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Relative abundance, activity pattern and habitat suitability of Great Argus (*Argusianus argus grayi*) in Sungai Wain Protected Forest, Balikpapan, East Kalimantan

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ABSTRACT

Great Argus (*Argusianus argus*) is a globally threatened species that is protected by law in Indonesia. This species is a habitat specialist that tends to be confined to primary forests and is susceptible to human disturbance and environmental change. Sungai Wain Protected Forest (SWPF) is an isolated lowland rainforest in Kalimantan. The rising deforestation rate has threatened species sustainability in recent decades, including the Great Argus in SWPF. This study aimed to systematically analyze camera trap data on the Great Argus's abundance, activity patterns, and habitat suitability prediction in SWPF. We used camera trap data from 2018-2022 at the SWPF. Great Argus's lowest relative abundance index was in 2020, and the highest was in 2022. Overall, the relative abundance index of the Great Argus was approximately 3.125 independent events per 100-day trap night. The activity pattern of the Great Argus started at dawn and then constantly decreased until dusk. The habitat suitability prediction for the Great Argus was mostly in primary forests. Distance to road and building were the variables that contributed the most to the results of habitat suitability modeling. Habitat loss and suitability are the determining factors for the sustainability of significant argus populations.

1. Introduction

The Great Argus (*Argusianus argus*), a large Phasianidae species, is primarily distributed in the Sundaic lowlands of Myanmar, southwest Thailand, the Malay Peninsula, Borneo, and Sumatra (BirdLife International 2001). It is defined as two subspecies: *A. a. grayi* in Borneo and *A. a. argus* in all other geographic ranges (Mackinnon and Phillipps 1993). Great Argus is solitary and territorial, particularly during mating, whereas males are prominent, with long plumage in a small territory (dancing ground) (Phillips 1990). This species exhibits a preference for specific habitats and vegetation characterized by Dipterocarpaceae with a slight understory cover (Davison 1981b). The Great Argus is currently under threat, with populations in Indonesia deemed safe only in well-managed conservation areas (McGowan and Kirwan 2020). This species is categorized as vulnerable under the IUCN Red List (BirdLife International 2020). The Bornean subspecies (*A. a. grayi*) is frequently hunted, and the feathers of individual males are used by indigenous people for traditional ceremonies (Nijman 1998). Higher poaching threats to the Bornean Great Argus could render this subspecies population more vulnerable (Winarni *et al*. 2009; Phillipps Q and Phillipps K 2011). Forest conversion and habitat fragmentation, driven by illegal logging, deforestation, and various human activities, pose significant risks to

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the survival of this species and its biodiversity (Helms *et al*. 2018; Simamora *et al*. 2021).

Bornean Great Argus are difficult to encounter in the wild but are easily recognized by their distinctive calls (Nijman 1998). Exploration of the Great Argus is more accessible using camera traps, as in previous studies in Sumatra (Winarni *et al.* 2005). Maximizing data resources from long-term camera trap observations will provide new insights for future management strategies. One of the potential habitat areas for the Great Argus in the province of East Kalimantan (Indonesian Borneo) is the Sungai Wain-Protected Forest (SWPF). SWPF management (Pro Natura Foundation) has a program for long-term camera trap observations of the frequent presence of the Great Argus. However, in-depth studies regarding the habitat suitability of the Great Argus still need to be conducted in the SWPF.

Previous studies have shown that the Great Argus in Borneo chose primary forests with relatively dry areas to avoid human disturbance (Herwono 1989; Nijman 1998). The availability of specific habitats for the Great Argus is becoming critical and its presence is cornered due to anthropogenic disturbances (Dawrueng *et al*. 2017). A study on the Bornean Great Argus in the SWPF has previously been conducted but is yet to be published. The susceptibility of Bornean Great Argus to anthropogenic disturbance is a significant consideration in this study, especially because *A. a. grayi*, a sub-species of Borneo, is yet to be well known. Ecological information regarding the Great Argus for habitat requirements in the SWPF has never been reported. This study aimed to estimate the relative abundance, describe the activity patterns, and predict the habitat suitability of the Great Argus in SWPF. This information can contribute to a broader understanding of its ecological role in ecosystems and may provide updated particulars for great argus, especially for the subspecies in Borneo.

2. Materials and Methods

2.1. Study Sites

This study was conducted at SWPF (01°02–01°10 s, 116°47–116°55'E) in Balikpapan, East Kalimantan, Indonesia (Figure 1). These study sites are predominantly lowland dipterocarp forests (Fredriksson and Nijman 2004). The total reserve area of the SWPF was 11,186

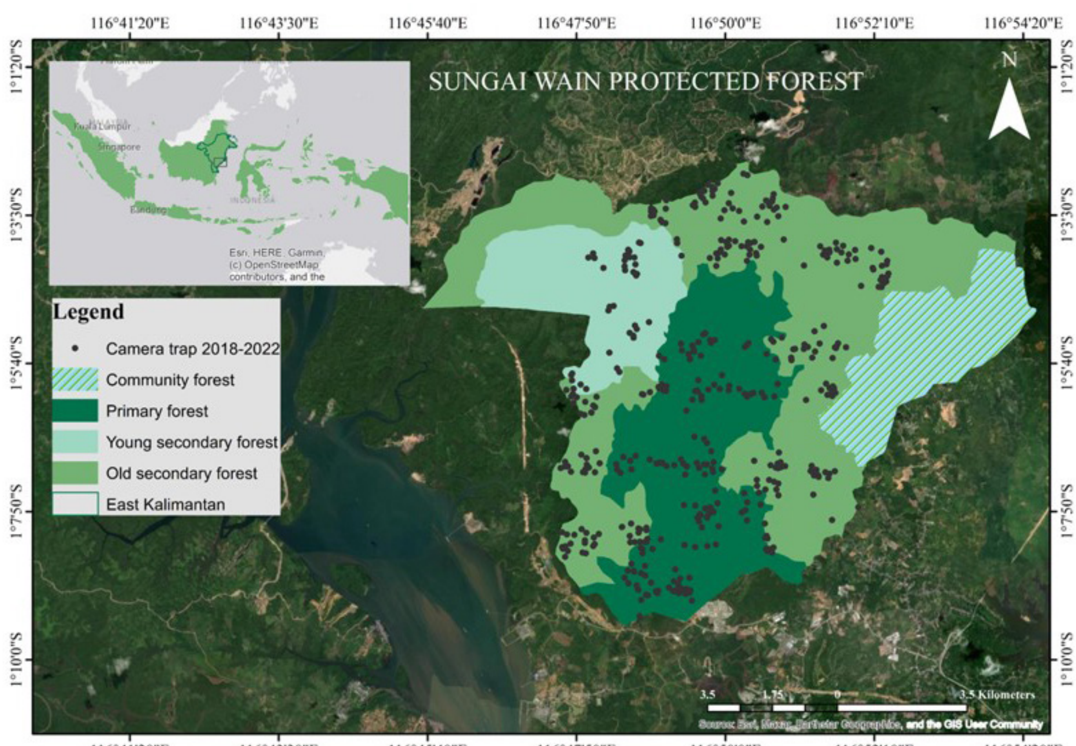

Figure 1. Map of the sampling area and location of camera stations in the SWPF, East Kalimantan, Indonesia. The forest types in the SWPF are categorized as primary forests, old secondary forests, young secondary forests, and community forests

ha, officially designated as a conservation area in 1934 (Fredriksson and de Kam 1999). All the sites consisted of primary forests, old secondary forests, young secondary forests, and community forests (Figure 1).

2.2. Camera Trapping

We used the camera trap data from 2018 to 2022 (15-25 camera trap units). Camera traps were deployed at nearly all sampling sites, excluding community forests (converted from reserve to agriculture) (Figure 1). We used several brands of camera traps: Blaze Video (Blaze Video Technologies Co., Ltd., Shenzhen, China), Bushnell HD (Bushnell Holdings, LLC, Kansas, USA), and Campark (Campark Electronics Co., Ltd. Shenzhen, China), Covert Illuminator (Covert Scouting Cameras, Russellville, Kentucky), Covert Maverick Red (Covert Scouting Cameras, Russellville, Kentucky), Funshion (Funshion Technology Co., Ltd. Beijing, China), and Reconyx (Reconyx, Inc., Holmen, Wisconsin, USA).

The settings, sensitivity, and performance of all the trap cameras were equalized to provide no significantly different outcomes. The time between shots (interval) of the camera trap was set to a minimum (5-10 s). The sensor sensitivity of the camera trap was set at a normal level. Each camera was set on a 2 km × 2 km sampling grid. The camera trap was placed on trees approximately 30-40 cm above the ground and 1.5-2 meters from the target and was operated for 24 h. The selection of camera installation sites was based on the criteria of being near animal trails, natural salt licks, and dancing grounds, particularly for the Great Argus. Each camera trap installation period was marked as one session (sampling period). One session lasted between the batteries and the SD card replacement (approximately 30 days). The maximum number of sessions was conducted three times at the same coordinates. The first session aimed to observe the presence of animals, the second continued to determine whether the target animals were captured, and the third continued to show great results. The location of camera traps is recorded using the Global Positioning System (GPS) Garmin 64s (Garmin Asia Corporation, New Taipei City, Taiwan).

2.3. Abundance of Great Argus

We estimated the abundance of Great Argus using the relative abundance index (RAI) and calculated the number of independent events per 100 trap nights. Independent events were defined as 1) consecutive photographs of individuals of the same or different species, 2) consecutive photographs of individuals within one species at intervals of more than 30 minutes, regardless of the number of pictures, and 3) non-consecutive photos of individuals of the same species. The number of active camera days was rated as trap nights, calculated for each installed camera until retrieved or the final exposure (O'Brien *et al*. 2003). RAI is a practical tool used to estimate the relative abundance of species, especially when individual identification is impossible (O'Brien *et al*. 2008; Lim *et al*. 2023). This provides a relative representation of a species within an area, indicating its commonness or rarity (Podgórski *et al*. 2020).

2.4. Activity Pattern

All independent events of the Great Argus were used to calculate activity patterns in the grid sampling area. We recorded the time data in camera traps; all-time data should be converted into radians (in the range of 0 to 2 × pi). The activity patterns of Great Argus were estimated and visualized using the 'activity' package on software R (Rowcliffe *et al*. 2014; Rowcliffe 2023). Histograms were created to plot the activity distributions of the Great Argus in the SWPF.

2.5. Data Source and Environmental Variables

We obtained the presence data for the Great Argus from the coordinates of the camera traps. Eight environmental variables were used and divided into four categories: 1) climate variables: annual mean temperature (bio1) and annual precipitation (bio12) (Karger *et al*. 2021); 2) physical variables: distance to the river (data from Pro Natura Foundation) and slope (USGS 2014); 3) resources: normalized difference vegetation index (NDVI) and land use (USGS 2020; USGS 2022); and 4) anthropogenic disturbance: distance to road and distance to building (OpenStreetMap 2023). The selection of the environmental variables was modified based on previous studies (Li *et al*. 2016; Rahman *et al*. 2017; Rahman *et al*. 2019; Jose and Nameer 2020; Neice and McRae 2021; Jaelani *et al*. 2023). All environmental variables were processed using ArcGIS version 10.7.1 to GIS data layers. We used spatially rated occurrence data on the SDM toolbox to reduce spatial autocorrelation so that for a total of 123 occurrence points, only 47 points were used. The resolution to rarefy the data of the Great Argus was based on an average territorial size of 14.5 ha (Winarni *et al*. 2009).

2.6. Habitat Suitability

We predicted the habitat suitability of Great Argus using Maximum Entropy (MaxEnt version 3.4.4). Environmental layers and significant Great Argus presence data are required to run the model. The presence data of the Great Argus in the SWPF consists of 47 coordinates used to run the model. We set the random test percentage to 25 % and the number of replicates to ten times. The maximum number of iterations was set to 5000, and bootstrapping was used to replicate the run type. A bias file was added to complete the modeling result, analyzed using the Gaussian Kernel Density of Sampling Localities on the SDM toolbox. SDMtoolbox provides various tools and functions to facilitate species distribution and ecological niche modeling in ArcGIS (Brown 2014). The AUC (area under the ROC curve) value used to measure the performance of a classification model, the AUC values between 0.5-0.7 indicate relatively low accuracy, and between 0.7-0.9 indicate proper accuracy (Swets 1988).

3. Results

A total of 9,078 photographs of 690 independent events of the Great Argus were collected from 22,082 trap nights (Table 1). During the sampling period of 2018–2022, independent events of the Great Argus occurred only in primary and old secondary forests. The highest RAI of the Great Argus was in the 2022 period (5.14 independent events per 100 trap–night), and the lowest RAI of the Great Argus was in the 2020 period (1.20 independent events per 100 trap–night) (Table 1). Unique and fascinating dancing was captured on the camera trap, and a male Great Argus attracted females (Figure 2). In addition, we found that the Great Argus in all grid sampling SWPF was a diurnal species. The peak activity pattern for the Great Argus occurred during the early morning and continued to decrease before dusk (Figure 3).

The average training area under the curve (AUC) for the modeling of great argus habitat suitability showed good performance (AUC=0.845±0.030) (Figure 4).

Table 1. Camera traps and RAI of Great Argus (*Argusianus argus grayi*) data during the 2018-2022 survey period in SWPF, East Kalimantan, Indonesia

Survey period	Total sampling grid	Total session	Total picture of all species	The total picture of the Great Argus	Trap-night (day)	Independent event of Great Argus	RAI
3 February 2018-11 January 2019	27	172	15,152	1,391	4,763	128	2.697
2 December 2018-29 December 2019	29	150	28,284	1,991	4,384	150	3.422
10 December 2019-31 December 2020	29	213	40,324	728	4,584	55	1.200
9 February 2021-28 December 2021	24	189	30,574	2,078	4,846	177	3.652
2 February 2022-28 January 2023	28	143	21,287	2,890	3,505	180	5.146
Total		867	135,62	9,078	22,083	690	

Figure 2. Great Argus (*Argusianus argus grayi*) was captured with a grid sampling camera trap while dancing lek in SWPF, East Kalimantan, Indonesia. The male performs while displaying its long feathers to the female (male on the right and female on the left)

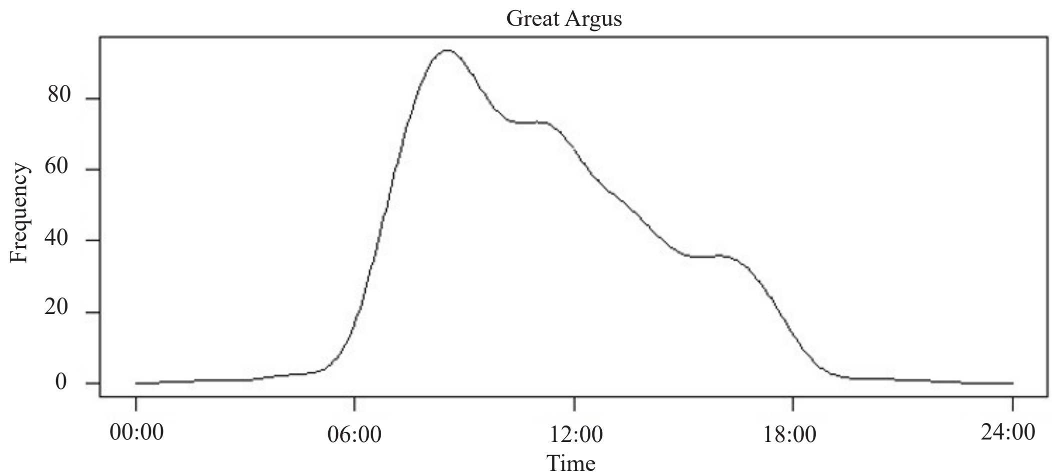

Figure 3. The activity pattern histogram of Great Argus (*Argusianus argus grayi*) (n=690) for all grid sampling areas in SWPF was done using the 'activity' package on software R (Rowcliffe *et al.* 2014; Rowcliffe 2023). The X-axis indicates the time of independent events, and the y-axis indicates the frequency

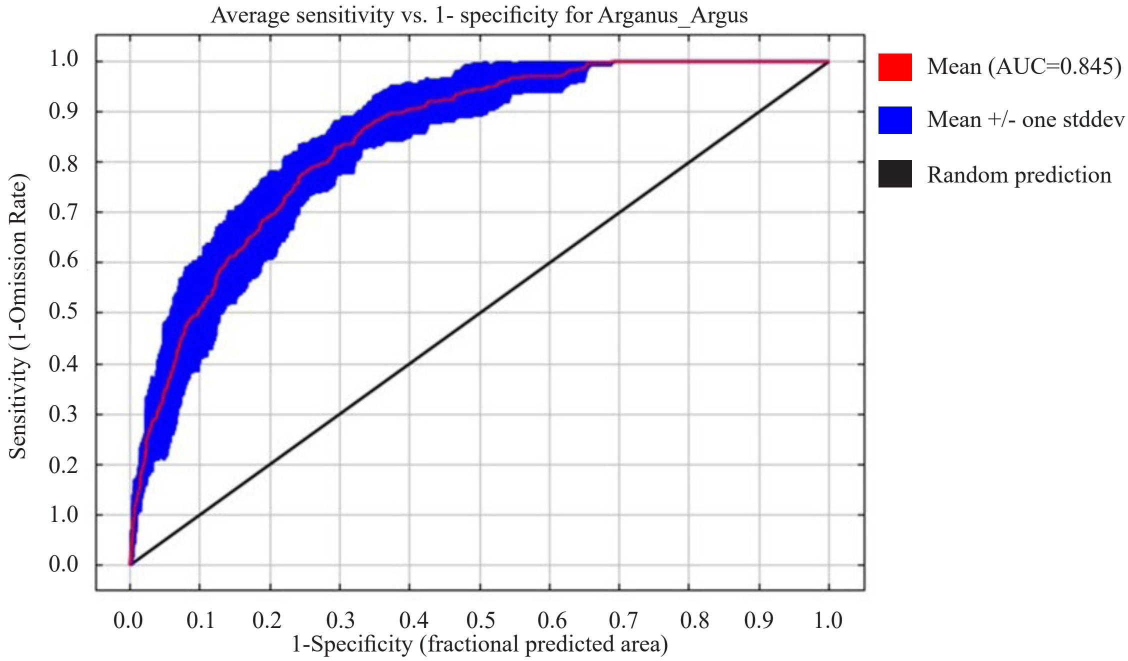

Figure 4. Graph of AUC for modeling habitat suitability of the Great Argus (*Argusianus argus grayi*) in SWPF, East Kalimantan, Indonesia

Based on the permutation importance (PI), the distance to the road was the most influential variable (22.8%) (Table 2). The results of the jackknife test showed that, with individual variables only, the highest variable importance was the distance to the road (Figure 5). Suitable areas are centralized in the core of the reserve and are dominated by primary forests with dense vegetation (Figure 6). Habitat suitability prediction was classified as suitable or unsuitable. The percentage of suitable areas was more extensive than that of unsuitable areas (Table 3).

Table 2. Analysis of environmental variables contributing to habitat suitability of the Great Argus (*Argusianus argus grayi*)

Environmental variables	Permutation importance (%)
Annual mean temperature (bio1)	2.3
Annual precipitation (bio12)	15.4
Distance to building	20.4
Distance to river	10.6
Distance to road	22.8
Land use	15.8
Normalized difference vegetation index (NDVI)	3.6
Slope	9.1

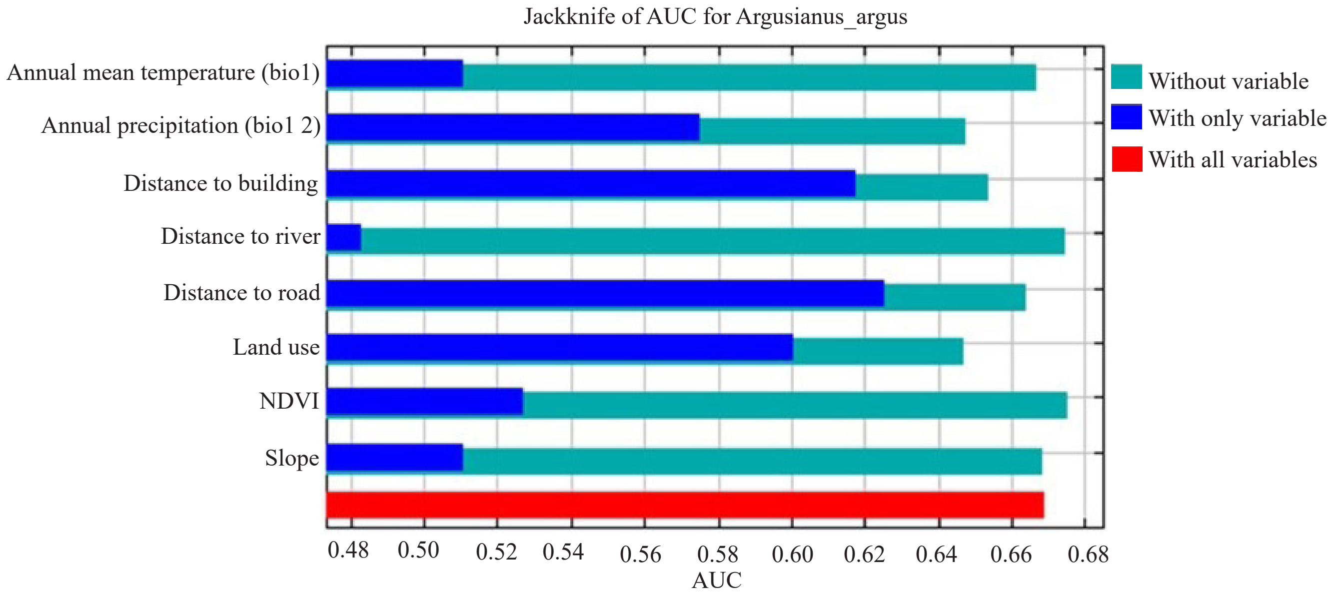

Figure 5. Graph of the jackknife test of variable importance using AUC on test data of the Great Argus (*Argusianus argus grayi)* in SWPF, East Kalimantan, Indonesia

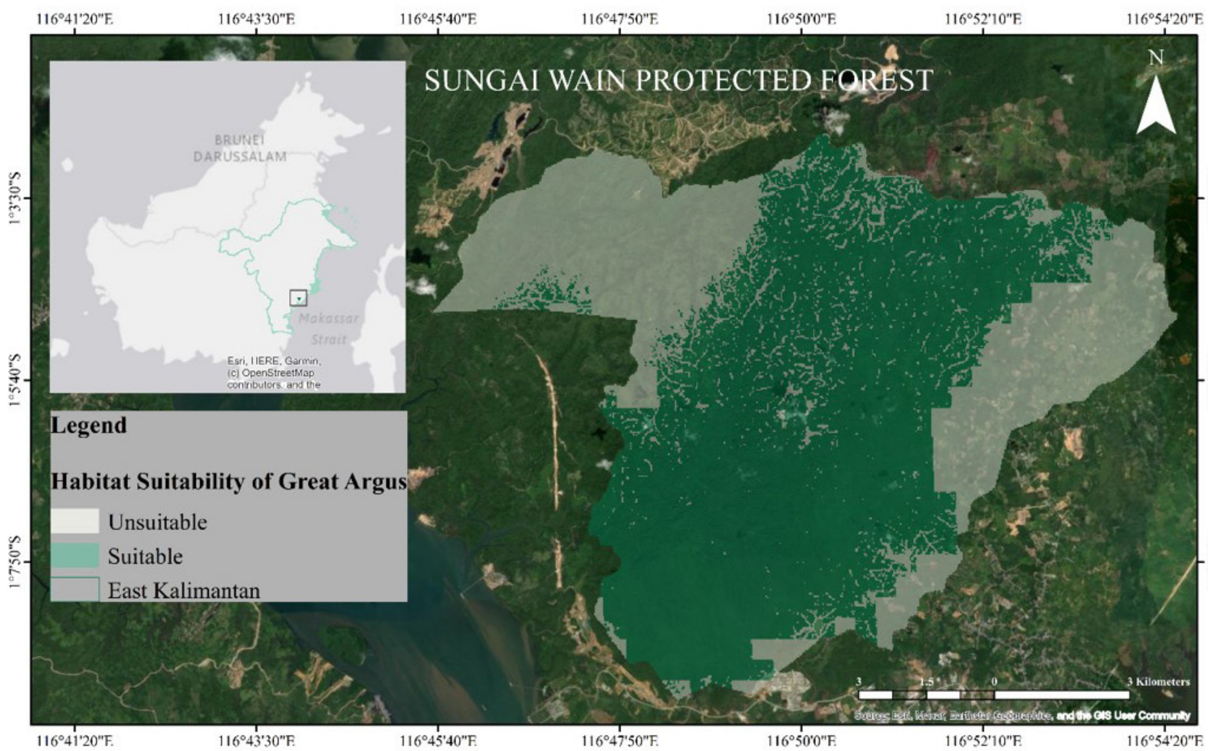

Figure 6. Habitat suitability modeling for the Great Argus (*Argusianus argus grayi)* in SWPF, East Kalimantan, Indonesia

Table 3. Percentage area of modeling habitat suitability for the Great Argus (*Argusianus argus grayi)* in SWPF, East Kalimantan, Indonesia

Habitat suitability	Area (Ha)	Percentage (%)
Unsuitable area	4,383	39.179
Suitable area	6,804	60.821

4. Discussion

Based on the RAI, the Great Argus in SWPF was relatively higher (average RAI = 3.125) than the Tanjung Datu NP in Sarawak (RAI = 0.482) (Mohd-Azlan *et al*. 2018). In 2020, the RAI of the Great Argus in the SWPF had the lowest value over five years. This is possibly due to increased poaching in SWPF during the COVID-19 lockdown period. During patrols in the SWPF, rangers caught various snares that endangered the animals. The stunning feathers of the Great Argus are the primary targets of poaching (Phillipps Q and Phillipps K 2011). Roads and settlements bordering this reserve are susceptible to poachers' entry. It is assumed that the impact of the pandemic has increased human activity in SWPF owing to economic pressures, as observed in Zimbabwe (Ndlovu *et al*. 2021). In Nepal, wildlife mortality increased during the COVID-19 pandemic, and poachers took advantage of security gaps in reserves near settlements, as conditions in SWPF (Koju *et al*. 2021). Reserve management consistently supports daily patrols to prevent poaching and illegal logging in SWPF (Fredriksson and Nijman 2004).

The detection time data from camera traps has provided us with fascinating insight into the activity patterns of the Great Argus in a more cost-effective and non-invasive way (Rowcliffe *et al*. 2014). This study confirms that the Great Argus only has a frequency of activity patterns during the daytime. The activity of the Great Argus started from dawn, with the peak activity observed in the morning, then constantly decreasing until dusk. There is no single photograph of the Great Argus at night in the SWPF, emphasizing the diurnal nature of this species. However, the vocalizations of the Great Argus in SWPF remained active during the night (H. Ramadhanti, pers. obs.). The activity results obtained using camera traps in a previous study also showed that the Great Argus was only active during the day, but still actively vocalized at night (Winarni *et al*. 2005; O'Brien and Kinnaird 2008). At night, no Great Argus are captured, as they remain stationary during vocalization (Winarni *et al*. 2005; Clink *et al*. 2021). Daytime activities of the Great Argus are mostly perching and foraging, and males stay on the dancing ground during the breeding season (Davison 1981a). Thus, understanding these activity patterns is fundamental to the behavior and ecology of species (Rowcliffe *et al*. 2014).

Our prediction showed the habitat suitability of the Great Argus, a measure of how well the environment meets the needs of the species, avoiding the forest edge of the SWPF due to increased anthropogenic disturbances. High levels of disturbance are primarily caused by highway activities, industrial areas, and settlements. The highest contributing variables in this study were distances to roads and settlements. Great Argus prefers to avoid human activities at forest edges (logging and poaching) (Dawrueng *et al*. 2017). In the Kayan Mentarang NP, the Great Argus is reported less frequently near the main river because it is the center of human activity, and rivers are used as the main means of transportation (Nijman 1998). This study also confirms previous findings that the Great Argus is a dominant inhabitant of primary forests with large trees and the least understory (Davison 1981b; Nijman, 1998; Johngard 1999; O'Brien and Kinnaird 2008; Winarni *et al*. 2009; Dawrueng *et al*. 2017). The response of the Great Argus to specific forest types suggests that it can be categorized as an interior forest specialist. Interior forest specialists are defined as species that only reside and nest in the forest interior and tend to avoid the forest edge (Whitcomb *et al*. 1981). The strict habitat specificity of the Great Argus decreases the possibility of recolonizing empty forest fragments (Winarni *et al*. 2009). The Great Argus in the SWPF is particularly vulnerable, showing less adaptability and tolerance to logged disturbed forest conditions. This highlights the urgent need for conservation efforts in this region. The SWPF is a relatively small reserve (±110 km^2) surrounded by agriculture, settlements, roads, and heavily burned forests (Fredriksson and de Kam 1999; Gilhooly *et al*. 2015; Dai *et al*. 2021; Ueda *et al*. 2022). In early 1998, SWPF caught fire, and only 40% of the primary forests were saved (Fredriksson 2002). In the last decade, fires that have occurred repeatedly each year from 2014 to 2019 have been reported (Dai *et al*. 2020). The remaining primary forest in the SWPF is essential for the Great Argus for breeding, feeding, and protection from anthropogenic disturbances. Primary forests have a greater opportunity to offer more food sources because of their vegetation structure, resulting in a high-quality habitat-carrying capacity (Nijman 1998). The dancing ground of the Great Argus tends to be located in a primary forest with characteristics consisting of animal trails and the least understory (Davison 1981b; Nijman 1998; Winarni *et al.* 2009). The male requires a spacious area to spread his long wings on the dancing ground and attract females before mating (Phillipps Q and Phillipps K 2011). Great Argus prefers primary forest in the core of the reserve, with low levels of human disturbance (Winarni *et al*. 2005; Dawrueng *et al*. 2017). The primary forests in the SWPF are the most suitable habitats for the Great Argus, and are crucial for their survival. The loss of these primary forests would significantly impact the Great Argus population and its ability to thrive in the reserve.

Anthropogenic disturbance will increase as years of development progress in areas around the SWPF reserve. Therefore, it is necessary to provide comprehensive protection to areas with potentially suitable habitats to maintain the existence of the Great Argus and their habitat. When primary forests no longer exist, restoring secondary forests is not a better option than maintaining primary forests, especially for habitat-specific species, such as the Great Argus. Habitat protection was the most appropriate way to preserve the population sustainability of the Great Argus. This pheasant deserves further protection because of its attractive and unique behavior.

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