LANDSCAPE ECOLOGY OF ENDEMIC BLACK-WINGED STARLING *Acridotheres melanopterus tricolor* (HORSFIELD, 1821) RELATED TO ENVIRONMENTAL FACTORS IN A TROPICAL SAVANNA OF INDONESIA

EKOLOGI LANSKAP JALAK PUTIH ENDEMIK *Acridotheres melanopterus tricolor* (HORSFIELD, 1821) TERKAIT DENGAN FAKTOR LINGKUNGANNYA DI SABANA TROPIS INDONESIA

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ABSTRAK

Jalak putih (*Acridotheres melanopterus tricolor*) merupakan spesies burung yang ada di Asia Tenggara, dan spesies ini masih ditemukan di lanskap sabana tropis Indonesia. Penelitian ini bertujuan untuk memperkirakan kepadatan populasi *A. m. tricolor* dan memodelkan hubungan kepadatan jenis ini dengan faktor lingkungannya pada beberapa tipe tutupan lahan di lanskap sabana Taman Nasional Baluran di Jawa. Faktor lingkungan yang diukur mencakup *Normalized Difference Vegetation Index* (NDVI), luas tutupan lahan, dan jarak ke sungai yang diperoleh dari *Landsat 8 Operational Land Imager* (OLI), dan dianalisis menggunakan Sistem Informasi Geografis (SIG). *General Additive Models* (GAM) dikombinasikan dengan *Principal Component Analysis* (PCA) digunakan untuk menganalisa korelasi kepadatan burung dengan faktor lingkungannya. Berdasarkan hasil penelitian, rata-rata kerapatan *A. m. tricolor* adalah delapan (8) ekor/ km^2. Model korelasi menunjukkan hubungan positif yang signifikan antara kepadatan burung dan NDVI dan hubungan negatif yang signifikan untuk faktor jarak ke sungai, sedangkan luas tutupan lahan tidak berkorelasi secara signifikan dengan kepadatan burung. Temuan ini menunjukkan bahwa vegetasi dan akses ke sumber air tetap merupakan faktor lingkungan yang relatif penting untuk mendukung populasi *A. m. tricolor* dan konservasi spesies ini di lanskap tropis. Kebaruan dari penelitian ini adalah pemanfaatan citra satelit dan SIG untuk melihat lanskap dan habitat dari *A. m. tricolor.* Selain itu, penelitian ini juga berkontribusi dalam memodelkan faktor lingkungan yang paling berpengaruh terhadap *A. m. tricolor* di lanskap sabana tropis Indonesia.

Kata kunci: *Acridotheres melanopterus tricolor*, kepadatan, lingkungan, NDVI, sungai.

ABSTRACT

The black-winged starling (*Acridotheres melanopterus tricolor*) is a bird species in Southeast Asia, and this species still exists within Indonesia's tropical savanna landscape. This study aims to estimate the population density of the *A. m. tricolor* and to model the relationship between this species density and its environmental factors in several land cover types in the Baluran National Park savanna landscape in Java. The environmental factors were Normalized Difference Vegetation Index (NDVI), land cover size, and distance to river obtained from Landsat 8 Operational Land Imager (OLI) and analyzed using Geographical Information System (GIS). General Additive Models (GAM) combined with Principal Component Analysis (PCA) was used to analyze the correlation of bird density with environmental factors. Based on the results, the average density of the *A. m. tricolor* was eight (8) inds./km^2. The correlation model showed a significant positive relationship between bird density and NDVI and a significant negative relationship for distance to river factors, while land cover size did not significantly correlate with the bird density. These findings suggest that vegetation and access to water sources remain a relatively important environmental factors for supporting *A. m. tricolor* populations and this species conservation in the tropical landscape. The novelty of this research is satellite imagery and GIS usage to elaborate the landscape and habitat of *A. m. tricolor*. In addition, this study also contributes to modelling the most overarching environmental factors of *A. m. tricolor* in Indonesia's tropical savanna landscape.

Keywords: *Acridotheres melanopterus tricolor*, density, environmental, NDVI, river.

INTRODUCTION

The black-winged starling *Acridotheres melanopterus tricolor*, a member of the Sturnidae family, is an endemic subspecies that only can be found in the tropical savanna landscape of East Java. Of the other subspecies, *Acridotheres melanopterus melanopterus* can be found across Java, while *Acridotheres melanopterus tertius* is endemic to Bali (Sadanandan *et al*. 2020). The *A. m. tricolor* usually lives in pairs or small groups, foraging in the open ground such as grass fields, resting in trees, or sometimes

in urban houses (MacKinnon *et al.* 2010). Currently, its population are decreasing sharply, and it has been classified as a protected bird species (Shepherd *et al*. 2015).

The decline *A. m. tricolor* populations in the wild have been caused by decreased quality and availability of habitat and by poaching (Shepherd *et al*. 2015). The decrease in habitat quality and availability is indicated by forest destruction or loss of nesting trees. The natural forest habitat of this species has been logged to fulfil demands ranging from firewood to household materials (Hosiana 2013). Besides logging, the *A. m. tricolor* is also threatened by illegal hunting activity as the species has commercial value as a singing bird. This pressure has threatened and reduced *A. m. tricolor* populations in nature and caused this species to become Critically Endangered (Nijman *et al*. 2018). Recently, it was estimated that fewer than 250 individuals *of A. m. tricolor* remain in the wild (Brillianti *et al*. 2019), and even as low as 180 birds remain (BirdLife International 2022).

On the island of Java, an important habitat for this subspecies is the Baluran National Park in East Java, as observed by Wulandari and Santoso (2020). The landscape of Baluran National Park is characterized by a combination of savanna, woodland, and acacia forest ecosystems, and this has provided a suitable habitat for bird populations. Recently the bird diversity in the Baluran Natural Park landscape was assessed and determined to consist of 56 families and 171 species (Winasis *et al*. 2009). While a number of bird communities in Baluran National Park have been studied, research emphasizing *A. m. tricolor* populations in Baluran National Park, in particular, are still limited. Studies of this species are required urgently, considering that this species is threatened. This study aims to assess the density and spatial distribution of the *A. m. tricolor* in the Baluran National Park tropical savanna landscape. The findings of this study are expected to provide baseline information to contribute to the *A. m. tricolor* conservation efforts in Baluran National Park and bird conservation in general.

MATERIALS AND METHODS

Study Area

The study area (Figure 1) was a tropical savanna landscape located in Baluran National Park in East Java, Indonesia (7.835^0-7.854^0 S, 114.439^0-114.461^0 E). The Baluran has a total area of 250 km^2 and consists of savanna, mangrove, evergreen, monsoon, and acacia forest land covers. The savanna land cover type accounts for 40% of Baluran's area; within this landscape, a river passes through the middle of

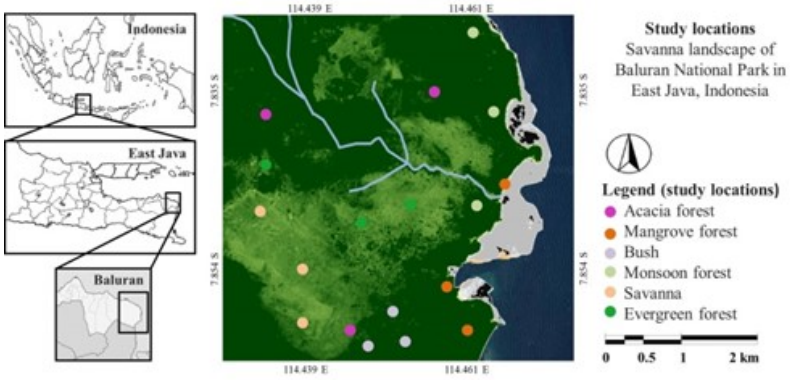

Figure 1. Map and overlay of study area and locations in 6 land covers in the savanna landscape of Baluran National Park in East Java, Indonesia.

the landscape, from the upstream area located in Mount Baluran and downstream on the Baluran coast to the east. The climate in Baluran is categorized as a dry climate with an annual rainfall range of 900-1,600 mm/year (Winasis *et al*. 2009). In general, Baluran is categorized as a lowland landscape since its northern and eastern regions are bordered directly by the sea (Wijaya *et al.* 2020). The elevation of Baluran ranges from as low as 0 m in the coastal area to 1,274 m above sea level at its highest point on Mount Baluran.

Bird Survey Methods

The bird survey was conducted in study locations encompassing sampled areas of 4 km^2 representing Baluran and covering acacia forest, mangrove forest, bush, monsoon forest, savanna, and evergreen forest land covers of Baluran. The bird survey followed methods by Buckland *et al*. (2001), Broekema and Overdyck (2021), Ma (2012), Thunhikorn *et al*. (2016), and Chiok *et al*. (2020) using a point count distance sampling methods by locating sampling point with three (3) replications in each land cover location. Since there were six (6) land covers, then there were 18 sampling points surveyed. At each sampling point, a line transect with a width of 50 m and length of 1,000 m was placed following Hakim *et al*. (2020). Bird surveys were conducted by walking along the line transect once a week for four (4) consecutive weeks in 2020 between 06:00-08:00 and 16:00-18:00 each day. This survey was conducted during the onset of the rainy season in December 2020, considering water as an important resource for wildlife in dry savannah ecosystems. During the survey, a handheld GPS unit (Garmin Etrex) was used to locate and verify the geocoordinates of sampling points where the birds were observed. The bird was observed using binoculars with magnifications of 10x and identified using a bird identification book (MacKinnon *et al*. 2010). Results of the bird survey were the bird density (D) denoted as inds./km^2 and calculated using the following equation (Buckland *et al*. 2008):

D = (number of observed individual)/(2 x transect width (50 m) x transect length (1,000 m))

Land Cover Classification

The land cover in Baluran was classified using Geographical Information System (GIS) methods with ArcView 3.2. The method starts with retrieving Baluran boundary and Landsat 8 Operational Land Imager (OLI) images of Baluran with a spatial resolution of 30 m per pixel. The Landsat 8 OLI imagery of the Baluran, taken in December 2020 with path/row was 117/65, then classified into several land cover types, including acacia forest, mangrove forest, bush, monsoon forest, savanna, evergreen forest, and river. The result is a thematic layer in shapefiles (shps) of Baluran land covers containing polygons representing each land cover type.

Environtmental Factor Analysis

The environmental factors of *A. m. tricolor* measured in this study include the size of land covers (km^2), distance to the river (m), and Normalized Difference Vegetation Index (NDVI). Land cover sizes of Baluran were determined by measuring the size of the polygon of land cover types in a thematic layer developed previously using GIS. While distance to the river was measured as the distance from the sampling points containing endemic black-winged starling to the nearest river.

The method used to measure NDVI of the Baluran landscape follows Philiani *et al*.

(2016), Kawamuna *et al*. (2017), and Sukojo and Arindi (2019). The NDVI is described as a simple graphical indicator that can analyze remote sensing measurements, often from a space satellite platform, assessing whether the observed target contains live green vegetation. The NDVI was measured by analyzing the wavelengths of a satellite image retrieved from Landsat 8 OLI containing vegetation images and, in this study, forest covers. This measurement is possible since the cell structure of leaves in the vegetation strongly reflects near-infrared light wavelengths ranging from 0.7 to 1.1 μm. The calculation of NDVI for each pixel of vegetation was as follows:
NDVI = near invisible red wavelength – red wavelength / near invisible red wavelength + red wavelength

The NDVI was denoted as a range from 0 (no vegetation) to 1 (high vegetation density). The NDVI values were then overlaid and mapped into Baluran landscape layers using GIS. The forest covers were then categorized and classified using NDVI as described in the following table:

Table 1. NDVI and forest cover scores.

NDVI	Forest covers
0 < NDVI < 0.3	< 50%
0.31 < NDVI < 0.4	50 – 69%
0.41 < NDVI < 1.0	70 – 100%

Landscape Ecology Analysis

Measurements of the Baluran landscape ecology metric followed Jung (2013) and Lustig (2016) using Landscape Ecology Statistics (LecoS) tool. LecoS assessed the landscape metric based on the previous land cover layer presented in the raster. The landscape metric measurement method follows Calamari *et al*. (2018). The metrics consisted of land cover diversity measured using the Shannon index, land cover proportion (%), the number of land cover patches, average land cover patch area (km^2), and land cover patch cohesion index. The Shannon index of landscape diversity was then categorized and classified from 0 to values more than 0, with 0 indicating no diversity.

Data Analysis

Acridotheres melanopterus tricolor density correlations with environmental factors were calculated using General Additive Models (GAM), modelled using Principal Component Analysis (PCA), and then validated using Akaike Information Criterion (AIC) (Wright *et al*. 2012). The AIC was developed using linear regressions. The measurement parameters included in AIC were AICc, ΔAICc, or the difference of AIC between a given candidate model and the best model with the minimum AIC, AICc weight, cumulative weight, and log -likelihood (He *et al*. 2016). Environmental factors correlating with *A. m. tricolor* density were included in the analysis to build the model. The best model was selected based on the model that has the lowest AIC values and the largest AICc weight.

RESULTS AND DISCUSSION

Land Covers

The studied Baluran landscape was a combination of diverse land covers (Figure 2). The Shannon landscape diversity index value was 1.57 and is considered to have moderate landscape diversity (Ewers *et al*. 2005). It consisted of savanna, mangrove, evergreen, monsoon, and acacia forest land covers. Northern parts of the studied area were dominated by acacia and monsoon forests. A fragment of evergreen forest and savanna was

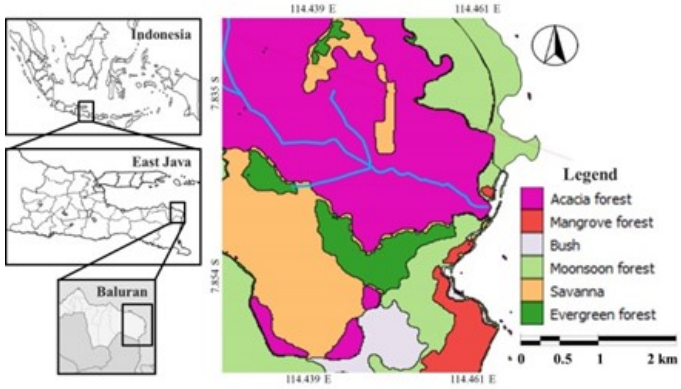

Figure 2. The savanna landscape land cover of Baluran National Park in East Java, Indonesia.

observed within the acacia forest. Central parts consisted of savanna combined with evergreen forest. Domination of monsoon forests was observed in the southern parts of the studied area. The eastern part is directly bordered by the Bali Strait. The east coasts of Baluran were bordered by monsoon and mangrove forests. Based on the size of land covers, the order of land covers was acacia forest > monsoon forest > savanna > evergreen forest > mangrove > bush (Table 2).

Environtmental Factors

The NDVI of each land cover type in Baluran varied (Figure 3). High NDVI with a value close to 1 was observed in monsoon forest cover in the north and the evergreen forest patch. Acacia covers show medium NDVI. The lowest NDVI values were observed in the savanna and bush covers nearby. Variation of NDVI in Baluran has affected the *Acridotheres melanopterus tricolor* density. In general, the mean density of *A. m. tricolor* was eight (8)

Table 2. Landscape metrics of land covers in Baluran National Park, East Java, Indonesia.

Land covers	Landscape metrics			
	Proportion (%)	Number of patches	Mean patch area (km^2)	Patch cohesion index
Acacia	31.3	25	1.63	9.92
Mangrove	3.74	5	0.34	6.79
Bush	1.24	2	0.13	3.89
Monsoon	17.86	57	0.40	9.86
Savanna	15.59	131	1.55	9.85
Evergreen	5.23	92	0.53	9.76

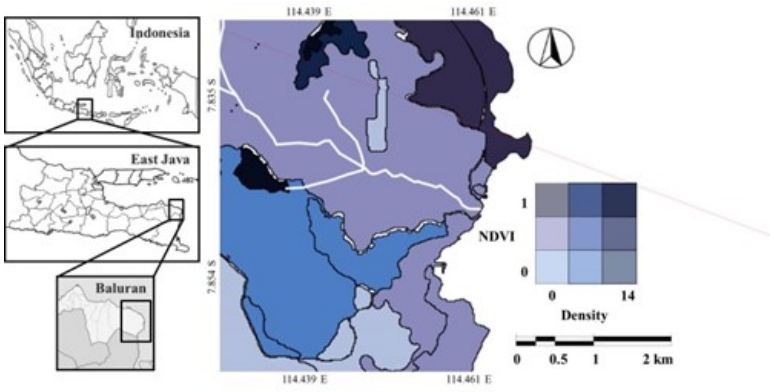

Figure 3. NDVI and *Acridotheres melanopterus tricolor* density in the savanna landscape of Baluran National Park in East Java, Indonesia.

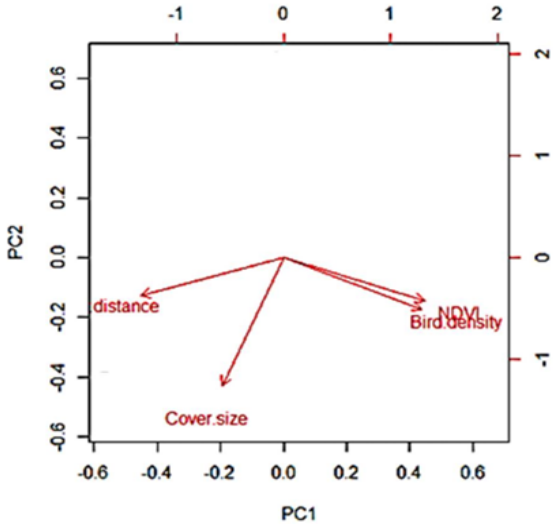

Figure 4. PCA of *Acridotheres melanopterus tricolor* density with land covers (cover size), NDVI, and distance to the river as environmental factors in Baluran National Park, East Java, Indonesia.

inds./km^2 (95%CI:4-12 inds./km^2). The highest *A. m. tricolor* density equaling 14 inds./km^2 was observed in the evergreen forest patch in the north and the large evergreen forest patch in the center (Figure 3). The evergreen forest patch in the central parts of Baluran was surrounded by savanna and monsoon forests. In the savanna, *A. m. tricolor* average density with values of nine (9) inds./km^2 was higher than *A. m. tricolor* mean density in acacia and monsoon forest covers. The *A. m. tricolor* average density in acacia and monsoon forests was six (6) and four (4) inds./km^2.

The density of *A. m. tricolor* was correlated with several environmental factors. Among those environmental factors, only NDVI and distance to river factors have significant effects. PCA (Figure 4) shows that the density increased following an increase in NDVI values. The first principal component (component 1 axis) had high loadings of *A. m. tricolor* density (1.00) and NDVI (0.996) (Table 3). In contrast, the second principal component (component 2 axis) had high loadings of land cover size (1.00) and distance to the river (0.625). In the savanna landscape, *A. m. tricolor* was observed concentrating in evergreen land covers with high NDVI value. In contrast, *A. m. tricolor* density declined following an increased distance to the river (Figure 5). This result indicates that water resources and distance to the river were limiting factors for *A. m. tricolor* in the savanna.

This study has also assessed the effects of combined and additive environmental factors. The combined environmental factors are represented by several models (Table 4). The first model was the combination of land cover size and NDVI, the second model was land cover size and distance to the river, and NDVI combined with distance to the river was the third model. The best model describing correlations

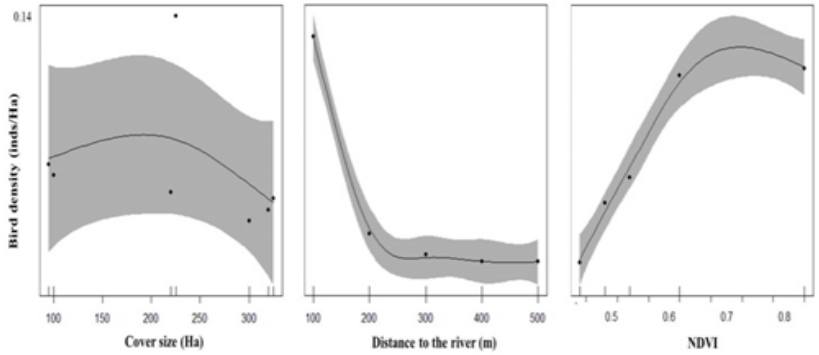

Figure 5. Trends and General Additive Models (Shaded area for 95%CI) of *Acridotheres melanopterus tricolor* density with land covers (cover size), distance to the river, and NDVI as environmental factors in Baluran National Park, East Java province, Indonesia

Table 4. AIC models of *Acridotheres melanopterus tricolor* density with the size of land covers, NDVI, and distance to the river as environmental factors in Baluran National Park, East Java province, Indonesia.

A. m. tricolor environmental factor models	AICc	ΔAICc	AICc Weight	Cum. Weight	Log likelihood
Model 1: C + N	44.87	4.41	0.08	1.00	4.23
Model 2: C + R	41.93	2.94	0.17	0.92	4.96
Model 3: N + R	40.46*	0.00	0.75	0.75	6.43

C = land cover size, N = NDVI, R = distance to the river, *best model

of environmental factors on *A. m.s tricolor* density was measured based on AICc and AICc weight values. Among three models, a model consisting of NDVI and distance to the river was selected as the best model since it has the lowest AICc (40.46) and largest AICc weight (0.75) values compared to other models. The second-best model comprised distance to river and land cover size factors.

In Baluran National Park, *Acridotheres melanopterus tricolor* density was high in both the closed ecosystem of the evergreen forest and in the open habitat of the savanna landscape. This finding is likely due to the close geographical proximity of the savanna ecosystem to the evergreen forest. The Baluran was a fragmented landscape consisting of several patches of land covers located close to each other. This fragmented landscape allowed the bird to use more than one habitat. A preference for the closed ecosystem of the evergreen forest can be related to the availability of trees. In the forest, the tree provides a natural cavity (Rogers *et al.* 2020) used by *A. m. tricolor* as nesting sites. Black-winged starlings preferred nest trees that were taller, bigger and had thicker canopies than their adjacent trees (Archawaranon 2006). Besides that, a preference for open savanna landscapes can be related to predator avoidance behavior. Vegetation can significantly reduce the ability of birds to see approaching aerial and terrestrial predators, which can lead to increased predation risk, as observed by Johnston and Smith (2018). Aerial predators in the study area include several raptor species, including owl, falcon, and hawk (He *et al*. 2016). Bird species belonging to Sturnidae have been observed foraging in a flock (Cavagna *et al*. 2013) while they were under attack by raptors, including peregrine falcon (*Falco peregrinus*) (Carter *et al*. 2008, Colorado 2013, Storms *et al*. 2019). Other Sturnidae bird species are known to commonly gather in large flocks, as can be seen in the European starling *Sturnus vulgaris*. Birds in larger groups detect predators earlier in an attack compared with birds in smaller groups. In the savanna, *A. m. tricolor* species were observed in high densities or flocks. Therefore this behavior can be attributed to a strategy to cope with the risk of predation (Devereux *et al*. 2006).

The density of *A. m. tricolor* under different land covers in Baluran National Park also depends on the diversity of the species' diet. Members of the Sturnidae family are omnivorous, consuming fruits, berries, grains, flower nectar, insects (including beetle larvae and adults, caterpillars, worms, flies, snails), and spiders. For the first ten days, juveniles are exclusively fed on invertebrates, almost all insects (Markula *et al*. 2009). Besides foraging

on insects, *A. m. tricolor* also forages on fruits and seeds make up a more important component of their diet (Peacock *et al*. 2007).

The *Acridotheres melanopterus tricolor* population in Baluran National Park had a significant correlation with distance to the river along with the NDVI factors. Distance to rivers and NDVI have been identified as important environmental factors supporting animal populations in the savanna landscape (Anderson *et al.* 2016). In this study, the density increased when the *A. m. tricolor* was gathered near water sources. In Baluran National Park, a river from the upstream area in Mount Baluran in the west passes the landscape to the downstream coastal area in the east. For birds, water resources, including river streams, are important since they can provide more spaces for nesting, shelter, and food (Mao *et al*. 2019). Birds seemed to rely more strongly on the river, especially during the drier year (Jackson *et al*. 2020). This fact is consistent with the savanna landscape condition in Baluran National Park, which also has a dry climate since it receives less rainfall, equal to only 900-1,600 mm/year. The importance of rivers, outside of providing water, is providing food sources, including insects (Mwansat *et al*. 2015) for insectivores and omnivores. In Baluran National Park, the savanna landscape and its river stream had an abundant diversity of insects considered suitable for supporting the *A. m. tricolor* population. According to the research of Sandy (2014), four insect families belonging to the Orthoptera order inhabit Baluran National Park.

Baluran National Park's *Acridotheres melanopterus tricolor* density may be very low. The 2009 survey report stated that there were only 25-35 flocks (Eaton *et al.* 2015). Thus, this research constitutes a significant contribution to the status of the species by updating the latest sightings and densities. In addition, this study provides, for the first time, empirical evidence of spatial models and environmental factors that have significant relevance to the density of *A. m. tricolor*. The best choice model and key environmental factor identified in this study can be used to further support the protection of Black-winged Starlings in specific savanna landscapes.

CONCLUSION

The presence of *A. m. tricolor* is currently threatened. In addition to threats, the presence of this species in their natural habitat has been hampered by a number of environmental factors, particularly in the dry environment of the tropical landscape. In the savanna ecosystems, water and vegetation are important sources for animals to survive. In our study, distance to the river and low vegetation covers are the limiting environmental factors for *A. m. tricolor* in The Baluran National Park. Then the future conservation efforts, mainly in this tropical savanna landscape, must incorporate the conservation of water bodies and vegetation, mainly the intact forest, including evergreen forest.

To the best of our knowledge, more rigorous conceptual and analytical tools are needed to assess the density and spatial distribution of the *A. m. tricolor* in the Baluran National Park tropical savanna landscape. Nevertheless, this novelty is critical to provide baseline information to contribute to the *A. m. tricolor* conservation efforts in Baluran National Park and bird conservation in general. As an example of a method that could be applied in this context, we employ satellite

imagery and GIS to elaborate on the landscape and habitat of *A. m. tricolor*. In addition, this study also contributes to modelling the most overarching environmental factors of *A. m. tricolor* in Indonesia's tropical savanna landscape.

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