Modelling the Distribution of *Dendrocygna javanica* in North Sumatera, Indonesia using Maximum Entropy Approach

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Abstract. *Dendrocygna javanica* (Horsfield, 1821) is a species of bird that lives in the South, Southeast and South Asian regions, especially on the islands of Kalimantan, Java and Sumatra, Indonesia. *D. javanica* is a member of the genus Dendrocygna and the Anatidae family with a unique characteristic-making a continuous sound when flying and therefore often called the Lesser Whistling Teal. This study aims to predict the distribution model of *D. javanica* in North Sumatra, Indonesia. The study area ranges from the districts of Central Tapanuli, Mandailing Natal, Medan, Langkat, Deli Serdang, Tebing Tinggi, Tanjung Balai, Asahan, and Siantar. A total of 35 points obtained from the study area were analyzed using the Maximum Entropy 3.4.0 application. The environmental variables used in this analysis are global elevation, global land, solar radiation, bioclims, global aspects, precipitation, temperature, water vapor pressure, and wind speed. The Jacknife test is used to evaluate important variables for predicting the distribution model. The resulting MaxEnt model has high accuracy with a significant AUC value of 0.968. The distribution model approach using MaxEnt can promise the potential distribution of *D. javanica* in North Sumatra so that it can be used as an effective tool in planning bird conservation.

1. Introduction

*Dendrocygna javanica* [1] is a species of the genus *Dendrocygna* and the *Anatidae* family [2] widely distributed in the South and Southeast Asia region, including Pakistan, India, Sri Lanka, the eastern and southern regions of China, and Indonesia, including the islands of Kalimantan, Sumatra, and Java [3]. *D. javanica* in Indonesia is very potential to be developed [4] because the Indonesian people have long been using this bird as a source of nourishment [5].

*Dendrocygna javanica* inhabit areas of river mouths, marshes, rice fields and puddles that are still filled with rain water [6]. *D. javanica* often builds its nest near fresh water with dense vegetation that allows its chicks to reach water after hatching and increase the hiddenness and protection of the nest from predators [7]. According to [8], *D. javanica* usually prefer freshwater lakes with abundant vegetation where the larger food is aquatic plants, insects, and aquatic invertebrates.

In 2004, around 120,000 - 165,000 grouse had been consumed in Indonesia and around 95% were marketed in the Banjarmasin region of South Kalimantan [9]. In Indonesia, consumption of these birds continues to increase every year. Overcatching of this bird will result in extinction [10]. At the moment, *D. javanica* lives in the geographical range between 1 to 30.2 million square kilometers [11] with an estimated global population of around 200,000 – 2,000,000 individuals [12], leading The Birdlife International in 2016 to classify this species in the Least Concern category. It is also...
suggested that this species is not on the verge of extinction [13]. However, according to [11], this species experiences a trend of decreasing population [14].

Research on the potential, distribution, and conservation efforts are very few, as well as the declining trend of the population of *D. javanica* in the world, giving rise to predictions that *D. javanica* in the future will enter the endangered category. No effort is made to conserve this bird species. This study aims to predict the distribution model of *D. javanica* in North Sumatra as one of its distribution areas using the Maximum Entropy (MaxEnt) approach. This research is expected to provide important information about the distribution of *D. javanica* in North Sumatra so that it can be used as information in the conservation of these birds.

2. Material and Methods

2.1. Coordinate Point Collection

Exploration of the distribution of *Dendrocygna javanica* in North Sumatra was carried out during 2019. Coordinates in North Sumatra province were obtained from Central Tapanuli district (5 points), Mandailing Natal (4 points), Medan (7 points), Langkat (5 points), Deli Serdang (2 points), Tebing Tinggi (3 points), Tanjung Balai (2 points), Asahan (1 point), and Siantar (6 points). All samples obtained were wild birds, and not livestock areas. The coordinates are as many as 35 points as shown in Table 1.

### Table 1. Sample coordinates of *Dendrocygna javanica* in North Sumatra, Indonesia

| No. | Regency       | Latitude | Longitude | No. | Regency       | Latitude | Longitude |
|-----|---------------|----------|-----------|-----|---------------|----------|-----------|
| 1.  | Siantar       | 2.924135 | 99.074996 | 2.  | Tanjung Balai | 3.008833 | 99.794118 |
| 3.  | Siantar       | 2.931893 | 99.031050 | 4.  | Tanjung Balai | 2.977474 | 99.616788 |
| 5.  | Siantar       | 2.972437 | 99.021909 | 6.  | Asahan        | 2.747390 | 99.715161 |
| 7.  | Siantar       | 2.996952 | 99.017360 | 8.  | Langkat       | 3.749266 | 98.517591 |
| 9.  | Siantar       | 3.012327 | 99.067056 | 10. | Langkat       | 3.719763 | 98.387774 |
| 11. | Siantar       | 2.997037 | 99.094436 | 12. | Langkat       | 3.918540 | 98.493734 |
| 13. | Belawan       | 3.815001 | 98.679984 | 14. | Langkat       | 4.106646 | 98.195342 |
| 15. | Belawan       | 3.810718 | 98.646332 | 16. | Langkat       | 3.579607 | 98.307114 |
| 17. | Belawan       | 3.798555 | 98.634829 | 18. | Central Tapanuli | 2.160599 | 98.183570 |
| 19. | Belawan       | 3.799583 | 98.591738 | 20. | Central Tapanuli | 2.149278 | 98.209147 |
| 21. | Belawan       | 3.727638 | 98.654913 | 22. | Central Tapanuli | 2.087000 | 98.252749 |
| 23. | Belawan       | 3.714275 | 98.707272 | 24. | Central Tapanuli | 2.099360 | 98.270257 |
| 25. | Belawan       | 3.906517 | 98.584189 | 26. | Central Tapanuli | 2.983300 | 98.328795 |
| 27. | Lubuk Pakam   | 3.601046 | 98.919785 | 28. | Mandailing Natal | 1.101194 | 99.457963 |
| 29. | Lubuk Pakam   | 3.621776 | 98.966564 | 30. | Mandailing Natal | 1.037554 | 99.567738 |
| 31. | Tebing Tinggi | 3.266979 | 99.102027 | 32. | Mandailing Natal | 0.673530 | 99.737723 |
| 33. | Tebing Tinggi | 3.217103 | 99.070608 | 34. | Mandailing Natal | 0.696705 | 99.742184 |
| 35. | Tebing Tinggi | 3.348141 | 99.176280 |
2.3. Species Distribution Prediction Model

The method used for modeling is Maximum Entropy or MaxEnt which looks for the best model among the many models produced [21,22] although the number of samples obtained is small [23,24]. Distribution prediction maps based on habitat suitability of D. javanica were created using the MaxEnt program version 3.4.0 [25] which was obtained freely from the Princeton website (http://www.cs.princeton.edu/~schapire/maxent). Maps are created by combining presence-only data with ecological layers. The MaxEnt program will estimate the probability distribution of maximum entropy for each environmental variable analyzed.

3. Result and Discussion

The Maxent model produces a map of species distribution based on habitat suitability on which the value of Area Under the Curve (AUC) represents model performance, response curves, and percentage table shows how each environment variable contributes to the Maxent model. The resulting map is a prediction model for the possibility of species presence in a region based on habitat suitability. The analysis is divided into four types of variables namely average temperature (1) land, elevation, slope, and aspect (2), bioclim of WorldClim (3), precipitation, solar radiation, wind speed, and water vapor pressure (4). AUC values on receiver operating characteristics obtained from the four types of variables are 0.845, 0.825, 0.933 and 0.937, respectively (Figure 1).

Area Under the Curve is a ranking approach to assess the performance of the model by determining the location of probable existence that has a higher rank than the background of the site (absence) at random [26]. The performance of the model is indicated by a high AUC value, where a value of 0.5-0.7 is considered low, 0.7-0.9 is considered useful and higher than 0.9 is considered highly accurate in measuring attendance and absence [27]. It is important to note that AUC values tend to be lower for species that have broad distribution coverage [28,29]. This study shows a useful model performance on the average temperature, land, elevation, slope, and aspect variables, and shows the performance of models that have high accuracy on bioclim variables, precipitation, solar radiation, wind speed, and water vapor pressure.
Figure 1. The results of the AUC curves in developing *D. javanica* habitat suitability model. Average temperature (A) land, elevation, slope, and aspect (B), bioclim from WorldClim (C), precipitation, solar radiation, windspeed, and water vapor pressure (D)

Figure 1 shows that the map produced in this study is highly accurate for use as a source of information on the distribution of *D. javanica* in North Sumatra, Indonesia. Numerous studies have shown that sample size affects the performance of species distribution models, and the results may be bad if some records are used [30,31]. AUC is the most widely used statistic for model evaluation. However, many studies have revealed that using only AUC values as a standard for measuring accuracy in distribution models might be misleading [32,33].

Table 3. The percentage of contribution by the environmental variable used to model the species distribution of the model's performance.

| Data, Variable                    | Percent contribution | Data, Variable        | Percent contribution |
|-----------------------------------|----------------------|-----------------------|---------------------|
| Land, Elevation, Slope, and Aspect|                      | Average Temperature   |                     |
| Aspect Undefined or < 2%         | 41.8                 | Temperature August    | 69.9                |
| Elevation                        | 24.2                 | Temperature September| 20.8                |
| Slope 15 % ≤ Slope ≤ 30 %        | 14.1                 | Temperature April     | 2.4                 |
| Slope 5 % ≤ Slope ≤ 10 %         | 7.5                  | Temperature February  | 2                   |
| Aspect East: 45˚ < aspect ≤ 135˚ | 2.4                  | Temperature January   | 1.8                 |
| Slope 5 % ≤ Slope ≤ 10 %         | 2.3                  | Temperature June      | 1.6                 |
| Aspect South: 135˚ < aspect ≤ 225˚ | 1.9                 | Temperature October   | 1.2                 |
| Slope 30 % ≤ Slope ≤ 45 %        | 1.8                  | Temperature November  | 0.1                 |
| Land Land Type                   | 1.6                  | Temperature July      | 0.1                 |
| Aspect West: 225˚ < aspect ≤ 315˚ | 1.1                 | Temperature May       | 0                   |
| WorldClim                        |                      | Precipitation, solar radiation, windspeed, and water vapor pressure | | | | | |
| Bioclim Max Temperature of Warmest | 28.6             | Water vapor October  | 21.2                |
Table 3 shows that land with a slope of less than 2%, the average temperature in August, Max Temperature of Warmest Month, and water vapor pressure in the month of October gives the greatest influence on the distribution of *D. javanica* in North Sumatra, Indonesia. Bioclim is a bioclimatic analysis and prediction system that was originally developed by [15]. Basically, Bioclim provides a means to predict the spatial distribution of plant and animal species [34–36]. Other than in Australia, Bioclim has also been successfully applied in Africa and North America [37].

*D. javanica*’s habitat is generally swampy or aquatic areas, hence the lack of slope. This is consistent with the results of research showing that the distribution area of *D. javanica* has inclination of less than 2% or undefined. The distribution of *D. javanica* is affected by anomalies of warm temperatures throughout the year based on analysis using Bioclim information. The reproductive season of *D. javanica* in the Indian and Burmese regions ranges from July to October [7]. Warm temperatures encourages these birds to soar in the air and mate with their females. *D. javanica* are also birds that like to migrate in October [38]. Preening in *D. javanica* was reported to be highest in October-November [39] in preparation for the birds’ mating season.

Results from the *D. javanica* distribution model in North Sumatra are presented in Figure 2. The distribution model is divided into 4 based on (1) average temperature, (2) land, elevation, slope, and aspect, (3), bioclim from WorldClim, and (4) precipitation, solar radiation, windspeed, and water vapor pressure. The distribution model image shows that the distribution of *D. javanica* in North Sumatra is found on most of the east coast of Sumatra and a small portion of the west coast of Sumatra. Medan Belawan, Langkat Regency, and Serdang Bedagai districts are the regions with the highest predictability. Meanwhile, a small part of the swamp area around the west coast of Central Tapanuli district also became suitable distribution areas for *D. javanica*. The Kualah and Panai river tributaries are also potential distribution areas based on land, elevation, slope, and aspect.

| Data       | Variable                                 | Percent contribution | Data       | Variable                                 | Percent contribution |
|------------|------------------------------------------|----------------------|------------|------------------------------------------|----------------------|
| Bioclim    | Month Precipitation of Driest Month       | 21                   | Data       | Water vapor pressure                     | August               | 21.2                  |
| Bioclim    | Temperature Seasonality                   | 13.3                 | Bioclim    | Precipitation of Coldest Quarter         | July                 | 13.4                  |
| Bioclim    | Precipitation of Warmest Quarter         | 6.9                  | Bioclim    | Precipitation of Warmest Quarter         | September            | 7.5                   |
| Bioclim    | Mean Temperature of Wettest Quarter      | 4.8                  | Bioclim    | Solar Radiation                          | January              | 5.8                   |
| Bioclim    | Mean Temperature of Driest Quarter       | 4.6                  | Bioclim    | Water vapor pressure                     | December             | 5.6                   |
| Bioclim    | Precipitation of Wettest Month           | 4.3                  | Bioclim    | Precipitation                            | May                  | 2.2                   |
| Bioclim    | Precipitation of Wettest Quarter         | 3.3                  | Bioclim    | Solar Radiation                          | April                | 2.1                   |
| Bioclim    | Precipitation Seasonality (Coefficient of Variation) | 2                  | Bioclim    | Solar Radiation                          | December             | 1.9                   |
Figure 2. The distribution model of *D. javanica* based on average temperature (A) land, elevation, slope, and aspect (B), bioclim from WorldClim (C), precipitation, solar radiation, windspeed, and water vapor pressure (D) using MaxEnt analysis

*D. javanica* is spread over a limited area and mostly in bodies of water [40]. Least potential areas are mostly non-swamp and aquatic areas, which are unsuitable habitats for *D. javanica* who like watery areas. *Dendrocygna javanica* is a bird with the highest abundance in the Muara Tapus region, Central Tapanuli district, North Sumatra [41]. [42] reported that in the Batu Lima region, Asahan district, in the wet paddy fields and freshwater swamps there were hundreds of *D. javanica* foraging at dusk around March. *Dendrocygna javanica* is also found in swampy areas in the village of Rugemuk in Deli Serdang district, North Sumatra [43]. This data shows that the results of the study are in accordance with data that have been reported by previous studies.

The results obtained from this study support the statement that the potential distribution area predicted by MaxEnt is an overestimation when compared to the actual niche of species, namely
habitat, because the MaxEnt model only considers the existence of fundamental niche-based data compared to actual data [44,45]. In reality, a species fails to spread due to geographical barriers, human disruption, or competition [46]. To restore species diversity, it is important to consider the impact of climate change on species distribution [47]. This method promises in predicting the potential distribution of D. Javanica and may prove a valuable tool in species conservation management.

4. Conclusions
In this study, we successfully modeled Dendrocygna javanica based on habitat suitability using environmental variables. This study produces a map with a useful model working on the average temperature, land, elevation, slope, and aspect variables, as well as the model's performance with high accuracy on bioclim variables, precipitation, solar radiation, wind speed, and water vapor pressure. The resulting AUC values are 0.845, 0.825, 0.933 and 0.937, respectively. The contribution percentage of environmental variables to the highest model performance on the aspect (undefined or <2%) was 41.8%, the average temperature in August was 69.9%, the max temperature of warmest month was 28.6% and the water vapor pressure in October and August was 21.2 %. The method of D. javanica distribution modeling in North Sumatra, Indonesia, promises to predict potential distribution as a valuable tool in the conservation of Dendrocygna javanica.

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