water quality and watershed hydrology, habitat and species composition, weather and climate, and even carbon storage (de Sherbin, 2002). Its influence on species distribution has been explored in the study of the *Anopheles arabiensis*' habitat distribution and invasion potential (Fuller et al., 2012), with Gabor et al. (2022) suggesting that it is the most critical determinant of the presence or absence of a species within the species distribution model.

Hence, it is imperative to determine the land cover changes within the sampling sites as they are established to impact species' presence. Forest classifications are emphasized in the preceding discussions on land cover changes, as the *tandikan* is a forest species that relies on closed and open forests as suitable habitats.

Figure 2.

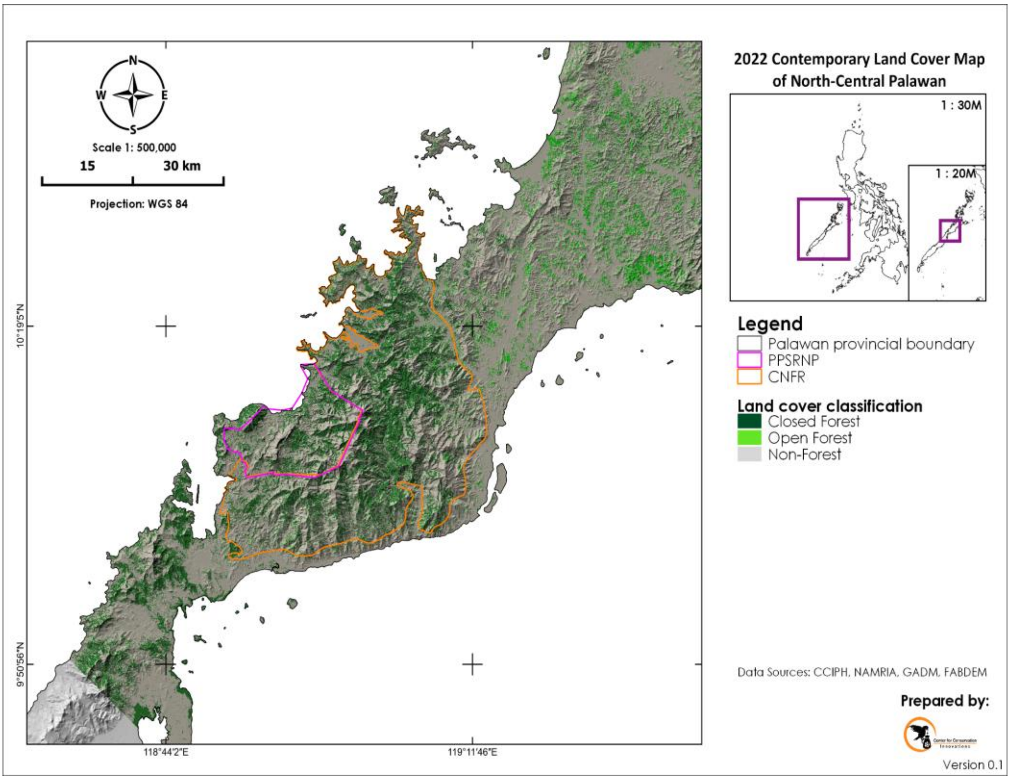
2022 Habitat suitability model of the Polyplectron napoleonis



The 2022 habitat suitability model shows the contraction of highly suitable habitats and the conversion of some moderately suitable habitats to low suitable habitats and low suitable to not suitable habitats. This result is attributed to the land cover changes within the two sampling sites, the Cleopatra Needle Forest Reserve and the Puerto Princesa Subterranean Park, showing diminished closed forests and open forests that have turned into barren lands or non-forests.

Figure 3.

2022 Palawan land cover map



The Philippines is vulnerable to solid typhoons that are said to be even augmented by climate change due to a large and rapidly growing population and localized environmental degradation (Holden, 2018). The Manila Observatory (n.d.) noted these observations and inferences on typhoon Rai/Odette: 1) It was the strongest typhoon to have hit the country in 2021. 2) It has hit areas not usually hard-hit by storms, like Palawan and Siargao. 3) It is predicted that typhoon frequency and intensity will increase in the coming years because of climate change. Palawan is located on the western part of the Pacific Ocean and is said to be shielded by its mountain ranges. However, this was not the case for typhoon Odette, as it was able to maintain its strength when it made landfall in the province, leaving massive damage to humans and biodiversity.

Fabien et al. (2022) used species distribution modeling to predict the impact of climate change on marine biodiversity. They found that "SDMs overestimate the gains and underestimate the losses of species richness under climate change.'' This may mean that the perceived diminishing and loss of suitable habitats in the 2022 habitat suitability model could be just an underestimation of the extent of damage the typhoon caused.

Conclusion and Recommendations

The SDM scenario for 2022, which was after Typhoon Rai/ Odette, shows the elevation and land cover as the habitat requirements with high percent contributions and permutation importance. Land cover appears to have the highest range value in terms of both percent contribution and permutation importance among all habitat requirements assessed.

These were the significant findings:

The highly and moderately suitable habitats for the genus *Polyplectron napoleonis*, a forest species, are closed and open forests.

The 2022 post-Odette SDM model reveals massive land cover changes, most notably with forests being converted into non-forests. The perceived diminishing and loss of suitable habitats of the *tandikan* in this model could be just an underestimation of the real impact of the typhoon on Palawan biodiversity.

Suggestions on study method and future research:

The number of species records could be increased (if data is available) to generate a higher AUC value in the MaxEnt application. The AUC value is indicative of the input data's validity.

Sampling sites could also be added, as only two out of five biodiversity areas of *tandikan* sightings were covered in the study. Presence records of *tandikan* from Mount Mantalingahan, San Vicente- Taytay-Roxas forests and Victoria and Anepahan Ranges could be used in further studies.

Conservation management implications:

Mallari et al. (2011) affirmed that *Polyplectron napoleonis* has the highest density estimate in old-growth forests, and any "reduction in extent or quality of this type" will lead to its population decline. Land cover maps presented in this study reveal the alarming state of Cleopatra's *Needle* Forest reserve, an old-growth forest, as showcased by the thinning of closed and open forests. This result is attributed to disturbances brought by human activities and natural disasters.

Therefore, the remaining old-growth forests in Palawan must be identified, effectively managed, and protected, as they could be the new habitat for the *tandikan.* This could be challenging, as even before Typhoon Rai/ Odette, Palawan recorded a loss of 23.4 kha of humid primary forests, or 14% of total tree cover, from 2002 to 2021 (Global Forest Watch, n.d.). With the two (2) sampling sites located at Puerto Princesa City, bearing 198 kha of primary forests, the remaining possible habitat options for the *tandikan* are Roxas, with 87.1 kha, Rizal, with 83.8 kha, and San Vicente, with 77.2 kha (Global Forest Watch, n.d.). Taytay, with 104 kha of primary forests, could not be recommended as a possible habitat option, as it was severely damaged by typhoon Odette, too (Global Forest Watch, n.d.).

Trophic rewilding, or the re-introduction of species in new habitats (Jarvie & Svenning, 2018), is also recommended in the areas Roxas, Rizal, and San Vicente, as earlier described to be old-growth forests. However, such practice should be done with extreme caution as a previous attempt to relocate *tandikan* in Calauit, an island in Busuanga, failed (Collar et al., 1998).

Further, the two (2) sampling sites within Puerto Princesa City, comprising 198 kha of primary forests, must be reforested, with the remaining *tandikan* species being closely monitored.

Likewise, threats to biodiversity should be constantly identified and addressed. The *tandikan's* affinity to lowland forests and vegetation necessitates stricter regulations for the over-extraction of forest products. Conversion of forests to open areas and other land uses must be controlled and prevented to maintain safe spaces for this bird species.

Lastly, the existing coverage and placement of protected areas in Palawan must be recalibrated and re-assessed in response to natural calamities. Authorities must create a sustainable conservation management plan that could mitigate the impacts of typhoons.

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