



The behavioral changes of birds as a result of urban noise levels

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ABSTRACT

Background: Bird conservation in Indonesia is still focused on the areas of conservation of specified government. As in the nature reserves, wildlife clan asylum and national park. Nevertheless there are birds that live outside conservation areas such as forest city. DKI Jakarta as the capital city of Indonesia with a population of the most populous and has a forest city as a habitat of birds in urban areas, it become necessary to know research, equity, diversity, wealth, abundance, similarity species of birds, the difference in noise level and noise influence toward activity-voiced bird in three forest city of DKI Jakarta. **Methods:** Data retrieval method using point count with 24 point edge and central region in each forest city. **Findings:** Based on the findings presented in Chapter IV of the thesis, the study showed that higher noise levels and greater human presence significantly reduced bird vocal activity across three urban forests in Jakarta. The average noise level was highest in PT JIEP City Forest (66.55 dB), while human activity peaked in Hutan Kota Srengseng with 152 individuals recorded. A statistically relevant pattern was found: bird vocalization activity and the number of vocalizing birds were highest in areas with lower noise and human presence, supporting the hypothesis that anthropogenic disturbance negatively impacts bird behavior. **Conclusion:** This study reveals that noise levels and human presence significantly affect bird vocal activity and species diversity in urban forests of Jakarta, with lower noise and fewer people correlating with higher bird sound activity and diversity, highlighting the ecological importance of preserving and managing these green spaces. **Novelty/Originality of this article:** This study presents a novel investigation by integrating spatial (edge vs. center zones).

KEYWORDS: birds; forest city; noise.

1. Introduction

Indonesia is a country located along the equator, stretching from Sabang to Merauke, and has a tropical climate with an annual rainfall that is relatively balanced with the dry season. This condition fosters high biodiversity potential, ranging from various plant species to a wide array of animals, including birds. Birds are one of the most utilized wildlife species by humans, serving as food sources, pets, economic commodities, and aesthetic elements. However, population growth and the intensive exploitation of bird species by humans have resulted in increased pressure on bird species and their natural habitats. The loss of vegetation consequently leads to the loss of food sources for birds (Naufalianto, 2025).

Birds are wildlife species capable of living in nearly all types of habitats, from polar regions to deserts, from coniferous forests to tropical rainforests, and from rivers to oceans. They exhibit high mobility and adaptability to diverse habitat types (Welly, 1982). Their

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wide distribution and adaptability enable urban forests to serve as bird habitats within cities. Birds, like other wildlife, exhibit three types of distribution patterns: random, which occurs due to environmental homogeneity; uniform, where birds tend to maintain distance from competitors; and clumped, where birds tend to live in randomly scattered groups (Jiang et al., 2025).

In Indonesia, 1,836 bird species have been identified, with 542 of them being endemic to the country (Indonesian Birds, 2025). One of the most distinctive features of birds compared to other animals is their ability to fly and produce vocalizations. Almost all bird species rely on song for communication and mate attraction. During the pre-copulation phase, male birds sing to attract females. Noise pollution can disrupt this critical process. Jakarta, the capital city of Indonesia, is the most densely populated area in the country with a wide range of human activities. According to the Regulation of the Minister of Public Works No. 05 of 2008, every city is required to allocate at least 30% of its area as green open space. Urban forests, as part of these green spaces, are distributed across the five municipalities of Jakarta and serve essential ecological functions in addition to their aesthetic and recreational roles. These urban forests are often adjacent to office buildings, residential areas, and roadways. Human activities such as the use of motor vehicles for transportation and daily social interactions within residential neighborhoods have the potential to generate environmental noise. This noise pollution can negatively impact other living beings that rely on sound for communication, such as birds.

Birds directly benefit ecosystems by acting as seed dispersers, pollinators, and natural pest controllers (Mariyappan et al., 2023). Indirectly, birds can serve as bioindicators of environmental health. Changes in the environment may cause birds to migrate, perish, or adapt, depending on their resilience. A higher diversity of bird species within an environment generally indicates better environmental quality (Kurnia et al., 2021). Haryadi (2016) conducted a study in two urban forests—Dramaga Research Forest and the Bogor Botanical Garden Urban Forest—and found differences in noise levels. Bird habitats closer to roadways exhibited lower species counts, and higher noise levels were associated with decreased bird vocalization activity.

In smaller green spaces such as city parks, Taman Situlembang, Taman Suropati, and Taman Menteng in Central Jakarta had varying levels of noise pollution. However, there were no significant differences in bird diversity or species similarity among these parks, suggesting that urban birds may have adapted to the existing noise conditions. The increasing noise pollution in Jakarta is suspected to affect bird vocalization activity in its urban forests, although the exact levels of bird vocalization activity and species diversity are not yet fully understood. Therefore, it is essential to conduct research to identify bird species and determine their vocal response to varying levels of noise pollution. Elevated noise levels are believed to be a significant factor contributing to the decline in bird vocalization activity (Haryadi, 2016).

So far, bird conservation efforts in Indonesia have primarily focused on government-designated protected areas such as nature reserves, wildlife sanctuaries, and national parks. However, many bird species inhabit areas outside of these conservation zones, including urban forests. Given Jakarta's status as the most densely populated city in the country and its urban forests serving as vital bird habitats, it is crucial to study the impact of noise on bird vocalization activity in three of Jakarta's urban forests. This study is limited to diurnal bird species found in three urban forests in Jakarta. It examines the relationship between noise levels and bird vocalization activity. Noise measurements will be conducted in both central and edge zones of each forest during the morning, afternoon, and evening periods.

Human activities, such as the use of motorized vehicles for transportation on roads and interactions within residential areas, have the potential to generate environmental noise. This noise constitutes a form of pollution that affects not only human comfort but also the lives of wildlife, including birds. Therefore, it is important to understand the extent to which human activities—particularly the levels of noise they produce—affect other living beings in the surrounding environment.

1.1 Morphological characteristics of birds

Birds represent one of the largest and most widely recognized groups of vertebrates, with an estimated 8,600 species distributed worldwide. Although birds are warm-blooded like mammals, they are more closely related to reptiles and began evolving approximately 135 million years ago (Mackinnon, 1995). Birds (Aves) possess several distinctive characteristics, including a body covered with feathers, two pairs of limbs with the forelimbs modified into wings and the hindlimbs adapted for perching or swimming. Each foot typically has four toes with clawed digits covered in a horny, scaly sheath. Their mouths form beaks or bills—protruding structures covered in keratinized layers. Modern birds lack teeth, and their tarsometatarsus is covered with keratinized skin often shaped like scales. The tail plays an essential role in maintaining balance and control during flight, while the beak is a hardened outer modification of the jaws (Peterson, 1980).

Ben-Noun (2023) described birds as feathered animals with forelimbs adapted for flight, hindlimbs suited for walking, swimming, or perching, toothless beaks, four-chambered hearts, lightweight skeletons, air sacs, warm-blooded physiology, no urinary bladders, and egg-laying reproduction. According to Mackinnon et al. (1999), bird species are generally described based on external morphological features that are easily observed. These include total body length (measured from beak to tail) as an indicator of body size, and the coloration of key parts such as the head, wings, tail, and both dorsal and ventral sides. In addition to feather color, the coloration of other body parts such as the legs and eyes can serve as distinguishing traits among species.

1.2 Bird ecology

Maurya (2024) defined ecology as the study of the structure and function of ecosystems, encompassing both nature and humans as integral components. Ecosystem structure refers to the condition of an ecological system at a specific time and place, including the density of organisms, biomass, distribution of nutrients, energy flow, and various physical and chemical factors that shape the system. Meanwhile, ecosystem function describes the causal relationships and interactions among components within the system. This definition highlights ecology as a discipline concerned with the intricate interrelationships between living organisms and all elements in their surrounding environment. In this context, birds play an essential ecological role. Sherry (2021) further emphasized the significance of birds as ecological balancers, particularly in tropical forests where insectivorous birds serve as key insect population regulators and contribute substantially to seed dispersal and flower pollination.

Beyond their ecological roles, birds are remarkable creatures that have, for centuries, inspired and delighted the people of Indonesia with their beauty and song (Rombang & Rudyanto, 1999). Birds also serve as reliable indicators of environmental health and biodiversity value. However, their populations are increasingly threatened by human exploitation for food, pets, economic needs, and aesthetic purposes. As the human population grows and bird utilization intensifies, pressure on bird species and their natural habitats increases. The loss of vegetation not only reduces suitable habitat but also depletes available food sources for birds (Naufalianto, 2025).

Within ecosystems, birds act as stabilizing agents due to their roles as apex predators, seed dispersers, and pollinators. Food availability is a critical factor regulating bird survival and population size in nature. For example, raptors such as eagles will thrive and even increase in population when food sources are abundant; conversely, their numbers decline when food is scarce. As top predators, eagles help control populations of their prey, such as rodents, thereby maintaining ecological balance in natural ecosystems.

1.3 Bird distribution

Birds are highly mobile animals, which contributes to their widespread global distribution. The distribution of bird species is influenced by the suitability of their habitat, including their ability to adapt to environmental changes, competition, and natural selection (Tan et al., 2025). The avian body form has proven to be highly effective for dispersal across the globe. Birds inhabit nearly every type of ecosystem, from the equator to polar regions. There are forest birds, grassland birds, mountain birds, water birds, seabirds that travel across oceans, and even cave-dwelling birds capable of navigating in darkness. Wherever there are trees, fish, insects, or other invertebrates, there are birds that feed on seeds, fruits, nectar, insects, fish, or act as predators and scavengers (Mackinnon, 1995). Birds are capable of occupying a wide range of habitats, including forests and non-forest areas such as plantations, agricultural fields, home gardens, caves, grasslands, savannas, and aquatic environments (Alikodra, 2002).

The extent of movement and dispersal range varies among bird species. Some occupy small, fixed territories and disperse slowly, while others have a much broader range of movement (Mackinnon, 1995). The movement of wildlife, whether on a small or large scale, reflects an effort to meet survival needs. Birds require corridors for movement that connect them to sources of biodiversity. Their distribution is influenced by their mobility and environmental factors such as habitat size, elevation, and geographic location. Birds are among the most evenly distributed wildlife species due to their ability to fly (Alikodra, 2002). The presence of birds in a particular habitat results from selection, as the habitat must meet their life requirements. This selection process determines the presence of birds in specific environments (Morelli et al., 2021). Flocking distribution patterns among birds are typically associated with abundant food resources, while solitary distribution patterns tend to occur in areas or periods where food availability is limited.

1.4 Urban birds

Urban bird communities are assemblages of individuals from various species that coexist within the same spatial and temporal context—namely, urban areas. Factors influencing bird communities in cities include habitat characteristics and disturbances caused by human activities (Hayes et al., 2023). Human settlements in Java have a long historical presence, supported by fertile volcanic soil, which has contributed to the island—along with Bali—bearing a high population density (Mackinnon, 1995). This has led to concentrated urban development, particularly in Java and especially in Jakarta, the capital of Indonesia. Land-use changes have had significant impacts on bird life, with lowland rainforests—once the most suitable bird habitats—now reduced to less than 2.5% of their original extent, rendering them a rare and critical habitat (Mackinnon, 1995). The continued presence of birds in Jakarta reflects the existence of remaining viable habitats within the city's urban forests. According to Patankar et al. (2021) birds are generally able to coexist with urban populations, provided that their essential needs—such as adequate and secure habitat—are met. Given the substantial ecological and economic benefits that birds provide, conservation efforts are essential. These efforts should not be the sole responsibility of ornithologists but must involve all levels of society, including urban communities.

1.5 Noise pollution

According to Davis Cornwell (1998), noise originates from the word “bising,” which refers to any sound that distracts, disturbs, or poses a threat to daily health. Noise is generally defined as unwanted sound and is considered a form of environmental pollution. Based on the Decree of the Minister of Environment No. Kep-48/MNLH/11/1996, noise is defined as undesirable sound generated by activities or operations at certain levels and times that may cause health problems and disturb environmental comfort. Major types of noise in urban areas include: traffic and transportation noise—originating from vehicles

such as cars, trucks, motorcycles, trams, trains, diesel engines, subways, seaplanes, and airplanes; industrial noise—produced by factories, workshops, construction projects, cooling towers, air conditioning units, and other sources; and human-generated noise—from sports, outdoor performances, and other recreational activities (Doelle, 1993). Noise levels can be measured using a sound level meter, which consists of a microphone, amplifier, and output device, and results are expressed in decibels (dB) (Haryadi, 2016).

Suriandjo & Tondobala (2013) categorized environmental noise into several types. Background noise refers to the continuous level of sound present in an area, excluding significantly louder, distinct sources. Ambient noise is the total sound present at a given location, including background noise and any other sounds that exceed background levels, resulting from a combination of both near and distant sources. Constant noise is defined as sound with fluctuations not exceeding 6 dB. According to the appendix of the Decree of the State Minister of Environment No. Kep-48/Menlh/11/1996 on Noise Level Standards, noise limits are divided into two main categories: one based on land use and the other on activity-based environments. This means that a specific activity environment may exist within a zone designated for a different land use. The land-use classifications are further divided into eight categories, as shown in Table 1.

Table 1. Noise level standards

No	Designated area/Activity environment	Noise level dB (A)
I.	Land use designation	
a.	Residential and housing	55
b.	Trade and services	70
c.	Office and commercial areas	65
d.	Green open spaces	50
e.	Industrial Areas	70
f.	Government and public facilities	60
g.	Recreational areas	70
h.	Special areas:	
	Airports	Referring to Decree of the Ministry of Transportation (SK Kemenhub)
	Train stations	Referring to Decree of the Ministry of Transportation (SK Kemenhub)
	Seaports	70
	Cultural heritage sites	60
II.	Activity Environment	
a.	Hospitals or similar facilities	55
b.	Schools or similar educational institutions	55
c.	Places of worship or similar facilities	55

(Ministry of Environment, 1996)

According to Mediastika (2009), the human ear's unequal sensitivity to sound frequencies makes it more practical to measure sound intensity using the decibel (dB) scale, which consists of values that are easier to interpret. He further explained that the lower threshold of human hearing is 0 dB, while the upper limit is 140 dB. Sound is a sensation perceived by the human auditory system, produced when sound waves are generated in the surrounding air through vibrations. These sound waves are longitudinal in nature and are perceived as sound only when they fall within the audible frequency range of 20 to 20,000 Hz.

1.6 Birds and noise

Birds are living organisms that communicate through both visual and acoustic means. Among these, acoustic communication is considered the most effective and advantageous for birds. Vocal communication offers several benefits: it operates over long distances, does not require visual contact, can be used at night, and functions effectively in dense habitats or under conditions where other forms of communication are limited. This allows birds to acquire various types of essential information. The primary functions of bird vocalizations include territory defense and mate attraction (Catchpole & Slater, 2003), as well as signaling danger, locating food, and expressing aggression (Marler, 2004).

The main components involved in acoustic communication are the signal-producing organ and the signal-receiving organ. In birds, the signal-producing organ is the vocal organ known as the syrinx. The syrinx is located at the base of the trachea, just above the two bronchi that lead to the lungs (King, 1989). In passerine birds, sound is produced through the oscillation of airflow over the labia within each bronchus, resulting in fluctuations in air pressure (Goller & Larsen, 1997). Positioned directly above the bronchi, the syrinx plays a crucial role in modulating the fundamental frequency and temporal dynamics of bird song.

The primary signal-receiving organ in birds is the ear. Unlike mammals, birds do not possess external ear structures. Instead, the avian ear consists of an external tympanic membrane, a middle ear, and an inner ear (Dooling & Popper, 2007). The hearing process begins when sound waves are received by the tympanic membrane. These vibrations are transmitted through the middle ear and into the inner ear via fluid pressure. In the inner ear, hair cells convert mechanical energy into neural signals, which are then transmitted to the brain.

One of the major factors that reduces the effectiveness of vocal communication is noise. This disruption occurs when vocalizations transmitted through the air—from the sender bird via the syrinx—interfere or "collide" with ambient noise, preventing the receiver bird from fully perceiving the acoustic signal through its auditory system (Haryadi, 2016).

Urban environments, which are typically associated with high levels of noise, often generate loud sounds from road traffic and other anthropogenic sources. This urban noise can significantly impact bird populations, particularly by disrupting their communication during critical periods such as the breeding season. Traffic noise, for example, has been shown to interfere with the vocal interactions of birds during mating activities (Proppe et al., 2013).

1.7 Effects of noise levels on birds

One of the most extensively studied sources of noise due to its impact on birds is traffic and transportation noise. The effects of such noise include behavioral changes, masking of communication signals between conspecifics, or interference with other biologically important sounds such as predator or prey cues. It can also lead to temporary or permanent hearing loss, elevated stress levels, altered reproductive hormone levels, and potentially threaten the survival of individuals or entire bird species (Dooling & Popper, 2007).

Previous studies have examined how birds change their behavior in response to noise. These changes occur at the species level, where birds in noisy environments exhibit higher vocalization frequencies and amplitudes compared to those in quieter areas (Brumm, 2004). This indicates an adaptation to noise through increased vocal pitch and loudness during communication. *Erithacus rubecula*, for instance, adapts to daytime noise by singing at night in order to reduce communication interference (Fuller et al., 2007). The impact of noise on avian fauna has also been shown to reduce species richness and presence significantly in habitats located near roadways (Herrera-Montes & Aide, 2011).

The threshold of noise tolerance for birds is estimated at around 60 dB (Dooling & Popper, 2007). Bird species respond differently to varying levels of noise, often modifying their vocalizations as an adaptive strategy. Some species are able to occupy noisy areas by adjusting their vocal behavior, while others that cannot adapt may be forced to relocate to

quieter habitats (Patón et al., 2012). According to Proppe et al. (2013), noise produced by human activity in urban areas can prevent female birds from hearing male bird songs, which may disrupt mating. Over time, this can lead to a decrease in bird populations as successful mating is reduced, ultimately affecting species diversity.

1.8 Urban forests

Urban forests are defined as areas of land located within or near cities, characterized by tree species associations that create a microclimate distinct from their surroundings (Fandeli, 2001). According to Zoer'aini (2005), an urban forest is a vegetation community composed of trees and associated plant species that grow in city areas or their peripheries. These forests may appear in linear formations, dispersed patterns, or clusters, with a structure that mimics natural forests, forming habitats that support wildlife and promote a healthy, comfortable, cool, and aesthetically pleasing environment. In accordance with Regional Regulation No. 63 of 2003 concerning urban forests, an urban forest is defined as a stretch of land within urban areas—on either state or privately owned land—where trees grow densely and continuously. It functions as an environmental buffer by regulating water and air systems, providing habitats for flora and fauna, and contributing aesthetic value. These areas are designated by authorized officials as official urban forest zones and constitute green open spaces dominated by trees.

Urban forests can be categorized into several types depending on their intended function, including: conservation urban forests, industrial zone urban forests, residential area urban forests, recreational urban forests, and urban forests designated for wildlife protection (Marini, 1996). Irwan (1994) classified the main functions of urban forests into three broad categories: landscape, environmental preservation (ecological), and aesthetic functions.

From a landscape perspective, the physical function of urban vegetation includes serving as a structural element that protects against natural conditions such as wind, sunlight, unattractive views, and unpleasant odors. Socially, well-organized vegetation layouts foster productive social interactions. From a health perspective, urban forests serve therapeutic purposes, supporting visual and mental well-being as well as recreation and physical activity. Ecologically, urban forests function as the "lungs" of the city by refreshing the air—producing oxygen necessary for respiration and absorbing surrounding carbon dioxide. They also help reduce urban temperatures and increase humidity levels. Furthermore, vegetation provides essential habitat space for various wildlife species. Birds, as a key component of ecosystems, play critical roles in controlling insect populations, facilitating pollination, and dispersing seeds—processes vital for forest regeneration. Additionally, urban forests help stabilize soil surfaces by preventing erosion caused by rain and wind, control air pollution from transportation activities, and act as noise buffers. Urban forests also serve as sites for the preservation of genetic resources (germplasm) and function as environmental bioindicators.

2. Methods

This research was conducted from February to March 2018 at three urban forests in DKI Jakarta: Srengseng Urban Forest, Kemayoran Urban Forest, and PT. JIEP Pulogadung Urban Forest. Data collection was carried out during three time periods: in the morning (06:00 to 09:00), at midday (10:30 to 13:30), and in the afternoon (14:30 to 17:30) Western Indonesian Time/ *Waktu Indonesia Barat* (WIB).

The equipment used in this study included a Celestron Impulse 10 x 25 binocular, the field guidebook *A Field Guide to the Birds of Sumatra, Java, Bali and Kalimantan* (MacKinnon et al., 1999), the Burungnesia Android application, a Nikon D90 DSLR camera with a Sigma APO DG 120–400 mm telephoto lens, a camera monopod, writing tools, yellow raffia string, data tables, a field board, a digital wristwatch, a digital counter, a stopwatch, a 50-meter

measuring tape, Microsoft Excel 2010 software, and a Smart Sensor Digital AS804 sound level meter.

2.1 Data collection method

First, Observation Point Determination. Noise levels, human activity, and bird diversity were measured at several observation points. The determination of observation points at each location was conducted using purposive sampling, based on the distance from noise sources (Haryadi, 2016). A total of 24 observation points were established within each urban forest site, consisting of 12 points located near roads and residential areas (edge areas) and 12 points situated farther from roads (core areas). Each point count had a 25-meter radius in all directions. To facilitate repeated observations, each tree at the observation points was marked with yellow raffia string.

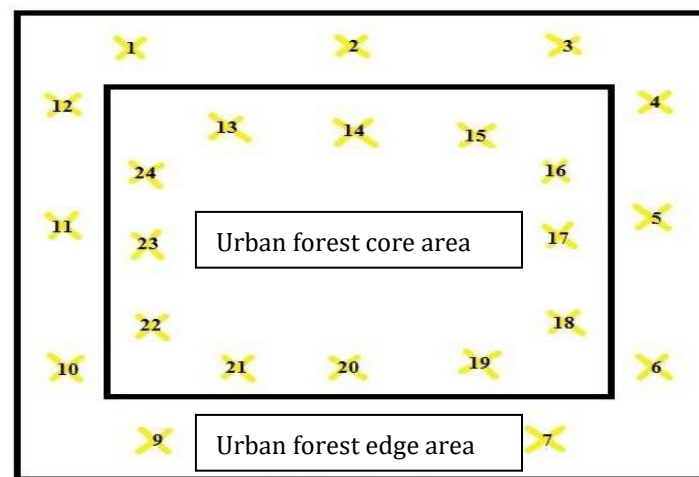


Fig. 1. Illustration of point count location determination

The second aspect is Noise Level. Measurements were carried out for 10 minutes at each point, with readings taken every five seconds using a Sound Level Meter. The device was placed at the center of each observation point, positioned 1.5 meters above the ground surface (Haryadi, 2016). The Smart Sensor Digital Sound Level Meter AS804 used in this study was capable of measuring automatically for 5 minutes. To ensure time distribution across the day, measurements were conducted for 5 minutes each in the morning, afternoon, and evening, totaling 15 minutes per day. This approach ensured a complete dataset representing noise levels consistently throughout the day.

The third aspect is Human Activity. Human presence at each observation site was recorded to represent activity levels. Data collection was conducted using the point count method at the same 24 points used for noise measurements. Observations were made for 5 minutes within a 25-meter radius. To ensure time balance, measurements were also carried out for 5 minutes in the morning, afternoon, and evening. The number of individuals present was counted using a digital counter, providing accurate and consistent data on human activity across time intervals.

The fourth component is Bird Diversity and Species Richness. Observations were conducted using the point count method at predetermined points. At each point, observations were made within a 25-meter radius for 5 minutes. This was repeated in the same 24 locations used for previous data collection. Observations were made in the morning, afternoon, and evening for 5 minutes each, totaling 15 minutes per day. The data collected included bird species identification, number of individuals, and behavioral activities, allowing for a comprehensive understanding of bird diversity across different times of day.

The fifth aspect is Bird Vocalization Activity. The number of bird calls was recorded using a digital counter. Vocal activity was documented based on the number of bird sounds

heard at each point count location. Data were collected at the same 24 points used for noise, human activity, and bird diversity observations. Each session lasted 5 minutes within a 25-meter radius, conducted evenly in the morning, afternoon, and evening, summing to 15 minutes per day. This ensured consistent data collection of bird vocalizations throughout the day.

2.2 Data analysis

First, Diversity. Diversity was analyzed using the Shannon diversity index (Magurran, 2004). This index was used as a measure to indicate the abundance of each species within a given habitat.

$$H' = - \sum (P_i \ln P_i) \quad (\text{Eq.1})$$

Note:

H': Shannon diversity index

P_i: The proportion of individuals of species *i* to the total number of individuals of all species ($p_i = n_i/N$)

Ln: Natural logarithm

The criteria for the Shannon-Wiener diversity index based on Krebs (1989) are as follows: $H' < 1.0 \rightarrow$ Low diversity; $1.0 \leq H' \leq 3.0 \rightarrow$ Moderate diversity; $H' > 3.0 \rightarrow$ High diversity. Second, Richness. Bird species richness was calculated based on the total number of species present in each habitat and was also estimated using the Margalef index (Magurran, 2004), which is defined as:

$$D_{mg} = (S - 1)/\ln N \quad (\text{Eq.2})$$

Note:

D_{mg} = Margalef species richness index

S = total number of species

N = total number of individuals

ln = natural logarithm

With the following criteria: D_{mg} < 2.5 = indicates a low level of species richness; $2.5 \leq D_{mg} \leq 4$ = indicates a moderate level of species richness; $D_{mg} > 4$ = indicates a high level of species richness. Third, Evenness. Evenness refers to the distribution of individuals among different species and can be obtained from the relationship between diversity (H') and maximum diversity. Evenness can also be described as the balance in the composition of individuals of each species within a community.

$$E = \frac{H'}{\ln S} \quad (\text{Eq.3})$$

Note:

E = Evenness (value ranges from 0 to 1)

H' = Diversity (Shannon-Wiener index)

ln = Natural logarithm

S = Number of species

With the following criteria: $E < 0.4$ = Low evenness; $0.4 \leq E \leq 0.6$ = Moderate evenness; $E > 0.6$ = High evenness. Fourth, Relative Abundance. Relative abundance was analyzed by calculating the ratio of the number of individuals of each species to the total number of individuals of all species (Bibby et al., 2000).

$$P_i = \frac{\text{Number of individuals of species } i}{\text{Total number of individuals of all species}} \times 100\% \quad (\text{Eq.4})$$

Note:

P_i = Relative abundance (%)

With the following criteria: KR < 2% = Non-dominant species; 2% ≤ KR ≤ 5% = Sub-dominant species; KR > 5% = Dominant species. Fifth, Bird Dominance. Bird dominance was determined based on the highest number of individual birds recorded during data collection in each urban forest. This was identified by observing the bird species with the highest percentage of relative abundance. Sixth, Noise. Noise levels were analyzed by comparing the average noise levels between the edge and center areas of each urban forest, including differences in average noise levels during the morning, afternoon, and evening. Seventh, Human Activity. Human activity was analyzed based on the differences in the number of people present in the edge and center areas of the forest, including variations in human presence in the morning, afternoon, and evening. Eighth, Bird Vocalization Count. The number of bird vocalizations was analyzed by comparing the types of vocalizing birds and the total number of bird calls between the edge and center areas of the urban forests. Ninth, The Effect of Noise on Bird Vocalization Activity. The effect of noise on bird vocalization was analyzed by comparing the average noise levels, number of people, and number of bird calls between the edge and center areas of the urban forest.

3. Results and Discussion

3.1 Noise levels in the three urban forests of DKI Jakarta

Based on the noise level measurements conducted in the three Urban Forests of DKI Jakarta, it was found that each point can exhibit varying levels of noise. The edge areas of the urban forests tend to have higher noise levels compared to the central areas, which consistently show lower levels of noise during the morning, afternoon, and evening. The differences in noise levels between the edge and central zones in Srengseng Urban Forest, Kemayoran Urban Forest, and PT JIEP Urban Forest are illustrated in figure 2.

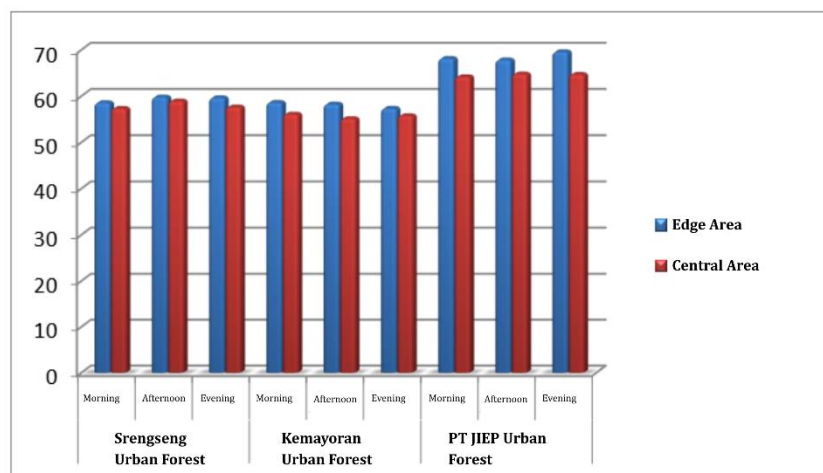


Fig. 2. Differences in noise levels between the edge and central areas in Srengseng urban forest, Kemayoran urban forest, and PT JIEP urban forest

The results of noise level measurements (Figure 2) in the three urban forests of DKI Jakarta show that each location can exhibit different levels of noise. In general, the edge areas of the urban forests tend to have higher noise levels than the central areas, across all time periods—morning, afternoon, and evening. In Srengseng Urban Forest, the highest noise level was recorded during the afternoon (10:30 AM – 1:30 PM) at 59.81 dB in the edge

area and 58.95 dB in the central area. The lowest levels were observed in the morning (6:00 AM – 9:00 AM), with 58.59 dB in the edge area and 57.34 dB in the central area. This is likely due to increased human activities near the forest during midday, including higher traffic volumes on nearby roads. The average noise level in Srengseng was 59.35 dB at the edge and 57.98 dB at the center, confirming that the edge area is generally noisier than the center.

Kemayoran Urban Forest is bordered by two major roads: Benjamin Sueb Street to the west and Griya Utama Street to the south. These roads are the main sources of noise in this area. One factor that distinguishes Srengseng from Kemayoran is that in Srengseng, additional noise is generated by cleaning staff using grass-cutting machines and by community events, such as group exercise sessions that use microphones. In contrast, the dominant source of noise in Kemayoran is the vehicular traffic from the surrounding roads.

As shown in Figure 2, the highest noise level in Kemayoran was observed in the morning (6:00 AM – 9:00 AM), with 58.63 dB in the edge area and 56.11 dB in the central area. The lowest noise was recorded in the evening (2:30 PM – 5:30 PM) at 57.35 dB on the edge and 55.14 dB in the central area during the afternoon. The average noise levels were 58.08 dB at the edge and 55.67 dB in the center. This differs from Srengseng, where noise peaked in the afternoon. In Kemayoran, morning traffic was the main contributor to noise, with heavier vehicle flow during that time. Once again, the edge areas consistently showed higher noise levels than the central areas.

PT JIEP Urban Forest is surrounded by four major roads: Pulobuaran Street to the north, Pulobuaran II Street to the east, Rawa Gelam Street to the west, and Pulo Ayang Street to the south. All four roads serve as primary sources of noise pollution. Another influencing factor in this location is traffic conditions, which are notably intense around PT JIEP. According to Figure 2, the highest noise levels in PT JIEP occurred in the evening (2:30 PM – 5:30 PM) at 69.61 dB in the edge area, and in the afternoon (10:30 AM – 1:30 PM) at 64.79 dB in the central area. The lowest levels were recorded in the afternoon at the edge (67.84 dB) and in the morning at the center (64.21 dB). The average noise levels were 64.57 dB at the edge and 60.07 dB at the center, with an overall mean of 62.31 dB. Once again, the edge was noisier than the center.

Overall, across the three urban forests studied, there is a consistent pattern: the edge areas have higher noise levels than the central areas. Haryadi (2016) explains that noise levels in habitats near roads are significantly higher than those in areas further away, as roads are the primary sources of noise. These differences in noise levels across the three urban forests are influenced by variations in noise sources such as traffic density and the nature of human activity in each location. A comparison of these noise measurements is shown in Figure 3 below.

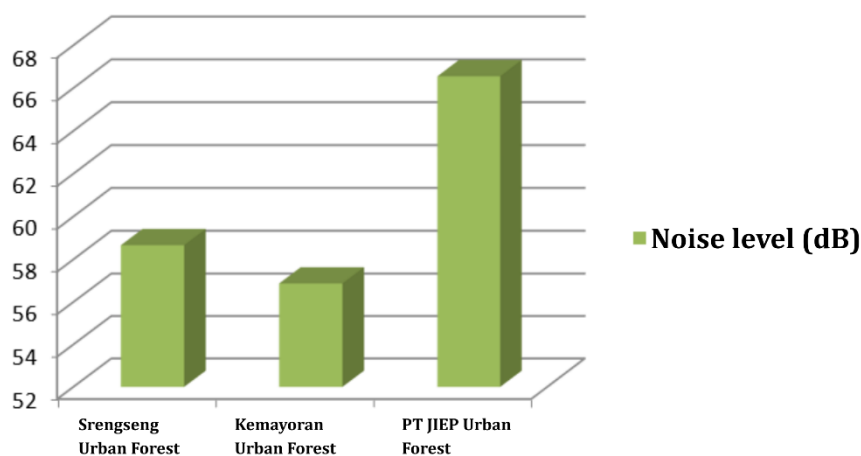


Fig. 3. Differences in noise levels across the three urban forests of DKI Jakarta

In the figure above, it can be seen that Srengseng Urban Forest has a moderate noise level of 58.66 dB. Kemayoran Urban Forest has a lower noise level at 56.87 dB, while the

highest noise level was recorded in PT JIEP Urban Forest at 66.55 dB. These differences in noise levels across the three locations are attributed to variations in traffic density and the presence of different domestic noise sources.

3.2 Human activity in the three urban forests of DKI Jakarta

Human activity was recorded based on different time periods by observing the number of people present at each urban forest location, as shown in the figure 4 below. The highest number of people recorded in Srengseng Urban Forest occurred during the afternoon (10:30 AM – 1:30 PM), with 111 individuals present in the central area and 45 in the edge area, totaling 156 people. During the study period at Srengseng, various human activities were observed, including the presence of cleaning staff, security personnel, and visitors who used the area for exercise, social activities, and institutional events.

In Kemayoran Urban Forest, the peak in human presence was recorded in the evening (2:30 PM – 5:30 PM), with 74 people in the central area and 61 in the edge area, making a total of 135 individuals. Observations at the Kemayoran site included activities such as water gate operators, security personnel, and cleaning staff disposing of trash inside the forest. In addition, many people were seen fishing in the lake area within the urban forest.

The highest number of people in PT JIEP Urban Forest was observed in the morning (6:00 AM – 9:00 AM), with 20 individuals in the central area and 7 in the edge area, totaling 27 people. During the observation period at this location, local residents were found occupying the land for housing and small-scale farming. There were no security officers or visitors observed, likely due to the absence of any supporting facilities within PT JIEP Urban Forest.

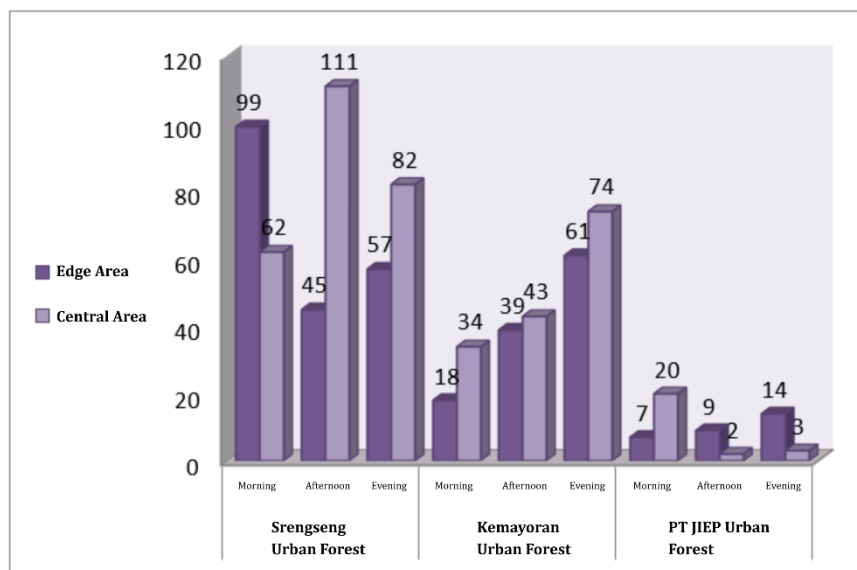


Fig. 4. Human presence in the three urban forests based on time differences

The average daily human presence at each urban forest site is shown in Figure 5 below. The highest average number of people per day was recorded in Srengseng Urban Forest, with 152 individuals. This was followed by 50 people in Kemayoran Urban Forest, and the lowest was in PT JIEP Urban Forest with only 18 individuals. The high number of visitors in Srengseng Urban Forest can be attributed to its well-developed facilities. In general, the condition of Srengseng Urban Forest is considered good. The area features a scenic lake, playgrounds, sports facilities, and other amenities (Sofyan, 2013).

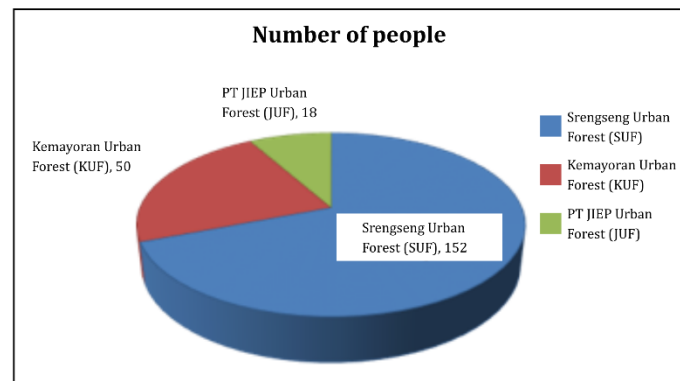


Fig. 5. Average daily human presence at each urban forest location

3.3 The impact of noise on bird vocalization activity in the three urban forests of DKI Jakarta

Based on Table 2, it can be seen that a total of 19 bird species were recorded vocalizing in Srengseng Urban Forest. Of these, 12 species—including Sooty-headed Bulbul (*Cucak Kutilang*), Eurasian Tree Sparrow, Javan Prinia, Brown Flycatcher, Collared Kingfisher, Scarlet-headed Flowerpecker, Black-headed Munia, Scaly-breasted Munia, Coconut Lorikeet, Zebra Dove, Dark-sided Flycatcher, and Oriental White-eye—were more frequently vocalizing in the edge area. Meanwhile, 7 species—such as Yellow-vented Bulbul, Asian House Swift, Common Tailorbird, Common Iora, Plaintive Cuckoo, Indian Cuckoo, and Brush Cuckoo—were more vocal in the center area. The noise level in Srengseng Urban Forest was higher at the edge (59.35 dB) compared to the center (57.98 dB) as shown in Figure 2, with an overall average of 58.66 dB (Figure 3). Human activity tended to be greater in the center area, and a significant difference in the number of people between the two zones was observed (Figure 4).

In Kemayoran Urban Forest, 10 bird species were observed vocalizing. Four species—including Sooty-headed Bulbul, Eurasian Tree Sparrow, Zebra Dove, and Brown Flycatcher—vocalized more at the edge, while six species—including Common Tailorbird, Yellow-vented Bulbul, Javan Prinia, Paddyfield Pipit, Peaceful Dove, and Asian House Swift—were more vocal in the center (Table 2). Noise levels were higher at the edge (58.08 dB) than in the center (55.67 dB) as shown in Figure 2, with an average of 56.87 dB (Figure 3). Human activity in Kemayoran tended to concentrate in the center, although there was no significant difference in the number of people between the two zones (Figure 4).

In PT JIEP Urban Forest, 10 bird species were also observed vocalizing. Four species—Javan Prinia, Brown Flycatcher, Scaly-breasted Munia, and Ashy Tailorbird—were more vocal at the edge, while six species—Sooty-headed Bulbul, Eurasian Tree Sparrow, Yellow-vented Bulbul, Zebra Dove, Peaceful Dove, and Black-headed Munia—were more vocal in the center (Table 2). Noise levels were higher at the edge (64.57 dB) than in the center (60.07 dB), with an average of 62.31 dB (Figures 2 and 3). In contrast to the previous sites, human activity in PT JIEP was more concentrated at the edge, although the difference in human presence between the two zones was not significant (Figure 4).

Birds in Srengseng Urban Forest were more frequently vocalizing in the edge zone, which is likely due to higher levels of human activity in the center. Activities such as trapping using recorded calls, nest collection, net installations, and the use of air rifles were observed in the central area. These activities may contribute to habitat disturbance and bird population decline. Human activities can significantly reduce bird populations through habitat alteration and hunting. The average noise level in Srengseng Urban Forest (58.6 dB) remains within the tolerable threshold for birds, as Dooling & Popper (2007) suggest that birds can generally tolerate noise levels up to 60 dB. Additionally, the impact of noise on birds can vary between species or groups (Haryadi, 2016).

Table 2. Number of bird vocalizations

Location	Indonesian birds name	Edge	Center
Srengseng urban forest	<i>Cucak Kutilang</i>	26	5
	<i>Gereja erasia</i>	54	7
	<i>Perenjak Jawa</i>	25	15
	<i>Sikatan Bubik</i>	55	40
	<i>Cekakak Sungai</i>	7	5
	<i>Cabai Jawa</i>	12	11
	<i>Bondol Jawa</i>	15	0
	<i>Bondol peking</i>	72	0
	<i>Madu Kelapa</i>	15	0
	<i>Tekukur</i>	7	2
	<i>Sikatan Sisi Gelap</i>	26	0
	<i>Kacamata Biasa</i>	2	0
	<i>Merbah cerukcuk</i>	95	119
	<i>Walet Linchi</i>	2	11
	<i>Ceriti</i>	2	7
	<i>Cipoh Kacat</i>	0	2
	<i>Wiwik Kelabu</i>	0	1
	<i>Kangkak Melayu</i>	0	12
	<i>Kangkak Ranting</i>	0	1
Kemayoran urban forest	<i>Cucak Kutilang</i>	44	28
	<i>Gereja erasia</i>	150	75
	<i>Tekukur</i>	5	0
	<i>Sikatan Bubik</i>	8	0
	<i>Ceriti</i>	2	3
	<i>Merbah cerukcuk</i>	16	52
	<i>Perenjak Jawa</i>	7	18
	<i>Blekak Sawah</i>	0	12
	<i>Perkutut</i>	3	9
	<i>Walet Linchi</i>	0	1
PT JIEP urban forest	<i>Perenjak Jawa</i>	3	0
	<i>Sikatan Bubik</i>	20	0
	<i>Bondol peking</i>	12	11
	<i>Remetuk Laut</i>	6	3
	<i>Cucak Kutilang</i>	7	12
	<i>Gereja erasia</i>	7	10
	<i>Merbah cerukcuk</i>	0	7
	<i>Tekukur</i>	0	10
	<i>Perkutut</i>	0	5
	<i>Bondol Jawa</i>	0	3

In contrast, in Kemayoran and PT JIEP Urban Forests, birds tended to vocalize more in the center areas, likely due to the lower noise levels there compared to the edges, which are adjacent to busy roads. This finding is consistent with the results of Haryadi (2016), who found that bird vocalization activity is lower in habitats close to roads and that increased noise levels have a significant negative effect on the frequency of bird vocalizations.

3.4 Bird species in the three urban forests of DKI Jakarta

The research recorded a total of 25 bird species in Srengseng Urban Forest (Table 3), including Javan Munia (*Lonchura leucogastroides*), Scaly-breasted Munia (*Lonchura punctulata*), Scarlet-headed Flowerpecker (*Dicaeum trochileum*), Collared Kingfisher (*Halcyon chloris*), Pacific Swallow (*Hirundo tahitica*), Common Iora (*Aegithina tiphia*), Sooty-headed Bulbul (*Pycnonotus aurigaster*), Eurasian Tree Sparrow (*Passer montanus*), Oriental White-eye (*Zosterops palpebrosus*), Indian Cuckoo (*Cuculus fugax*), Hodgson's Hawk-Cuckoo (*Cuculus saturatus*), Silver-rumped Spinetail (*Rhaphidura leucopygialis*), White-breasted Waterhen (*Amaurornis phoenicurus*), Black-crowned Night Heron (*Nycticorax nycticorax*), Malayan Night Heron (*Gorsachius melanolophus*), Brown-throated

Sunbird (*Anthreptes malacensis*), Yellow-vented Bulbul (*Pycnonotus goiavier*), Javan Prinia (*Prinia familiaris*), Zebra Dove (*Geopelia striata*), Small Minivet (*Pericrocotus saturatus*), Asian Brown Flycatcher (*Muscicapa dauurica*), Dark-sided Flycatcher (*Muscicapa sibirica*), Spotted Dove (*Streptopelia chinensis*), Asian House Swift (*Collocalia linchi*), and Plaintive Cuckoo (*Cacomantis merulinus*), with a total of 252 individual birds observed. Several species were found exclusively in Srengseng Urban Forest and not in the other two locations. These include: Common Iora, Oriental White-eye, Indian Cuckoo, Hodgson's Hawk-Cuckoo, Black-crowned Night Heron, Malayan Night Heron, Brown-throated Sunbird, Small Minivet, and Plaintive Cuckoo.

Tabel 3. Birds in Srengseng urban forest, Kemayoran urban forest, and PT JIEP urban forest

No	Birds	Species	SUF	KUF	JUF
1	Chinese Pond Heron	<i>Ardeola bacchus</i> *		ü	
2	Javan Pond Heron	<i>Ardeola Speciosa</i>		ü	
3	Javan Munia	<i>Lonchura leucogastroides</i>	ü		ü
4	Scaly-breasted Munia	<i>Lonchura punctulata</i>	ü	ü	ü
5	Scarlet-headed Flowerpecker	<i>Dicaeum trochileum</i>	ü	ü	
6	Sunda Woodpecker	<i>Dendrocopus javensis</i>			ü
7	Collared Kingfisher	<i>Halycon chloris</i>	ü		
8	Pacific Swallow	<i>Hirundo tahitica</i>	ü	ü	ü
9	Common Iora	<i>Aegithina tiphia</i>	ü		
10	Sooty-headed Bulbul	<i>Pycnonotus aurigaster</i>	ü	ü	ü
11	Eurasian Tree Sparrow	<i>Passer montanus</i>	ü	ü	ü
12	Oriental White-eye	<i>Zosterops palpebrosus</i>	ü		
13	Indian Cuckoo	<i>Cuculus fugax</i>	ü		
14	Hodgson's Hawk-Cuckoo	<i>Cuculus saturatus</i>	ü		
15	Silver-rumped Spinetail	<i>Rhaphidura leucopygialis</i>	ü		ü
16	White-breasted Waterhen	<i>Amaurornis phoenicurus</i>	ü	ü	
17	Ashy Woodswallow	<i>Arthamus leucorhynchus</i>			ü
18	Striated Heron	<i>Butorides striatus</i>		ü	
19	Black-crowned Night Heron	<i>Nycticorax nycticorax</i>	ü		
20	Malayan Night Heron	<i>Gorsachius melanolophus</i> *	ü		

Note:

*birds protected under Regulation of the Minister of Environment and Forestry (PERMEN LHK) No. 20 of 2018

SUF: Srengseng Urban Forest

KUF: Kemayoran Urban Forest

JUF: PT. JIEP Urban Forest

In Kemayoran Urban Forest, a total of 19 bird species were recorded (Table 3), including: Chinese Pond Heron (*Ardeola bacchus*), Javan Pond Heron (*Ardeola speciosa*), Pacific Swallow (*Hirundo tahitica*), Sooty-headed Bulbul (*Pycnonotus aurigaster*), Eurasian Tree Sparrow (*Passer montanus*), White-breasted Waterhen (*Amaurornis phoenicurus*), Chinese Egret (*Egretta eulophotes*), Pacific Reef Heron (*Egretta sacra*), Little Egret (*Egretta garzetta*), Yellow-vented Bulbul (*Pycnonotus goiavier*), Little Cormorant (*Phalacrocorax sulcirostris*), Javan Prinia (*Prinia familiaris*), Zebra Dove (*Geopelia striata*), Spotted Dove (*Streptopelia chinensis*), Asian House Swift (*Collocalia linchi*), Scaly-breasted Munia (*Lonchura punctulata*), Striated Heron (*Butorides striata*), Asian Brown Flycatcher (*Muscicapa dauurica*), and Scarlet-headed Flowerpecker (*Dicaeum trochileum*), with a total

of 267 individuals recorded. Bird species found exclusively in Kemayoran and absent in the other urban forests include: Chinese Pond Heron, Javan Pond Heron, Striated Heron, Chinese Egret, Pacific Reef Heron, Little Egret, and Little Cormorant.

In PT JIEP Urban Forest, 14 species were recorded, including Javan Munia (*Lonchura leucogastroides*), Scaly-breasted Munia (*Lonchura punctulata*), Sunda Woodpecker (*Dendrocopos javensis*), Pacific Swallow (*Hirundo tahitica*), Sooty-headed Bulbul (*Pycnonotus aurigaster*), Eurasian Tree Sparrow (*Passer montanus*), Silver-rumped Spinetail (*Rhaphidura leucopygialis*), Ashy Woodswallow (*Artamus leucorhynchus*), Yellow-vented Bulbul (*Pycnonotus goiavier*), Javan Prinia (*Prinia familiaris*), Zebra Dove (*Geopelia striata*), Golden-bellied Gerygone (*Gerygone sulphurea*), Asian Brown Flycatcher (*Muscicapa dauurica*), and Spotted Dove (*Streptopelia chinensis*), with a total of 122 individual birds recorded.

Species found only in PT JIEP and not in other sites include Sunda Woodpecker, Ashy Woodswallow, and Golden-bellied Gerygone. Across all three urban forests, a total of 35 bird species from 21 families were recorded. The Ardeidae family was the most dominant, represented by 8 species. This large family is widely distributed globally and consists of long-legged, long-necked, and long-billed birds typically adapted for catching fish, small vertebrates, or invertebrates (MacKinnon et al., 1999).

According to the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. P.20/MENLHK/SETJEN/KUM.1/6/2018 on protected plant and animal species, three protected bird species were identified in the three urban forests of DKI Jakarta (Figure 6): (a) *Ardeola bacchus* (Chinese Pond Heron), (b) *Egretta eulophotes* (Chinese Egret) — both found in Kemayoran Urban Forest, and (c) *Gorsachius melanolophus* (Malayan Night Heron) — found in Srengseng Urban Forest.

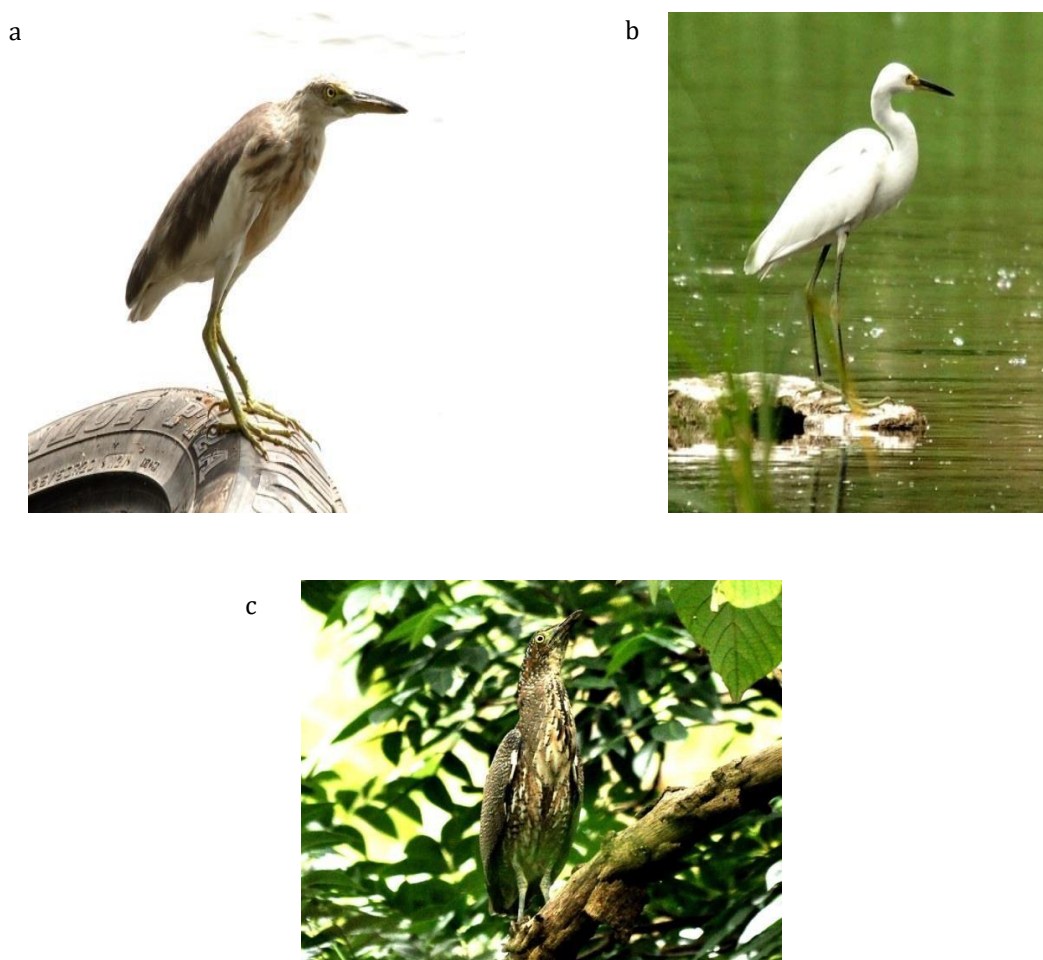


Fig. 6. Protected bird species: (a) *Ardeola bacchus*; (b) *Egretta eulophotes*; (c) *Gorsachius melanolophus*

3.5 Diversity, richness, and evenness of birds in the three urban forests of DKI Jakarta

Based on the research conducted in Srengseng Urban Forest, the number of bird species found in the edge area was 20 species, and in the center area 21 species, with a total of 25 species recorded (Table 4). Species found exclusively in the edge area included the Dark-sided Flycatcher (*Muscicapa sibirica*) and the Small Minivet (*Pericrocotus saturatus*). Bird species found only in the center area were the Plaintive Cuckoo (*Cacomantis merulinus*), Malayan Night Heron (*Gorsachius melanolophus*), Black-crowned Night Heron (*Nycticorax nycticorax*), White-breasted Waterhen (*Amaurornis phoenicurus*), Common Iora (*Aegithina tiphia*), Javan Munia (*Lonchura leucogastroides*), and Scaly-breasted Munia (*Lonchura punctulata*). Meanwhile, bird species recorded in both edge and center areas included the Scarlet-backed Flowerpecker (*Dicaeum trochileum*), Collared Kingfisher (*Halcyon chloris*), Pacific Swallow (*Hirundo tahitica*), Sooty-headed Bulbul (*Pycnonotus aurigaster*), Eurasian Tree Sparrow (*Passer montanus*), Oriental White-eye (*Zosterops palpebrosus*), Malaysian Hawk-Cuckoo (*Cuculus fugax*), Large Hawk-Cuckoo (*Cuculus saturatus*), Silver-rumped Spinetail (*Rhaphidura leucopygialis*), Brown-throated Sunbird (*Anthreptes malacensis*), Yellow-vented Bulbul (*Pycnonotus goiavier*), Plain Prinia (*Prinia familiaris*), Zebra Dove (*Geopelia striata*), Asian Brown Flycatcher (*Muscicapa dauurica*), Spotted Dove (*Streptopelia chinensis*), and Glossy Swiftlet (*Collocalia linchi*).

Tabel 4. Number of bird species, diversity, richness, and evenness in three urban forests of DKI Jakarta

Location	Region	Number of species	H'	Dmg	E'
Srengseng urban forest	Edge	20	2.293	3.717	0.449
	Center	21	2.205	4.334	0.478
	Overall areas	25	2.349	4.34	0.425
Kemayoran urban forest	Edge	18	2.301	3.366	0.456
	Center	16	2.183	3.082	0.448
	Overall areas	19	2.306	3.222	0.413
PT JIEP urban forest	Edge	12	2.153	2.598	0.509
	Center	13	2.444	2.931	0.597
	Overall areas	14	2.401	2.706	0.5

In Kemayoran Urban Forest, 18 species were recorded in the edge area and 16 in the center area, with a total of 19 species (Table 4). Species found only in the edge area were Scaly-breasted Munia (*Lonchura punctulata*), Striated Heron (*Butorides striatus*), and Asian Brown Flycatcher (*Muscicapa dauurica*). Species found only in the center area included the Scarlet-backed Flowerpecker (*Dicaeum trochileum*). Bird species recorded in both areas included Chinese Pond Heron (*Ardeola bacchus*), Javan Pond Heron (*Ardeola speciosa*), Pacific Swallow (*Hirundo tahitica*), Sooty-headed Bulbul (*Pycnonotus aurigaster*), Eurasian Tree Sparrow (*Passer montanus*), White-breasted Waterhen (*Amaurornis phoenicurus*), Chinese Egret (*Egretta eulophotes*), Pacific Reef Egret (*Egretta sacra*), Little Egret (*Egretta garzetta*), Yellow-vented Bulbul (*Pycnonotus goiavier*), Little Cormorant (*Phalacrocorax sulcirostris*), Plain Prinia (*Prinia familiaris*), Zebra Dove (*Geopelia striata*), Spotted Dove (*Streptopelia chinensis*), and Glossy Swiftlet (*Collocalia linchi*).

In PT JIEP Urban Forest, 12 bird species were recorded in the edge area and 13 in the center, with a total of 14 species found (Table 4). Species found only in the edge area was Plain Prinia (*Prinia familiaris*), while species exclusive to the center included Javan Munia (*Lonchura leucogastroides*) and Sunda Woodpecker (*Dendrocopos javensis*). Bird species observed in both areas included Scaly-breasted Munia (*Lonchura punctulata*), Pacific Swallow (*Hirundo tahitica*), Sooty-headed Bulbul (*Pycnonotus aurigaster*), Eurasian Tree Sparrow (*Passer montanus*), Silver-rumped Spinetail (*Rhaphidura leucopygialis*), Ashy Woodswallow (*Artamus leucorhynchus*), Yellow-vented Bulbul (*Pycnonotus goiavier*), Zebra Dove (*Geopelia striata*), Golden-bellied Gerygone (*Gerygone sulphurea*), Asian Brown Flycatcher (*Muscicapa dauurica*), and Spotted Dove (*Streptopelia chinensis*).

In Srengseng Urban Forest, the diversity, richness, and evenness indices for the edge area were $H' = 2.293$, $Dmg = 3.717$, and $E' = 0.449$, respectively, while in the center area they were $H' = 2.205$, $Dmg = 4.334$, and $E' = 0.478$. Diversity (H') was higher in the edge area due to a more balanced distribution of individuals among species compared to the center, and both areas were classified as having moderate diversity. Richness (Dmg) was higher in the center (high category) compared to the edge (moderate category), as more species were found in the center area (Table 4). Evenness (E') was also higher in the center area due to a more uniform distribution of individuals among species, with both areas classified as having moderate evenness.

In Kemayoran Urban Forest, the indices for the edge area were $H' = 2.301$, $Dmg = 3.366$, and $E' = 0.456$, while in the center they were $H' = 2.183$, $Dmg = 3.082$, and $E' = 0.448$. Diversity was slightly higher in the edge area, likely due to a more balanced species composition. Richness was also higher in the edge area (moderate category) because more species were recorded compared to the center (Table 4). Evenness was greater in the edge area, possibly due to an edge effect which influences species abundance, distribution, and interactions (Haryadi, 2016). Both zones fell into the moderate evenness category.

In PT JIEP Urban Forest, the edge area had $H' = 2.153$, $Dmg = 2.598$, and $E' = 0.509$, while the center area had $H' = 2.444$, $Dmg = 2.931$, and $E' = 0.597$. Diversity and evenness were higher in the center area due to a more balanced individual distribution among species, while richness was also slightly higher in the center. Both zones were categorized as having moderate diversity, richness, and evenness.

Overall, the diversity, richness, and evenness indices for the three urban forests in DKI Jakarta were: Srengseng Urban Forest ($H' = 2.349$, $Dmg = 4.34$, $E' = 0.425$), Kemayoran Urban Forest ($H' = 2.306$, $Dmg = 3.222$, $E' = 0.413$), and PT JIEP Urban Forest ($H' = 2.401$, $Dmg = 2.706$, $E' = 0.5$). The highest diversity index (H') was found in PT JIEP Urban Forest due to the more even distribution of individuals across species, supported by the relatively lower relative abundance (Table 5). The highest species richness (Dmg) was found in Srengseng Urban Forest (high category), attributed to the greater number of species found (Table 4). The highest evenness (E') was also found in PT JIEP Urban Forest, driven by more uniform species distribution, influenced by its diversity index, and categorized as moderate.

3.6 Relative abundance and dominance of birds in the three urban forests of DKI Jakarta

Relative abundance refers to the proportion of individuals of a particular species compared to the total number of individuals of all species in a community (Bibby et al., 2000). Birds exhibit varying levels of abundance across different habitats, and high bird abundance is generally supported by the habitat's capacity to meet feeding requirements and other life necessities (Rifat, 2013). The research conducted in the three urban forests in DKI Jakarta revealed differences in relative abundance values. As shown in Table 5, Srengseng Urban Forest had six bird species with the highest relative abundance values: Yellow-vented Bulbul (*Pycnonotus goiavier*) at 26.98%, Silver-rumped Spinetail (*Rhaphidura leucopygialis*) at 20.63%, Glossy Swiftlet (*Collocalia linchi*) at 13.49%, Scaly-breasted Munia (*Lonchura punctulata*) and Eurasian Tree Sparrow (*Passer montanus*) both at 5.56%, and Pacific Swallow (*Hirundo tahitica*) at 5.16%. The lowest relative abundance values, each at 0.4%, were recorded for eight species: Common Iora (*Aegithina tiphia*), White-breasted Waterhen (*Amaurornis phoenicurus*), Black-crowned Night Heron (*Nycticorax nycticorax*), Malayan Night Heron (*Gorsachius melanolophus*), Zebra Dove (*Geopelia striata*), Small Minivet (*Pericrocotus saturatus*), Dark-sided Flycatcher (*Muscicapa sibirica*), and Plaintive Cuckoo (*Cacomantis merulinus*).

In Kemayoran Urban Forest, six species showed high relative abundance values: Eurasian Tree Sparrow (*Passer montanus*) at 23.22%, Javan Pond Heron (*Ardeola speciosa*) at 15.36%, Glossy Swiftlet (*Collocalia linchi*) at 14.98%, Pacific Swallow (*Hirundo tahitica*) at 11.99%, Chinese Pond Heron (*Ardeola bacchus*) at 8.24%, Sooty-headed Bulbul (*Pycnonotus aurigaster*) at 7.12%, and Yellow-vented Bulbul (*Pycnonotus goiavier*) at 5.62%. The lowest relative abundance, at 0.37%, was recorded for three species: Scarlet-

backed Flowerpecker (*Dicaeum trochileum*), Striated Heron (*Butorides striatus*), and Asian Brown Flycatcher (*Muscicapa dauurica*).

Table 5. Relative abundance of birds in three urban forests in DKI Jakarta

Location	Indonesian birds name	Species	Total	KR
Srengseng urban forest	Merbah cerukcuk	<i>Pycnonotus goiavier</i>	68	26.98
	Kapinis Jarum Kecil	<i>Rhaphidura leucopygialis</i>	52	20.63
	Walet Linchi	<i>Collocalia linchi</i>	34	13.49
	Bondol peking	<i>Lonchura Punctulata</i>	14	5.56
	Gereja erasia	<i>Passer montanus</i>	14	5.56
	Ceriti	<i>Hirundo tahitica</i>	13	5.16
	Cipoh Kacat	<i>Aegithina tiphia</i>	1	0.4
	Kareo Padi	<i>Amaurornis phoenicurus</i>	1	0.4
	Kowak Malam Kelabu	<i>Nycticorax nycticorax</i>	1	0.4
	Kowak Melayu	<i>Gorsachius melanolophus</i>	1	0.4
	Perkutut	<i>Geopolia Striata</i>	1	0.4
	Sepah Kecil	<i>Pericrocotus saturatus</i>	1	0.4
	Sikatan Sisi-gelap	<i>Muscicapa sibirica</i>	1	0.4
	Wiwik Kelabu	<i>Cocomantis merulinus</i>	1	0.4
Kemayoran urban forest	Gereja erasia	<i>Passer montanus</i>	62	23.22
	Blekok Sawah	<i>Ardeola Speciosa</i>	41	15.36
	Walet Linchi	<i>Collocalia linchi</i>	40	14.98
	Ceriti	<i>Hirundo tahitica</i>	32	11.99
	Blekok Cina	<i>Ardeola bacchus</i>	22	8.24
	Cucak Kutilang	<i>Pycnonotus aurigaster</i>	19	7.12
	Merbah cerukcuk	<i>Pycnonotus goiavier</i>	15	5.62
	Cabai Jawa	<i>Dicaeum trochileum</i>	1	0.37
	Kokokan Laut	<i>Butorides striatus</i>	1	0.37
	Sikatan Bubik	<i>Muscicapa dauurica</i>	1	0.37
PT JIEP urban forest	Bondol peking	<i>Lonchura punctulata</i>	21	17.21
	Kekep Babi	<i>Arthamus leucorynchus</i>	18	14.75
	Cucak Kutilang	<i>Pycnonotus aurigaster</i>	16	13.11
	Gereja erasia	<i>Passer montanus</i>	14	11.48
	Ceriti	<i>Hirundo tahitica</i>	12	9.84
	Kapinis Jarum-kecil	<i>Rhaphidura leucopygialis</i>	9	7.38
	Caladi Ulam	<i>Dendrocopus javensis</i>	2	1.64
	Perenjak Jawa	<i>Prinia familiaris</i>	2	1.64

In PT JIEP Urban Forest, five bird species showed relatively high abundance: Scaly-breasted Munia (*Lonchura punctulata*) at 17.21%, Ashy Woodswallow (*Artamus leucorynchus*) at 14.74%, Sooty-headed Bulbul (*Pycnonotus aurigaster*) at 13.11%, Eurasian Tree Sparrow (*Passer montanus*) at 11.48%, Pacific Swallow (*Hirundo tahitica*) at 9.84%, and Silver-rumped Spinetail (*Rhaphidura leucopygialis*) at 7.38%. The lowest relative abundance, at 1.64%, was recorded for two species: Sunda Woodpecker (*Dendrocopos javensis*) and Plain Prinia (*Prinia familiaris*).

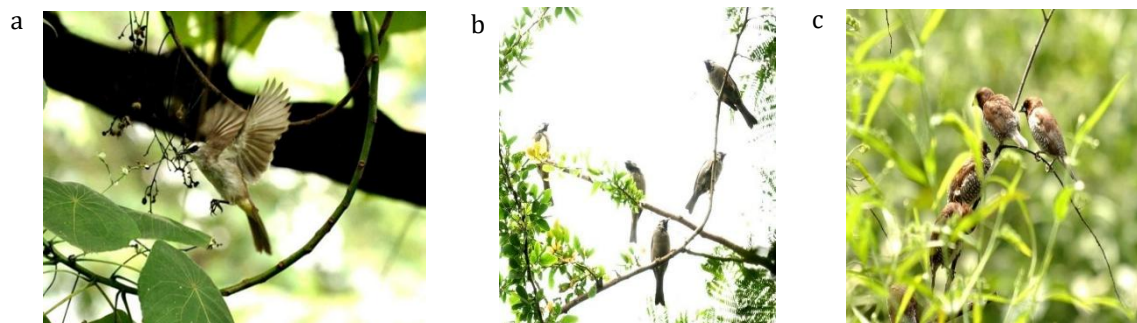


Fig. 7. Dominant bird species: (a) Yellow-vented Bulbul (*Pycnonotus goiavier*); (b) Eurasian Tree Sparrow (*Passer montanus*); (c) Scaly-breasted Munia (*Lonchura punctulata*)

Based on the data above, the most dominant bird species in Srengseng Urban Forest is the Yellow-vented Bulbul (*Pycnonotus goiavier*), in Kemayoran Urban Forest is the Eurasian Tree Sparrow (*Passer montanus*), and in PT JIEP Urban Forest is the Scaly-breasted Munia (*Lonchura punctulata*). This dominance is influenced by habitat conditions that support a high availability of food, allowing these species to outnumber others. Their high abundance is also attributed to the fact that these bird populations tend to live in large groups or pairs, resulting in a greater number of individuals being observed during the survey.

4. Conclusions

Based on the results of the study conducted in three urban forests in DKI Jakarta, the following conclusions can be drawn. Noise levels in the three urban forests varied between edge and central zones. The noise level was generally higher in the edge areas compared to the central areas of the urban forests. Areas with higher noise levels tended to have fewer bird vocalizations, whereas areas with lower noise levels showed a greater number of bird vocalizations. The highest average noise level was recorded at the PT JIEP Urban Forest, reaching 66.55 dB. Furthermore, human presence also influenced noise levels and bird vocalization activity. The highest average human presence was observed in the Srengseng Urban Forest, with a total of 152 individuals. The greater the human presence, the higher the noise levels, which correlated with a decrease in the number of vocalizing birds. Conversely, when human presence was lower, the number of vocalizing birds tended to increase.

In general, bird vocalization is influenced by two main factors: noise level and human presence. Bird vocalization activity and the number of vocalizing birds were higher under conditions of low noise and minimal human presence. In contrast, under conditions of high noise and dense human presence, bird vocalization activity and the number of vocalizing birds declined. Regarding species richness, Srengseng Urban Forest recorded the highest number of species, with 25 species identified, followed by Kemayoran Urban Forest with 19 species, and PT JIEP Urban Forest with 14 species. In total, 35 different bird species were observed across the three urban forests, including three protected species as listed in the Regulation of the Minister of Environment and Forestry (PERMEN LHK) No. 20 of 2018.

Meanwhile, the bird species diversity index (H') showed relatively balanced values across the three locations: 2.349 in Srengseng Urban Forest, 2.306 in Kemayoran Urban Forest, and 2.401 in PT JIEP Urban Forest. Each urban forest also had a dominant species with the highest relative abundance. In Srengseng Urban Forest, the most abundant species was the Yellow-vented Bulbul (*Pycnonotus goiavier*), in Kemayoran Urban Forest it was the Eurasian Tree Sparrow (*Passer montanus*), and in PT JIEP Urban Forest it was the Scaly-breasted Munia (*Lonchura punctulata*).

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Author Contribution

All authors contributed to the conception, design, data collection, analysis, interpretation, and drafting of the manuscript. Each author reviewed and approved the final version for submission and publication.

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The authors declare no conflict of interest.

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