

HABITAT SUITABILITY SPATIAL MODEL OF NEAR THREATENED SUNDA TEAL *ANAS GIBBERIFRONS* (MULLER, 1842) (ANSERIFORMES: ANATIDAE) IN MUARA ANGKE WETLANDS, JAKARTA, INDONESIA

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ABSTRACT

Wetland ecosystems are important habitats for many waterbird species, including the IUCN near-threatened Sunda Teal *Anas gibberifrons*, a species that inhabit wetlands in Indonesia. Muara Angke is one of few remaining wetlands located in Jakarta and has potential as an important habitat for Sunda Teal. This study aims to assess and model suitable habitat for near-threatened Sunda Teal in remaining wetlands in Muara Angke in Jakarta, Indonesia. The study areas include an ecotourism park, the western and eastern parts of the Angke protected forest, and the wildlife reserve. Remote sensing data and geographic information system (GIS) analysis were employed to assess Sunda Teal's habitat suitability. Some environmental variables negatively influencing habitat suitability for the species include the presence of fishponds and settlements, and represent anthropogenic disturbance. In contrast, variables that may positively influence the species include the occurrence of gastropod and crustacea, both groups being known as food resources, and mangrove cover. The highly and moderately suitable habitats were estimated to form 32.36% and 23.48% of the total wetlands, respectively. In contrast, 12.17% was considered unsuitable for Sunda Teal. The ecotourism park had the most unsuitable habitats. In contrast to the ecotourism park, the protected forest, followed by the wildlife reserve, had more moderately and highly suitable habitats.

Key words: *Anas*, GIS, habitat, suitability, wetland

INTRODUCTION

Anatidae is a distinct waterbird family including swans, geese, and ducks. These shorebird species were inhabiting a wetland. In Indonesia's wetlands, one of the best known anatid species is the Sunda Teal *Anas gibberifrons*. There are 13 anatid species in Indonesia. This native Indonesian species inhabit mangrove forest and associated wetlands and has a wide distribution from southern Sumatra (Iqbal, 2016), to Java, Sulawesi, Bali, East and West Nusa Tenggara islands, south of Kalimantan (Mann, 2008; Myers, 2016; Sugiarti et al., 2019), excluding Maluku and Papua. The wild population of Sunda Teal was estimated to number between 6,700 and 67,000 individuals (BirdLife International, 2022; Sugiarti et al., 2019). Despite what is presumed to be stable population, Sunda Teal is precautionarily suspected to be undergoing moderately rapid population declines owing to hunting pressure and habitat degradation across its distribution in Indonesia. It has therefore been classified as Near Threatened by the IUCN (IUCN, 2022).



Using habitat suitability studies (Sanare et al., 2015; Dondina et al., 2020) to better guide plans to conserve species such as Sunda Teal is one way of improving the conservation of the species. Predicting habitat appropriateness using a modeling approach based on geographic information systems (GIS) is a methodological tool that can be used to support conservation programs (Ottaviani et al., 2004). Habitat suitability models have been used to predict the occurrence of species in forested habitats by modeling appropriate environmental conditions. This approach is appropriate for biodiversity evaluation since it can be applied on a large number of species. Nevertheless, statistical validation is required, both to test the accuracy of the input information and to deal with presence data. As a result, habitat suitability analysis has been frequently used in certain ornithological research. In the Taita Hills, Kenya, Obunga et al. (2022) have modeled the most suitable habitat to improve the conservation status of two critically endangered endemic Afrotropical forest birds and confirmed that reforesting open and degraded sites next to areas predicted as highly suitable for the species proved to be a solution to support bird conservation. In Indonesia, Purify et al. (2019) have used this analysis to identify important areas of waterbird habitats for conservation in the mangrove ecotourism area of Lantebung, Tamalanrea District, Makassar City.

On Java, Jakarta is one of the cities that has been known to provide important habitat for waterbirds in Muara Angke. There were 106 bird species, including 22 migratory bird species (Mayalanda et al., 2014). Recently, the wetlands along with the bird species in Muara Angke were threatened due to the reduction of wetland ecosystems (Sasongko et al., 2014). Although the ecology of Sunda Teal has been extensively studied (Purify et al., 2019; Sugiarti et al., 2019), comparatively little quantitative information is available on the habitat requirements of this species, in particular at the well-known Muara Angke wetlands on the Jakarta Coast. Therefore, this study aims to assess and model the suitable habitat for near-threatened Sunda Teal in the remaining wetlands in Jakarta. The findings from this study may be beneficial for the conservation of Sunda Teal along with its wetland ecosystems in Indonesia.

MATERIALS AND METHODS

Study area

The study areas in wetlands of Muara Angke constituted four sampling locations (Table 1), including (1) an ecotourism park, (2) the western and (3) eastern parts of the Angke Kapuk protected forest, and (4) a wildlife reserve (Fig. 1, Table 1). The ecotourism park is bordered by fishponds in the west. In contrast, the western parts of the Angke Kapuk protected forest are bordered by Jakarta Bay in the north and fishponds in the west. The eastern parts of the Angke Kapuk protected forest are bordered by Jakarta Bay in the north and the Angke River in the east. The wildlife reserve was bordered by the protected forest in the north and Angke River in the east. Human habitation in the south bordered the whole study area. Regarding the hydrological conditions of the study area's environments, all of the study areas are wetlands that were permanently influenced by the tide and inundated by seawater.

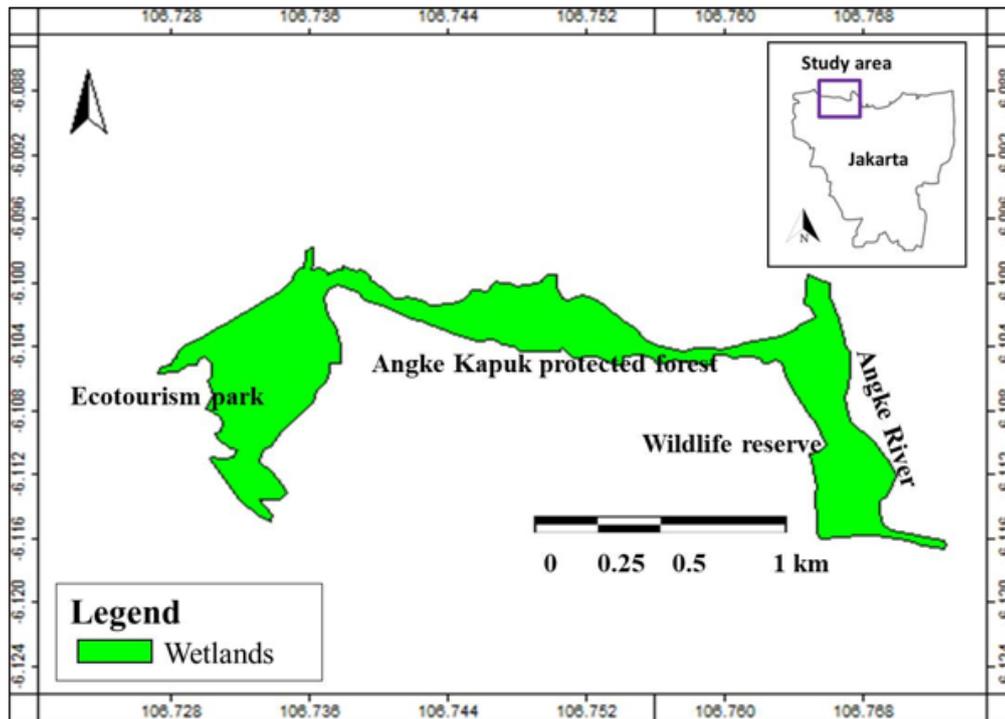


Figure 1. A map of the study area shows four study areas in the wetlands of Muara Angke, Jakarta located in (1) an ecotourism park, the (2) western and (3) eastern parts of the Angke protected forest, and in the (4) wildlife reserve.

Table 1. Locations and descriptions of the study area in the wetlands of Muara Angke, Jakarta

Study area	South latitude	East longitude
Ecotourism park, bordered by fish ponds in the west.	6.099 ⁰ S - 6.116 ⁰ S	106.728 ⁰ E - 106.736 ⁰ E
Western parts of Angke Kapuk protected forest, bordered by Jakarta Bay in the north and fish ponds in the west.	6.09 ⁰ S - 6.116 ⁰ S	106.736 ⁰ E - 106.748 ⁰ E
Eastern parts of Angke Kapuk protected forest, bordered by Jakarta Bay in the north and Angke River in the east	6.09 ⁰ S - 6.116 ⁰ S	106.748 ⁰ E - 106.760 ⁰ E
Wildlife reserve, bordered by protected forest in the north and Angke River in the east	6.09 ⁰ S - 6.116 ⁰ S	106.760 ⁰ E - 106.768 ⁰ E

Mangrove survey

Mangroves were surveyed because mangrove provides habitats for shelter, nesting, and foraging for the Sunda Teal. The mangrove survey was conducted using the purposive random sampling method following Krebs (1999), Hutabarat (2009), and Sofian et al. (2012; 2019) by making observation plots with the size of each plot being 10 x 10 m. There were 10 plots selected randomly in each sampling location. Each individual mangrove was identified, and its coordinates were recorded using a Garmin Etrex Global Positioning System (GPS) handheld device at the observation plot. Mangrove species identification was conducted using mangrove identification book and field guide (Chapman, 2016; Hirsch, 2016; Tomlinson, 2016). The recorded mangrove species are then tabulated for further habitat suitability analysis.

Gastropod and crustacea survey

The gastropod and crustacea surveys were conducted using the purposive random sampling method following Krebs (1999) and Basyuni et al. (2018) by making 10 observation plots selected randomly with the size of each plot being 10 x 10 m or equal to 100 m². The plots for gastropod and crustacea survey were the located in the same plots for the teal's observation. Gastropod and crustacea were surveyed because they are known to be food resources for Sunda Teal (Moore et al., 2006; Collins et al., 2017). Individuals of gastropod and crustacea were collected from the substrate at a depth of 10 cm considering the maximum length of Sunda Teal bill (Pérez-Vargas et al., 2016) using a 0.1 m² Van Veen Grab and sieved using a mesh sieve sized 0.5 mm to separate the gastropod and crustacea from the sediment (Sahidin & Wardiatno, 2016). The collected gastropods and crustaceans were then identified and its coordinates were recorded using a GPS handheld device at the observation plot. The identification of gastropod and crustacea was done using identification books and field guides (Kira, 1965; Roberts et al., 1982; Abbot, 1991; Setyobudiandi et al., 2010; Sahidin, 2020). The presence and abundance of gastropod and crustacea is then tabulated into a Geographical Information System (GIS) with SAGA (System for Automated Geoscientific Analyses) GIS version 2.1.2 to be mapped into habitat suitability thematic layers.

Sunda Teal survey

The Sunda Teal survey in the wetlands of Muara Angke, Jakarta was conducted for two months from July to August 2021. The survey techniques used were visual encounter surveys and multiple surveys through random visits. Multiple surveys were implemented by visiting the survey locations with replications. The survey was conducted during various time periods of the day using direct observations and supported with binoculars. During survey, a point count method was used to measure the Sunda Teal density using a 100 m x 100 m plot replicated 3 times in each study area (Ralph et al., 1998; Obunga et al., 2022). The density of species was calculated based on the number of species individuals divided by the area of the plot. Based on the knowledge of Sunda Teal activities, field surveys were carried out at 05.30–7.00 am and continued at 04.00–06.15 pm. The presences of Sunda Teal at four distinct study areas, including an ecotourism park, western and eastern parts of Angke Kapuk protected forest, and a wildlife reserve were recorded using GPS. The identification of Sunda Teal was done using a field guide (MacKinnon & Phillipps, 1993). The presence of birds was then tabulated into a Geographical Information System (GIS) to be mapped into habitat suitability thematic layers.

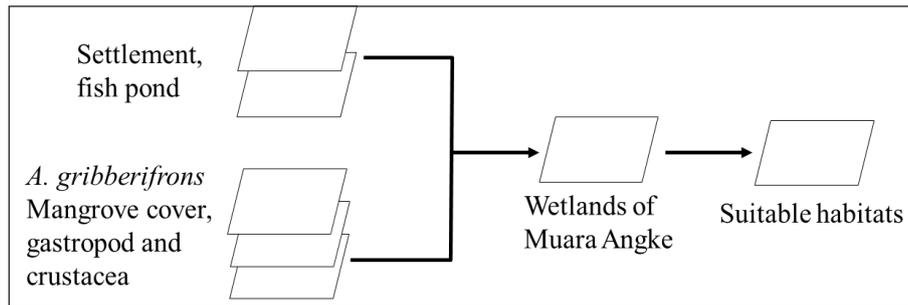


Figure 2. A flowchart of the suitability analysis with the required variables includes settlement, fish pond, SundaTeal *A. gibberifrons* presence, mangrove covers, and gastropod and crustacean presence.

Habitat suitability analysis

In this study, the habitat suitability analysis was achieved through the combinations of remote sensing and GIS analyses using SAGA GIS version 2.1.2 (Alevizos, 2016), following Orimoloye et al. (2019), Philiani et al. (2016), and Sukojo and Arindi (2019). First, Landsat 8 satellite imagery of the Muara Angke wetlands was retrieved and classified using supervised classification to determine the mangrove and land cover types using SAGA version 2.1.2. The categories for land cover classifications were mangroves, water bodies, fishponds, and settlements. The result of mangrove and land cover mapping is a thematic layer. The GPS coordinates of Sunda Teal, gastropods, and crustaceans were then overlaid on layers of mangrove forest cover and land cover mapping for a more in-depth analysis of habitat suitability.

For assessing habitat suitability (Fig. 2), the main environmental variables (Rew et al., 2020) that had an influence on the occurrence of Sunda Teal were identified based on previous studies (Ji et al., 2007; Debela et al., 2020), including environmental variables that pose a threat to the species and environmental variables that support the species. Inverse environmental variables include the presence of fishponds and settlements that represent anthropogenic influence and disturbance. In contrast, converse environmental variables include gastropod and crustacea representing food resources for Sunda Teal and mangrove cover representing nesting habitats for the species. The environmental variables were then assigned a score and weight based on their contribution to Sunda Teal. If the variables pose a negative effect, then it is given 1. In contrast, if the variables have a positive effect, the score is 2. Those scores of each variable were then summed up to calculate a habitat suitability score. The habitat suitability score was then interpolated and classified into 4 classes (Convertino et al., 2011; Zhang et al., 2019). from the least to the most suitable, including unsuitable, scarcely suitable, moderately suitable, and highly suitable.

Chi-square statistical analysis

Chi-square statistical tests (χ^2) was performed to assess if there were significant differences in gastropod and crustacea abundances among study areas. The significance level used was $p < 0.05$.

RESULTS

This study assessed the habitat suitability of Sunda Teal in Muara Angke's wetlands. To achieve the goals of this study, first, the variables that are supposed to have a controlling effect on Sunda Teal's life was identified. Depending on the identified variables, the wetland was spatially categorized into four classes include unsuitable, scarcely suitable, moderately suitable, and highly suitable habitats. The detailed results of the determining variables include fishponds and settlements as disturbances and gastropod and crustacea combined with mangrove cover used to assess the final habitat suitability of Sunda Teal of Muara Angke wetlands were explained as follows.

Mangrove and land covers

Land covers along with their mangrove covers on the study area in the wetlands of Muara Angke can be seen in Fig. 3. The land cover consists of mangrove forest and is followed by a mosaic of water bodies and fishponds. Mangrove forest cover was very dense in the western and eastern parts of the Angke Kapuk protected forest followed by the wildlife reserve and less in the ecotourism park. In contrast, combinations of water bodies and fishponds were observed in the wildlife reserve and more common in the ecotourism park and fewer in the protected forest. The presence of water bodies in the wildlife reserve was due to the presence of the Angke River and previously converted wetlands into fishponds. Residential housing area was found on the south border of the protected forest and on the east side of ecotourism parks. The mangroves in the study area were dominated by *Rhizophora* sp. The density of mangrove *Rhizophora* sp. ranged from 3,807.2 trees/ha to 1,399.5 trees/ha.

Gastropods and crustacea in the wetlands

Gastropods and crustacea species include *Melanoides* sp. for gastropods and *Portunus* sp. for crustaceans. The density of benthic infauna was significantly different ($p < 0.05$) in each study area ($\chi^2 = 464.848$, $p = 0.000$), indicating influences and effects of study area locations and land covers. From the 10 observation plots sized at 100 m² selected randomly, the total number of collected individuals was 1933 individuals for gastropods and 33 individuals for crustaceans. Gastropods have the highest density (193.3 individuals/100 m²) and crustaceans have the lowest density (3.3 individuals/100 m²). Within the study area (Fig. 4), gastropods were more abundant in the ecotourism park, in the eastern parts of protected forest through to the wildlife reserves. In contrast, crustaceans appeared to be limited to the ecotourism park and rarely seen in protected forest and wildlife reserve.

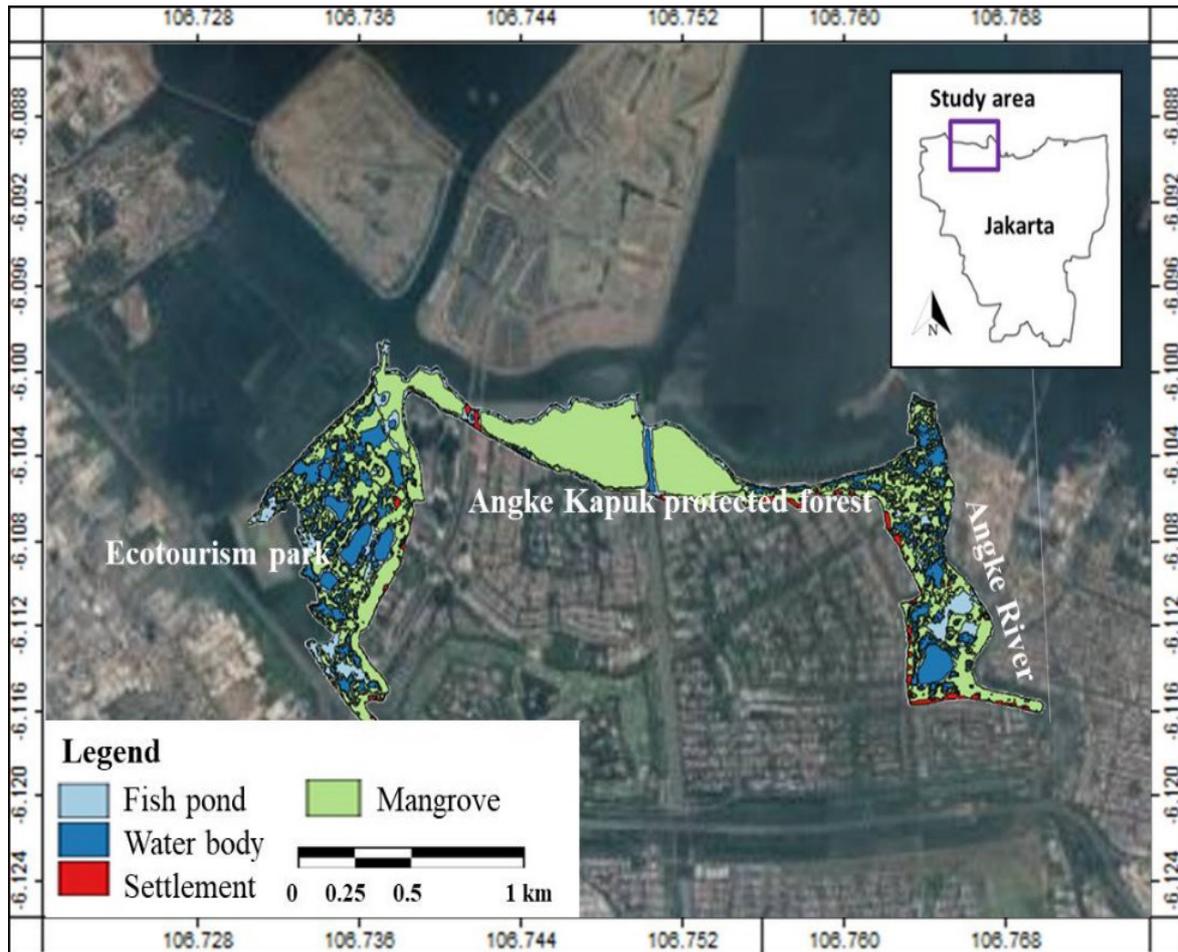


Figure 3. Mangrove and land covers in the wetlands of Muara Angke, Jakarta.

Sunda Teal in the wetlands

This study confirmed the average density of *A. gibberifrons* in the studied wetlands was 1.56 individuals/ha. Sunda Teal individuals were widely distributed from the protected forests to wildlife reserve and limited to ecotourism park. The distributions of Sunda Teal were related to the availability of habitat for nesting and food resources include gastropods and crustaceans in the wetland ecosystems in the particular protected forest and wildlife reserve. These wetlands are characterized by diverse mangrove species and muddy substrates. Dense mangrove covers, as seen in the protected forest, provide suitable habitats for Sunda Teal by providing nesting sites for this species.

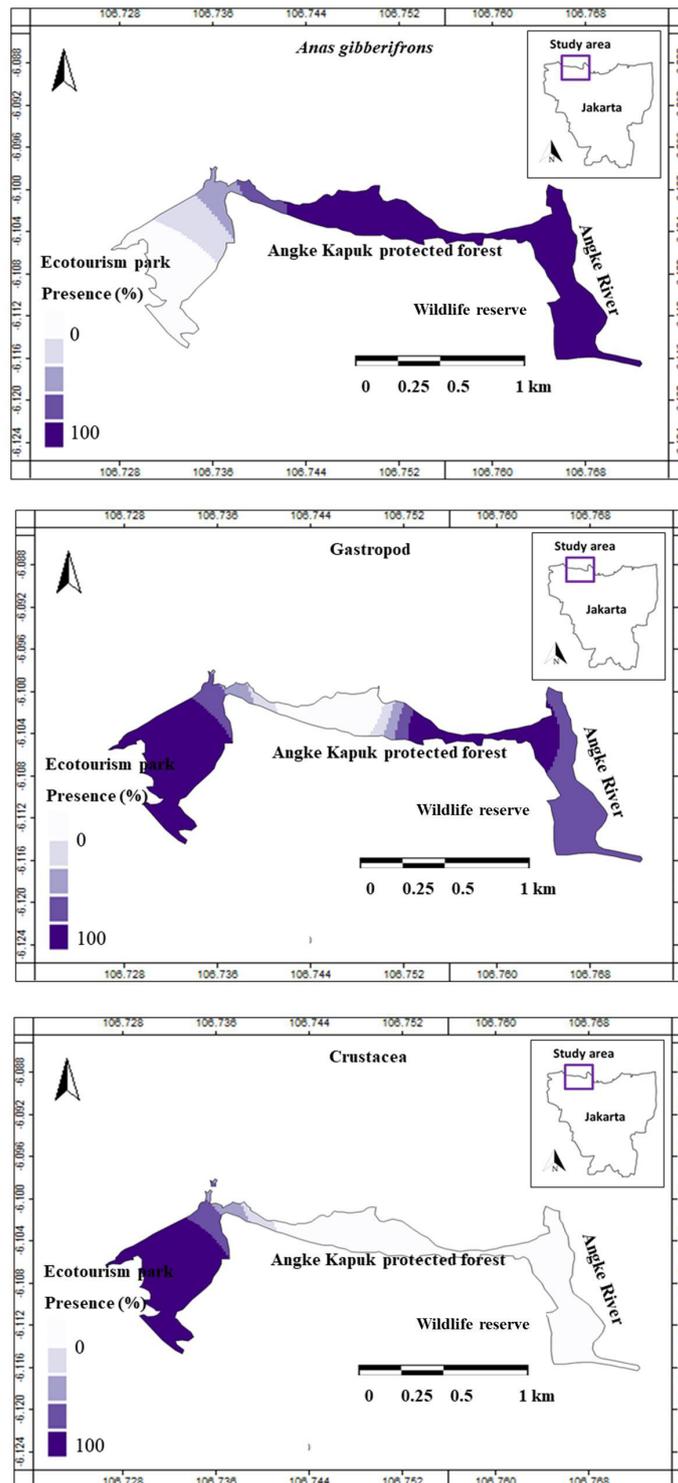


Figure 4. Presences of Sunda Teal *A. gibberifrons*, gastropods, and crustaceans in the wetlands of Muara Angke, Jakarta.

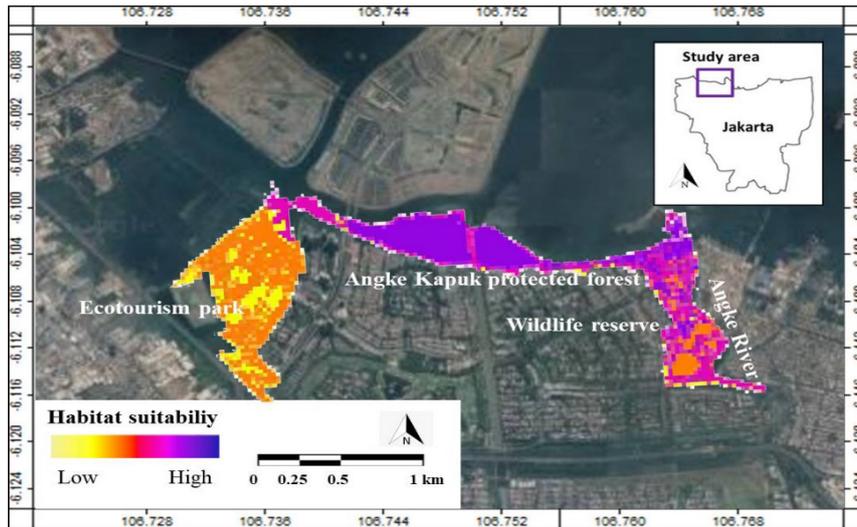


Figure 5. Suitable habitats for Sunda Teal *Anas gibberifrons* in Muara Angke wetlands, Jakarta. The suitable habitats are classified into low (unsuitable), moderate (scarcely suitable, moderately suitable), and high (highly suitable).

Sunda Teal habitat suitability

In this study, the total area of studied wetlands in Muara Angke was 276.8 ha. Based on the habitat suitability analysis, the highly and moderately suitable habitats were 32.36% and 23.48% of the total wetland cover, respectively (Fig. 5). In contrast, 12.17% was considered unsuitable for Sunda Teal. The ecotourism park had the most unsuitable habitats. In contrast to the ecotourism park, the protected forest, followed by the wildlife reserve, had more moderately and highly suitable habitats. Based on the results (Fig. 6), 25.0–66.2% of the ecotourism park was categorized as unsuitable and scarcely suitable habitat for Sunda Teal, and only 8.7% as moderately suitable. For the area of protected forest and wildlife reserve, 22.4–75.6% of protected forest and wildlife reserve was considered as highly suitable habitat and 21.8–50.5% as moderately suitable habitat. Only 2.5% of the protected forest and 4.9% of the wildlife reserve were considered unsuitable for Sunda Teal.

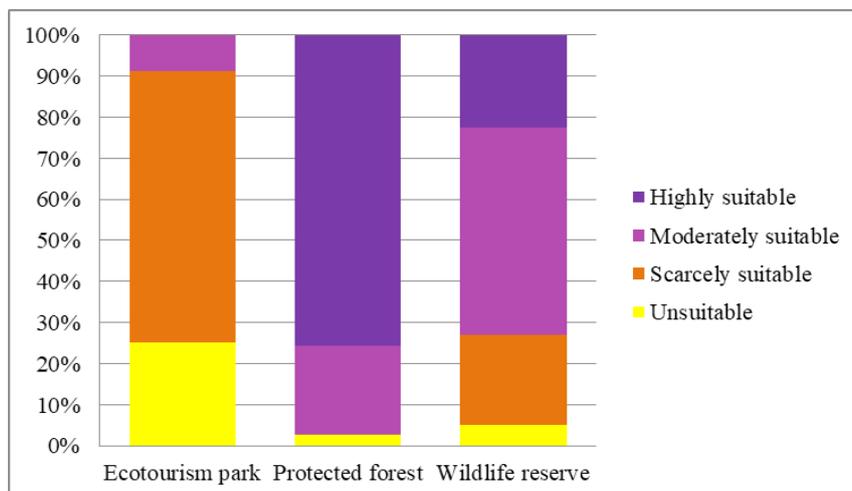


Figure 6. Compositions of the suitable habitats for Sunda Teal *Anas gibberifrons* includes unsuitable, scarcely suitable, moderately suitable, and highly suitable in the wetlands of Muara Angke, Jakarta.

DISCUSSION

The findings of this study on the presence of Sunda Teal mostly in protected forest and wildlife reserves agreed with recent studies. Shafira (2022) recently discovered Sunda Teal in the protected forest and wildlife reserve area, with a density of 10.48 individuals/ha in the protected forest and 1.15 individuals/ha in the wildlife reserve. However, in this study, parts of the wetlands where gastropods and crustaceans occur, were considered suitable habitats for Sunda Teal. The choice of habitat by waterbirds in wetlands is strongly influenced by the availability of food sources and the ease of getting food according to the daily needs of each water bird species foraging in a particular area (Pierce & Gawlik, 2010). Swans, geese, and ducks have a wide range of diets, from being entirely herbivorous to almost completely carnivorous (Arzel et al., 2006). Many Anatidae can shift their diet from a primarily granivorous to a primarily invertebrate diet, which has been attributed to the need for egg production. A shift to more energy-rich food from a primarily granivorous to a primarily invertebrate diet is seen in adults to be pure herbivores (Gates et al., 2001).

Areas in the wildlife reserve that are characterized by the availability of water bodies and abandoned fishponds were also considered as suitable habitats. Besides the presences of gastropods as potential food resources, the presence of aquatic plants and water height is also important variables for Sunda Teal. Water height is likely a determinant factor influencing the accessibility or ease of obtaining food in wetland ecosystems (Calle et al., 2016).

Some parts of the wetlands in the Muara Angke were considered unsuitable for Sunda Teal. Those areas were settlements bordered on the southern parts of the wetlands. The other areas were some patches of fishponds located mainly in the eastern parts. The presence of settlements and fishponds poses a threat by reducing the size of the wetlands and mangrove covers and leading to habitat reductions. Besides reducing the species' habitats, the presence of settlements and fishponds is also a direct disturbance to the species due to people accessing the site. Human disturbance may arise from recreational activities like boating and hunting (Fe'ret et al., 2003; Schummer & Eddleman, 2003), and also from agriculture, industrial work, and transportation (Skylberg et al., 2005). There are also some parts within the Muara Angke protected forest that were not suitable due to the presence of a highway that intersects the forest in the middle.

The presence of humans in wetland environment has an impact on the presence, distribution, and quantity of animals. Human activity is a type of disturbance that can have an impact on the population dynamics of water birds, influencing their behavior, abundance, and/or dispersion. Birds' reactions to human presence can vary greatly. Birds may reduce the amount of time spent foraging for food and may flee when humans approach them (Thomas et al., 2003). As a result, existing ecotourism park and fishing activity common in nearby fishponds should take into account the spatial characteristics of Sunda Teal habitat as well as the distance between this species and visitors. This is critical when choosing on locations for infrastructure such as tourist walkways and bridges.

CONCLUSION

To conclude, this study has attempted a spatial analysis of important variables for Sunda Teal to assess habitat suitability at the remaining wetlands in Muara Angke, Jakarta. By finding suitable habitats for Sunda Teal, it will accelerate the conservation efforts by determining the parts of Muara Angke that should be prioritized to be protected. The finding confirms that the ecotourism park had the most unsuitable habitats. In contrast to the ecotourism park, the protected forest, followed by the wildlife reserve, had more moderately and highly suitable habitats. Then, conservation efforts should be emphasized on the protected forest and the wildlife reserve to protect the Sunda Teal in the remaining wetlands in Muara Angke, Jakarta.

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