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Population Density and Habitat Characteristics of Southern-Cassowary (*Casuarius casuarius*) at Wasur National Park, Merauke

FAHRUN SAHARA MAWARDHA[1], DYAH PERWITASARI-FARAJALLAH[2*], YENI ARYATI MULYANI[3]

[1]Animal Biosciences Study Program, Graduate School, IPB University, Jalan Raya Dramaga, Bogor, 16680, Indonesia
[2]Department of Biology, Faculty of Mathematics and Natural Sciences, IPB University, Jalan Agatis, IPB Dramaga Campus, Bogor 16680, Indonesia
[3]Department of Forest Reseources Conservation and Ecotourism, Faculty of Forestry and Environment, IPB University, Jalan Ulin, Dramaga Campus, Bogor 16680, Indonesia

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Southern Cassowary (*Casuarius casuarius*) is a seed disperser of North Australia and Southern Papua lowland forest ecosystem. Despite its dominant distribution in Southern Papua, there is a lack of information regarding its population and habitat characteristics. Due to its high sensitivity, the southern cassowary is rarely seen across the forest, yet the signs of its presence (feces and footprints) are abundant. This study analyzed the distributions, population, and habitat characteristics of the southern cassowary's in Sota and Wanggo Resort, Wasur National Park, Southern Papua. Maximum Entropy results showed that its distribution focused on the northeastern area of Wanggo Resort and several points north of Sota Resort. Using fecal distance sampling, this study found that the southern cassowary population density in Wasur National Park areas was 0.8 ind/km^2, primarily in lowland forests. The area corresponds to the variables that most influence the southern cassowary, which are NDVI, annual precipitation, and distance to the road. These findings underscore the urgency of local stakeholders to pay specific attention to lowland forests in Wasur National Park.

Key words: Lowland forest, Frugivore, Indirect signs survey, Double-wattled cassowary, Distance sampling

INTRODUCTION

The southern cassowary (*Casuarius casuarius*) is a seed disperser in Northern Australia (Queensland), Aru Island, Seram Island, and Southern Papua (Indonesia) to Papua New Guinea (Beehler *et al.* 2001; Gregory & Allen 2017). The importance of the southern cassowary's role in the environment makes it classified as protected animal according to the Regulation of the Indonesian Ministry of Environment Number P.20 of 2018 (Rumeu *et al.* 2017). Nevertheless, the population of the southern cassowary still declines because of illegal hunting and habitat disruption due to land clearing(Gregory & Allen 2017).

Studies on the southern cassowary population in Papua are still limited. The most recent studies on this species were reported from Australia and Seram Island (Moore 2007; Puttileihalat 2007). Southern cassowary in Papua can be found in Wasur National Park (WNP), South Papua. National Park officers' surveys from 2019 to 2023 showed that this species was found at Sota and Wanggo Resorts in WNP. Two of its habitats in both Resorts are lowland forest and grassland. A study about its habitat in WNP was conducted by La Hisa (2022), but the study was limited to one area, Tabutar, Sota Resort.

Southern cassowary tends to be sensitive towards humans, making it difficult to find in its natural habitat. However, its presence signs, such as feces, are abundant and easier to find. This information has the potency to become southern cassowary population density data (Thomas *et al.* 2010). In the indirect survey method, the animal's cues (nests, sounds, or feces) are the objects of detection rather than the animal itself. This study aimed to analyze southern cassowary's distribution and population by using indirect method, and describe southern cassowary habitat characteristics in two resorts of Wasur National Park.

MATERIALS AND METHODS

Study Area. The study was conducted from February to July 2023. The observation area was divided into three areas in three villages from Sota Resort: Tabutar, Kilor, and Samleber, and three villages in Wanggo Resort: Wam, Kamnosari, and Kondan. The total observation area was 28.93 km^2.

*Corresponding author:
E-mail: witafar@apps.ipb.ac.id

Each area is determined based on the presence of southern cassowary and its presence signs based on the information from the locals, the WNP officers' survey data from 2019 to 2023, the ecosystem suitability of southern cassowary in the area, and area accessibility.

Feces Daily Production Rate. The production of feces was observed in two adult southern cassowaries for five days in WNP's Wallaby Sanctuary and the southern cassowary kept by residents. The procedure modified from the study by Eycott *et al.* (2013). Southern cassowary was put in a separate enclosure from the main cage for one day, then returned to the main cage. The feces left in the separate enclosure were recorded and then analysed using the formula from Thomas *et al.* (2010):

$$r = \frac{\text{number of feces}}{\text{number of animals} \times \text{total days in enclosure}} \quad (1)$$

Southern Cassowary Distribution. The southern cassowary distribution is known based on its environmental variable suitability in WNP, which were temperature, precipitation, distance to the waterway, land cover, distance to road, distance to the building, and NDVI (Pangau-Adam *et al.* 2015; Neice & McRae 2021). All environmental data obtained from open-source data, such as United States Geological Survey (USGS), OpenStreetMap, European Space Agency (ESA), and Climatologies at High resolution for the Earth's Land Surface Areas (CHELSA) (USGS 2014, 2020; ESA 2021; Karger *et al.* 2021; OpenStreetMap 2024a, 2024b, 2024c). The coordinates were obtained from direct encounters, footprints, and feces of southern cassowary in the research area and data from WNP southern cassowary census data from 2019 to 2023. The analysis performed was maximum entropy (Maxent) in ArcGIS 10.7.1 (Stephens *et al.* 2006).

Population Density. A preliminary survey was conducted for one day to identify the southern cassowary's presence signs (feces or footprint) and its habitat, then confirmed with the literature (Moore 2003). Southern cassowary feces are shaped like a pile of fruits, with a wet texture that gets drier over time (Figure 1). Population survey using line transect distance sampling based on the encountered feces (Thomas *et al.* 2010), with 20 transects ranging from 1-1.5 km in length (Table 1). Every transect was traced simultaneously per observation area. The perpendicular distance between the feces and the observer was measured (Hayes & Buckland 1983), recorded, and its coordinates were recorded using a GPS. The feces density was then converted to population density using feces production daily rate and decay rate using DISTANCE software version 7.5 (Marques *et al.* 2001).

Vegetation Analysis. Vegetation analysis was conducted in the lowland forest by making 17 plots in the southern cassowary "Presence" and "Absence" area based on signs of the southern cassowary, which were fresh feces, fresh footprints, or direct encounters with the southern cassowary. The identification of southern cassowary and their signs are based on literature (Moore 2003; Beehler & Pratt 2016) and preliminary survey results (Figures 1 and 2).

Data from seedlings, saplings, poles, and trees were recorded for each plot. The data recorded were the plant species and their number, this data then further analyzed to know each plant stage density (2). Diameter breast height was recorded only for pole and tree stage. Canopy density per plot was measured using normalized difference vegetation index (NDVI) performed in ArcGIS 10.7.1. Plant identification was based on literature (La-Hisa *et al.* 2012; La-Hisa 2022) and information from locals. The analysis that used was Wilcoxon-Mann Whitney test to compare vegetation characteristics, the important value index (IVI) to find the dominant plants, and Gini-Simpson index and Jaccard index analysis to compare plant diversity and similarity between the "Presence" and "Absence" plots.

$$\text{Density} = \frac{\text{Number of species - i individuals}}{\text{Plot area}} \quad (2)$$

RESULTS

Feces Daily Production Rate. Southern cassowary feces observed in both locations were 37 feces, with the resident's cage produced 20 feces, while the WNP wallaby sanctuary it produced 17 feces. The analysis results show that 3.7 feces of southern cassowary were produced daily.

Southern Cassowary Distribution Estimation. Maxent analysis (AUC = 0.87) shows that southern cassowary distribution based on the area suitability is mainly affected by NDVI and annual precipitation (Table 2). Based on the variables mentioned, the estimation of southern cassowary distribution in WNP is in the northeastern area of Wanggo Resort and several points in the northern area of Sota Resort. The total area suitable for southern cassowary is 171471.66 Ha or 39.57% of the total WNP area (Figure 3).

Southern Cassowary Population Density Based on Feces Encounter. The total feces observed was 89, with the highest encounter in Tabutar (N = 61) and Kilor (N = 17), both in Sota Resorts. The feces found in other area in Sota Resort, Samleber, were four feces while in Wanggo Resorts there were only seven feces found. This makes the total feces found in this study

A B

Figure 1. Southern cassowary feces. (A) fresh feces, (B) old feces

Table 1. Line transects in each location

Resort	Sota			Wanggo			Total
Research location	Tabutar	Kilor	Samleber	Wam	Kamnosari	Kondan	
Totals transect	5	5	3	2	3	2	20
Length per transect (km)	1.5	1.5	1	1	1.5	1.5	27.5

A B

Figure 2. Southern cassowary footprints. (A) fresh footprint, (B) old footprint

Table 2. Environmental variable's contribution towards southern cassowary's presence

Environmental variables	Permutation importance (%)
Normalized Difference Vegetation Index (NDVI)	37.4
Annual precipitations (bio12)	26
Annual temperature (bio1)	8.9
Land use	6.1
Distance to road	12.5
Distance to waterway	8.2
Distance to building	0
Slope	0.8

mainly from Sota Resorts. The density estimation analysis result show that southern cassowary density is 0.8 ind/km^2.

Southern Cassowary Habitat. The total plots made were 17 plots in the "Presence" area and six plots in the "Absence" area. Both areas showed no significant difference in habitat characteristics except for seedling density which is higher in the "Presence" area (Table 3). Unlike their habitat characteristics, plant communities between both plot

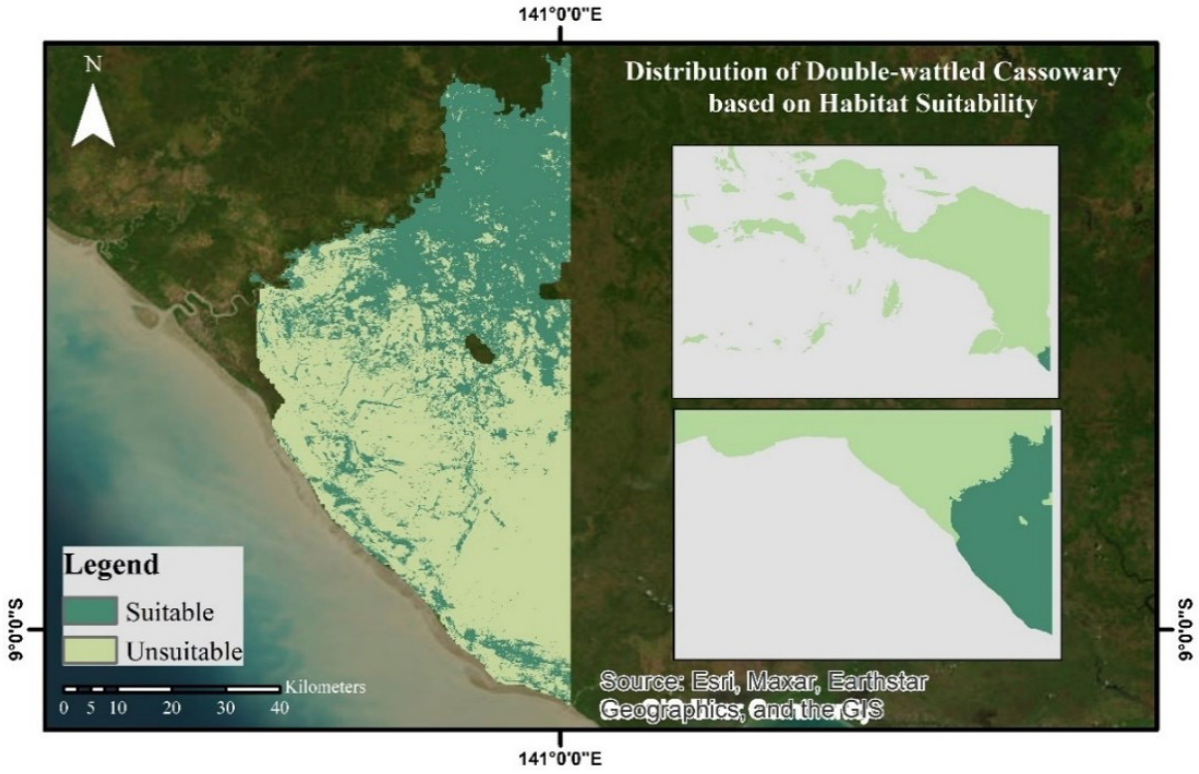

Figure 3. Southern cassowary distribution estimation according to habitat suitability

Table 3. Vegetation character between habitats

Variable	Mean		p-value
	Presence area	Absence area	
Seedling density (ind/m^2)	1.39±0.2	0.01±0.2	0.01*
Sapling density (ind/m^2)	0.11±0.01	0.16±0.03	0.53
Pole density (ind/m^2)	0.01±0.002	0.01±0.002	0.16
Tree density (ind/m^2)	$0.3 \times 10^{-2} \pm 0.0002$	$0.3 \times 10^{-2} \pm 0.0005$	0.11
Pole diameter (cm)	13.37±1.9	13.08±1.7	0.75
Tree diameter (cm)	44.35±9.7	41.65±13.8	0.61
Normalized difference vegetation index (NDVI)	0.36	0.36	0.34

Value with '*' means a significant difference (p-value <0.05)

types are different from each other (Table 4), which were indicated by the very low similarity index at all plant stages. The total number of plant species in the "Presence" area is higher, even reach more than three times higher at seedling level than in the "Absence" area (Table 4). Thus makes the diversity index in the "Presence" area slightly higher than the "Absence" area (Table 4). The dominant plant species of the "Presence" area mostly are the southern cassowary diet, while the "Absence" area is dominated by non-diet plant species (Table 5).

DISCUSSION

Southern Cassowary Distribution Estimation. The distribution of the southern cassowary in WNP is known to be most influenced by the NDVI and annual precipitation variables. Other members of the Palaeognathae group, such as ostriches and emus, show similar results with a tendency to select areas with high NDVI values as considerations for areas with higher plant productivity and source of water (Verlinden & Masogo 1997; Madani *et al.* 2016). In addition to being related to water sources, precipitation is also known to affect the time of flowering plants, thus relating to the abundance of forage fruits produced (Van Schaik *et al.* 1993).

Based on the variables explained previously, the possible distribution of the southern cassowary in TNW is focused in the northeastern area of the Wanggo Resort and several points north of the Sota Resort. Wasur National Park consists of several different ecosystems in each Resort. Based on the 2024 land cover map of the WNP Office, the Wanggo Resort is dominated by the lowland forest ecosystem, while the Sota Resort is dominated by swamp forest. Although the lowland forest ecosystem is centered in the Wanggo Resort area, the most frequent encounters of signs of the southern cassowary were found in the Sota Resort. In addition to the difference in seasons during observation, the two observation locations in the Wanggo Resort, Kondan and Kamnosari directly border residential areas and

Table 4. Total plant species, community similarity, and diversity of lowland forest

Stratum	Total plant species		Similarity index	Diversity index	
	Presence	Absence		Presence	Absence
Seedling	48	13	0.15	0.90	0.85
Sapling	44	15	0.16	0.94	0.82
Pole	39	17	0.17	0.95	0.92
Tree	51	22	0.18	0.97	0.90

Presence: lowland forest with presence sign, Absence: lowland forest without presence sign. Similarity index value approaches 1 means both data set categorized similar. Diversity index approaches 1 means diversity categorized high

Table 5. Dominant plant species in lowland forest

Stratum	Presence area		Presence area	
	Species	IVI (%)	Species	IVI (%)
Seedling	*Endiandra fulva**	39.88	*Corypha utan*	37.28
Sapling	*Aglaia* sp.*	29.40	*Choriceras tricorne*	34.58
Pole	*Endiandra fulva**	25.24	*Cananga odorata*	32.96
Tree	*Buchanania arborescens**	14.59	*Lophostemon* sp.	34.67

IVI= Important value index. Species with '*' categorized as southern cassowary diet

rice fields, also hunting reports from the nearest village. This will affect the southern cassowary distribution of that goes deeper into the forest to avoid the area (Pangau-Adam & Noske 2012; pers. comm. Balai Taman Nasional Wasur).

Southern Cassowary Population Density Based on Feces Encounter. The highest feces encountered in this study were in Tabutar and Kilor, both located in the Sota Resort. Higher rainfall intensity in February and March in both locations is associated with the abundance of fruit in the forest (Dunham *et al.* 2018; Badan Meteorologi Klimatologi dan Geofisika 2021). This affects the amount of food consumed and also the number of defecations of the southern cassowary. In addition to the abundance of food fruit, abundant water sources are also known to affect the abundance of the southern cassowary in nature (Pangau-Adam *et al.* 2015), thus affecting the number of feces found in the field.

The southern cassowary density analysis result in WNP is slightly higher than the study in Mission Beach, Australia (0.48 ind/km^2) with direct census and mapping of the southern cassowary method (Moore 2007). The higher population density of the southern cassowary in WNP may be due to lower anthropogenic disturbance than the southern cassowary habitat in Australia. Its habitat in Australia is known to be threatened by land conversion, and its population is threatened by being hit or attacked by invasive species such as dogs (Dennis 2023). However, it is possible that the anthropogenic disturbance experienced by the southern cassowary in WNP is considered less due to the lack of information of its threats. Using the distance sampling method, a study on the same genus, *Casuarius unappendiculatus*, in Nimbokrang, Papua, showed a higher population density of 3.9 ind/km^2 (Pangau-Adam *et al.* 2015). Unlike WNP and Mission Beach, Nimbokrang has a wider, continuous forest with minimal anthropogenic disturbance and a higher abundance of fruit trees and water sources. This affects the denser population density of *Casuarius unappendiculatus* in Nimbokrang, Papua (Pangau-Adam *et al.* 2015) .

Southern Cassowary Habitat. Southern cassowary in WNP is mainly found in lowland forest which found at the altitude of 0-1,000 meters above sea level with three to four canopy stratum, has the characteristics of a tree that sticks out with a height up to 45 m, large plank roots, with liana (Sub Direktorat Inventarisasi dan Pemolaan Kawasan Konservasi 2020). The lowland forest in WNP has a dense seedling density and big tree diameters. This is due to the feces of southern cassowary that formed a pile of fruits it consumed. These fruits then germinate close together, making the seedling density more dense (Alexandre 1978). It is known that large tree diameters tend to be more productive, so they will produce much fruit (Pennington & Sarukhán 2005), thus attracting the presence of the southern cassowary.

Lowland forest with signs of southern cassowary clearly has different types of plant species with higher plant diversity compared to the area without southern cassowary signs. That may be influenced by the role of the southern cassowary as a seed disperser affects plant diversity in its forest habitat (Wandrag *et al.* 2017). Cassowary also has a role as a keystone species that maintains the complexity and structure of a community (Dew & Boubli 2005). Thus the absence of southern cassowary can significantly impact the diversity in the lowland forest area.

Southern cassowary population density estimation in WNP is 0.8 ind/km^2, with the dominant habitat in lowland forest, which has a dense seedling density, big tree diameter, relatively high NDVI value, and plant composition mainly consists of the southern cassowary diet. Southern cassowary distribution in WNP focused

on the northeastern area of Wanggo Resort and several areas north of Sota Resort. This study is the first on the population of southern cassowaries in WNP. This study was also independently funded, so it was limited by many limitations. Therefore, further research with a broader area coverage is needed understand the southern cassowary in WNP.

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