Journal of Biotechnology and Natural Science
Vol. 2, No. 1, August 2022, pp. 10-19
ISSN 2808-2508

Environmental Quality of Prambanan Temple's and Ratu Boko Temple's Green Open Spaces Based on Soundscape and Guild of Bird

[1,2*]Inggita Utami, [1]Eva Nurulia Yahya, [1]Wida Afriandini, [1]Ajeng Silvi Dwipayana, [1]Salsa Aprilia Utami, [1]Baiq Dara Meilina Arliani, [1]Khairunnisrina Ramadhani

[1]Biology Department, Faculty of Applied Science and Technology, Universitas Ahmad Dahlan
[2]Laboratory of Ecology and Systematics, Universitas Ahmad Dahlan
inggitautami@bio.uad.ac.id
* corresponding author

ARTICLE INFO

Article history
Received : Juny 7th 2022
Revised : July 2nd 2022
Accepted: August 30th 2022

Keywords
ACI
Anthrophony
Birds
NDSI
Vehicles

ABSTRACT

Sleman Regency has the most temples as cultural heritage in Yogyakarta, supported by Green Open Space (GOS). The area is a habitat for urban birds and can be used as an indicator of environmental quality. This study aims to analyze the environmental quality based on the soundscape and character of the bird community in the GOS of Prambanan Temple and Ratu Boko Temple. Sound recordings were taken with a smartphone, and the recording time was set using the Arbimon touch in the morning, afternoon, and evening. The sound recordings were used to calculate acoustic indexes. The sound recordings and spectrograms are processed to identify bird species and to calculate the Bird Community Index. The number of bird species was higher in the Ratu Boko area. According to the NDSI value, the sound of biophony at Ratu Boko Temple was more dominant than anthrophony and geophony. The environmental quality in the Prambanan Temple area was in the lower category than the one in the Ratu Boko Temple area, which was classified as a medium category. The area's topography, the arrangement of vegetation, and the noise of vehicles due to the proximity to the highway affected the environmental quality of temple areas.

How to Cite: Utami, I., Yahya, E. N., Afriandini, W., Dwipayana, A. S., Utami, S. A., Arliani, B. D. M. & Ramadhani, K. (2022). Environmental Quality of Prambanan Temple's and Ratu Boko Temple's Green Open Spaces Based on Soundscape and Guild of Birds. Journal of Biotechnology and Natural Science, 2(1), 10-19.

1. Introduction

The Special Region of Yogyakarta (Yogyakarta Province) is one of the priority tourism provinces in Indonesia because it is rich in historical cultural heritage, such as temples. Most of the temples in Yogyakarta Province are located in Sleman Regency, such as Prambanan Temple, Ratu Boko Temple, Sewu Temple, and several other temples concentrated in Prambanan District. According to Presidential Decree number 1 of 1992, a temple also has an area in the form of a land area around it which serves as tourism parks and environmental conservation. The temple area, which is managed as a tourist park (cultural park), is categorized as Green Open Space (GOS)[16]. According to Rushayati et al.[23], green open spaces, especially urban areas, contain plants and

vegetation to support ecological, socio-cultural, and architectural benefits, to support economic benefits for the surrounding community.

Green Open Space has ecological roles, including carbon dioxide absorption and oxygen production, groundwater conservation, windbreaks, climate amelioration, and habitat for wildlife such as birds by providing food and place for survival[6]. The quality of green open space in the temple area needs to be monitored continuously, and it can be seen from the diversity of bird species.

Birds are wild animals commonly found in urban areas and can be used as indicators of environmental quality and change[26]. According to research conducted by Bura[3], using the line transect method, eighteen species of birds were found in the Prambanan temple tourism park area with vegetation composition composed of trees and understorey plants. Besides being distinguished by their body morphology, bird species can also be identified by their sound[9, 25]. Soundscape is part of environmental acoustics, whose objects are all sounds, both natural and artificial, and are composed of biophony (living things other than humans), anthrophony (humans and their activities), and geophony (natural activities, such as rain) sounds[24]. The soundscape method makes it easier to identify biophonic sounds such as bird sounds to be more efficient than making direct observations in the field. The identified birds can be used to calculate the Bird Community Index (BCI), which can measure environmental quality[12]. According to Mardiastuti et al.[17], the BCI calculation is obtained from the guild of each bird species, and data on the number of individuals is not used in the calculation. The seven guild categories include feed, species origin, reproduction, nesting, active time, and the type of habitat inhabited by birds[22]. Research on BCI measurements is generally combined with bird identification in the field, but BCI measurements can also be carried out after sound identification.

Various acoustic indices can be used to analyze sound recordings. According to Fuller et al.[10], the Normalized Difference Soundscape Index (NDSI) works by evaluating the level of anthropogenic disturbance in the acoustic environment by calculating the ratio of biophony and other sounds. The NDSI index has a range of values from 1 to +1, with +1 indicating that the audible signal contains only biophony[15]. The Acoustic Complexity Index (ACI) can be used to determine the biodiversity of a place based on the sound variants of the identified species, such as the sound of birds. ACI is one of the more efficient ways to determine biodiversity through sound in an ecosystem and observe changes in the environment over time[13]. It serves as a more efficient and faster monitoring tool regarding the dynamics of animals in an ecosystem[21]. Research on birds is critical because birds are dynamic and can indicate environmental changes in the area[2]. Previous research has never detected and identified birds with soundscapes, so this research is a new method to analyze the quality and disturbance in locations prone to anthropogenic disturbances, such as the green open space in a temple area. This study aimed to analyze the environmental quality based on the soundscape and character of the bird community in the GOS of Prambanan Temple and Ratu Boko Temple. These temples are the most visited by tourists in Sleman Regency[27]. The condition of the natural ecosystem in the green open space in the temple area continues to be under pressure, so conservation efforts need to be made.

2. Method

2.1. Tools and Materials

The tools used in this research were smartphones, clip-on, laptops, Arbimont-Touch applications, GPS essentials, audacity software, Rstudio software, and Xeno-canto website. The materials used in this study were the coordinates and samples of bird sounds at the Ratu Boko Temple and Prambanan Temple locations.

2.2. Determinations of Research Locations

The sampling point was determined randomly on the green open space included in the tourist park area of Prambanan Temple and Ratu Boko Temple, Sleman Regency, Yogyakarta province.

The determined sampling point was marked with the coordinates using the Essential GPS. Point A (110°29'36"E 7°45'18"S) representing the GOS of the Prambanan Temple and point B (110°29,044'E 07°46,285'S) representing the GOS of the Ratu Boko Temple (Figure 1) were depicted on a sampling location map with the Google Earth pro.

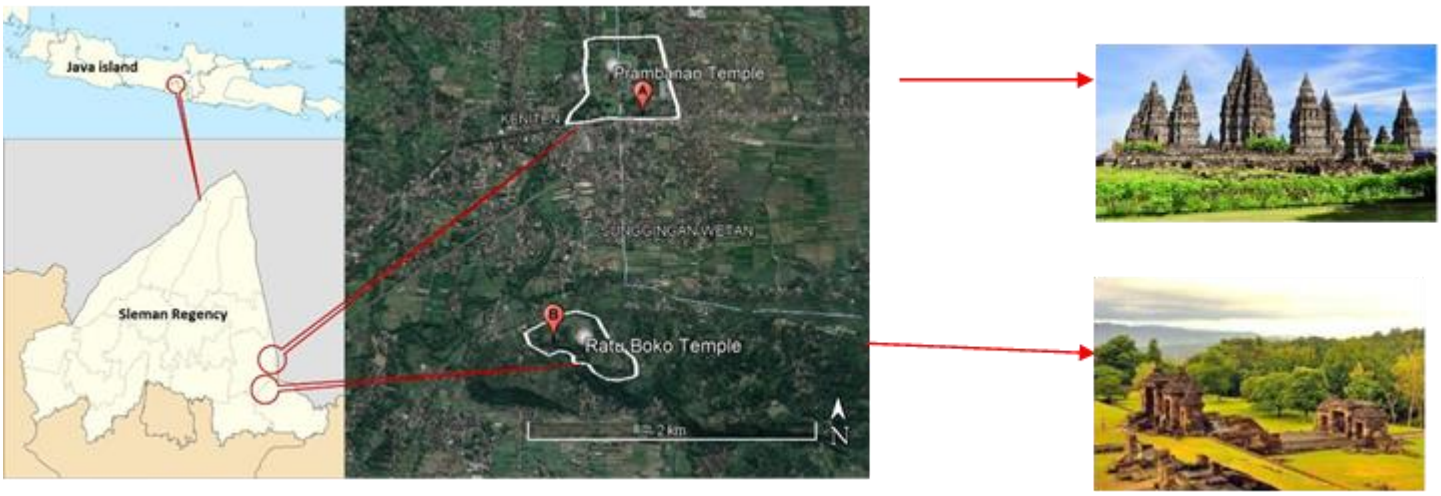


Fig. 1. Audiomoth placement points at both sampling locations

2.3. Data Collection and Analysis

Sound recording at points A and B was taken in October 2021 using a smartphone placed on a tree. Smartphone equipped with Arbimon-Touch application with an additional clip-on. Arbimon-Touch application was set for three days for data collection every morning at 06:00 – 08:00, noon at 11:00 – 13:00, and afternoon at 16:00 – 18:00 (Western Indonesia Time) with a recording interval of 5 minutes recording on and 10 minutes off. According to Staler (2003), the chirping of birds in the morning is a vocal warm-up. Then after dawn, birds take on a higher chirping tempo after hundreds of vocal warm-ups until evening. The recorded sound was then entered into the Audacity software. The sound of the bird and spectrogram were validated with the database on the Xeno-Canto to identify the bird species. The identified birds were determined by the guild character to assess the quality of green open space by the Bird Community Index (BCI). According to Mardiastuti et al.[17], the Bird Community Index (BCI) is a diversity index that is practically used to assess the quality of green open space by grouping bird species based on guilds, namely feed, the origin of birds, reproduction method, type of nest, active time and habitat of birds. BCI calculation in this research was carried out by following BCI modification by Mardiastuti et al.[17] and Rumblat[22]. Sound recordings were also used to process sound dominance at the sampling location through the Acoustic Complexity Index (ACI) and Normalized Difference Soundscape Index (NDSI). Sound recordings were processed in R studio software using special scripts to obtain ACI and NDSI scores. In addition, sounds that can affect the quality of GOS (such as vehicle noise and other anthropogenic activities and sounds of natural activities such as rain and lightning) during the observations were recorded as potential disturbances, especially to biophony. The average BCI, NDSI, and ACI values at points A and B in the morning, noon, and afternoon were analyzed descriptively with bar charts and graphs. The analysis was carried out to compare the environmental quality of the two GOS at Prambanan and Ratu Boko temples.

3. Results and Discussion

3.1. Bird Identifications Based on Sounds

Based on the results of the identification of bird sounds at point A (Prambanan Temple) and point B (Ratu Boko Temple), 13 species of birds from various families were found. Based on table 1, seven bird species were identified in the GOS of Prambanan Temple and nine bird species in the GOS of Ratu Boko Temple. The bird families that dominated in the Prambanan Temple and Ratu Boko Temple areas were the Alcedinidae, Columbidae, and Estrildidae. The species from

Alcedinidae generally have a loud voice, live in open areas near rivers, actively hunt, eat insects, amphibians, to Pisces[1, 18]. Columbidae is adaptive to urban environments in open areas such as green open spaces. Columbidae sounds are distinctive, loud, and easily recognizable[18]. Estrildidae likes bush and rice fields rich in food sources, namely grains, and can adapt to the urban environment[4]. Four hundred meters to the northwest and north of Prambanan Temple, and around Ratu Boko Temple are rice fields where Estrildidae live. The difference in the number of bird species found from several habitat types is influenced by vegetation conditions at Prambanan Temple and Ratu Boko Temple. This theory follows the statement by Hamzati & Aunurohim[11] that the vegetation structure is one of the keys to bird species richness at the local level. The diversity of habitat types influences the diversity of bird species. The very close relationship between bird communities and the habitat diversity index shows that birds are highly dependent on trees, poles, and shrubs[5]. There are differences in bird communities' structure in areas with different vegetation structures or between natural and disturbed vegetation[20]. The vegetation in Ratu Boko Temple area has more tree complexity than that of Prambanan Temple area, where the surrounding environment is starting to decrease in natural vegetation due to its proximity to residential areas and roads.

Table 1. Result of Sound Identification of Bird Species

No	Family	Species Name	Local Name	Presenc		Conservation status**)
				PT	RBT*)	
1	Aegithinidae	*Aegithina tiphia*	Cipoh Kacat	-	√	LC, NP
2	Alcedinidae	*Halcyon cyanoventris*	Cekakak jawa	-	√	LC, NP
3	Alcedinidae	*Todiramphus chloris*	Cekakak sungai	√	-	LC, NP
4	Cisticolidae	*Orthotomus sutorius*	Cinenen Pisang	-	√	LC, NP
5	Columbidae	*Spilopelia chinensis*	Tekukur biasa	√	-	LC, NP
6	Columbidae	*Geopelia striata*	Perkutut Jawa	-	√	LC, NP
7	Cuculidae	*Cacomantis merulinus*	Wiwik kelabu	√	√	LC, NP
8	Estrildidae	*Lonchura leucogastroides*	Bondol jawa	-	√	LC, NP
9	Estrildidae	*Lonchura punctulata*	Bondol peking	√	√	LC, NP
10	Laniidae	*Lanius schach*	Bentet kelabu	√	-	LC, NP
11	Nectariniidae	*Cinnyris jugularis*	Madu sriganti	√	-	LC, NP
12	Passeridae	*Passer montanus*	Gereja erasia	-	√	LC, NP
13	Pycnonotidae	*Pycnonotus aurigaster*	Cucak kutilang	√	√	LC, NP
		Species Total		**7**	**9**	

a. *) PT : Prambanan Temple; RBT: Ratu Boko Temple

b. **) LC: less concern; NP: non-protected

3.2. Environmental Quality Based on Bird Community

The bird species identified in the GOS of Prambanan Temple and Ratu Boko Temple areas can be used to analyze environmental quality based on the Bird Community Index (BCI) value[12]. The BCI value at the Ratu Boko Temple location was higher than that of Prambanan Temple (Figure 2), with a low environmental quality category in the Prambanan Temple area and a medium environmental quality category in the Ratu Boko Temple area. The BCI value at the Ratu Boko Temple location was higher because more specialist birds were found at Ratu Boko Temple. The specialist birds found in the Ratu Boko Temple area were Perkutut Jawa (*Geopelia striata*), Cipoh Kacat (*Aegithina tiphia*), and Cinenen Pisang (*Orthotomus sutorius*) because the three birds nest on

the ground and are specialists[22]. Specialist bird species are susceptible to disturbance by human activities, and the Prambanan Temple area is very high in anthropogenic disturbances because it is adjacent to the main road connecting Yogyakarta and Solo and is surrounded by densely populated residential areas. Although at 400 m from point A there is a river that adds to the variety of resources in that location, the environmental quality is still in the low category. On the other hand, the position of Ratu Boko Temple is far from the main road, and its elevation is at 214 m above sea level, which is higher than the Prambanan Temple elevation, 164 m above sea level, with a denser vegetation density. The Ratu Boko Temple area condition slightly increased the number of birds present at the sampling location. This fact follows Intari[14] theory that a landscape with more specialist bird species represents good environmental conditions.

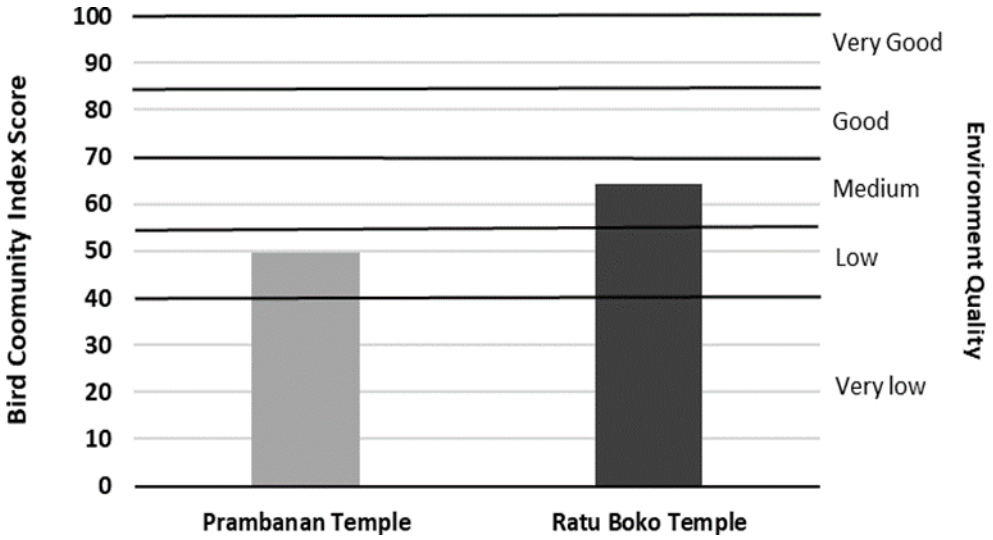


Fig. 2. Environmental Quality of the in Temple GOS Sampling Area in Sleman Regency

The scores from the feed guild, origin, and reproductive strategy in the bird communities identified by their voices at points A and B were considered balanced (Figure 3). On the other hand, the nest laying guild scores, activity time, and primary habitat of birds identified in the Ratu Boko Temple area were higher than in Prambanan Temple (table 3). According to the classification of birds based on their guild, there were many species of birds in laying nests in the Ratu Boko Temple area, such as Perkutut Jawa (*Geopelia striata*), Cipoh Kacat (*Aegithina thipia*), and Cinenen Pisang (*Orthotomus sutorius*), which laid their nests on the ground, Gereja Erasia (*Passer montanus*) in buildings, Cucak Kutilang (*Pycnoboyus aurigaster*) in holes, and Cekakak Jawa (*Halycon cyanoventris*) on a cliff. According to Rumblat[22], ground-nesting birds belong to a specialist group, in which these types of birds generally nest in areas with minimal human activity to avoid threats from predators. This matches the situation at Ratu Boko Temple, classified as having less human activity than Prambanan Temple. The presence of various bird species in Ratu Boko can indicate good environmental quality. Specialist birds are bird species vulnerable to the environment and cannot adapt to environmental changes[19]. The presence of more specialist birds in the Ratu Boko Temple area put the environmental quality in the middle category and higher than the Prambanan Temple area.

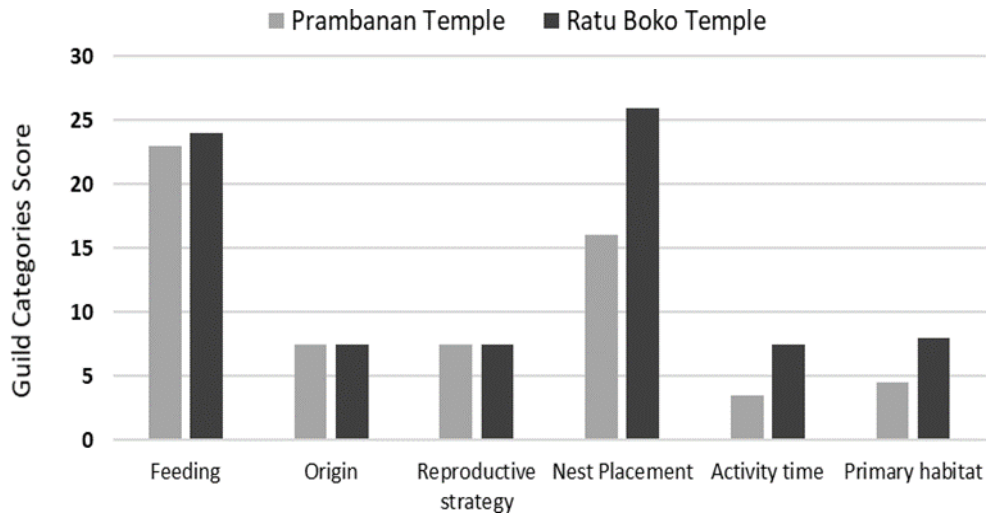
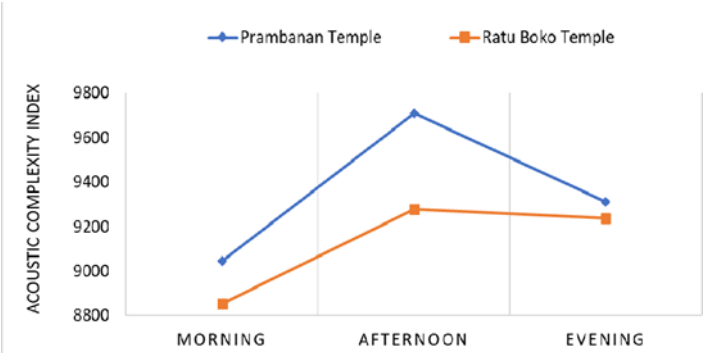


Fig. 3. The Value of the Bird Guild Category in the Green Open Space Area of Prambanan Temple and Ratu Boko Temple

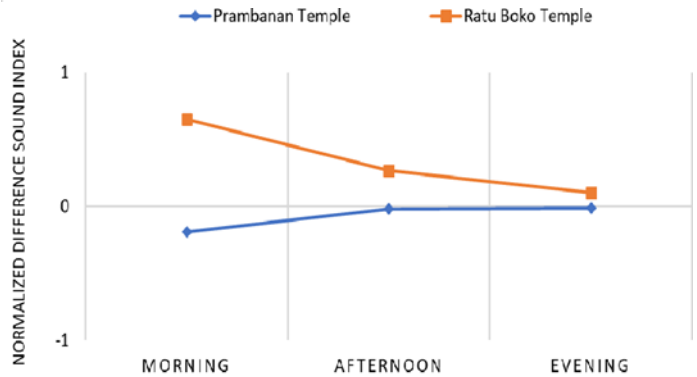
3.3. Environmental Quality Based on Acoustic Index

Sound recordings taken at points A and B contained biophony, anthrophony, and geophony components which could be analyzed for composition using acoustic indices in the soundscape. Based on Figure 4a, it can be concluded that the average ACI value at point A (Prambanan Temple) was higher than point B (Ratu Boko Temple). Contrary to this, the mean NDSI value at point B was higher (positive value with a mean value of 0.34) than location A, which was known to have a negative NDSI mean of up to -0.07. Therefore, the results of the two indices were predicted as high biophonic activity, precisely at location B, which made the NDSI value at location B higher. Still, the dominant anthropogenic sound at location A increased the ACI value at location A. The high biophonic activity at location B was evidenced by the average sound of the birds identified at location B being higher than at location A (Figure 5). According to Pieretti & Farina[21], the Acoustic Complexity Index can describe the complexity of the soundscape of avian groups such as birds chirping. Still, human-made disturbances such as vehicle noise can increase the ACI value and weaken the correlation with bird sounds. Setyantho et al.[24] argues that if the NDSI value is zero or negative, then the proportion of biophony is the same or even weaker than anthrophony. The NDSI pattern from points A and B was different (figure 4b) because there were different proportions between anthrophony and biophony due to different disturbances. Sampling point A is known to be 40 m from the main road connecting Yogyakarta City and Jalan Solo so that the vehicle noise is very high, compared to the distance from location B to the highway, which is quite far, which is around 920 m. High anthropogenic disturbances are evenly distributed throughout the observation time, morning, afternoon, evening, as evidenced by the negative NDSI value of location A throughout the recording time.



Location	ACI			
	morning	afternoon	evening	**Mean**
Prambanan Temple	9046	9709	9313	**9356**
Ratu Boko Temple	8854	9278	9237	**9123**

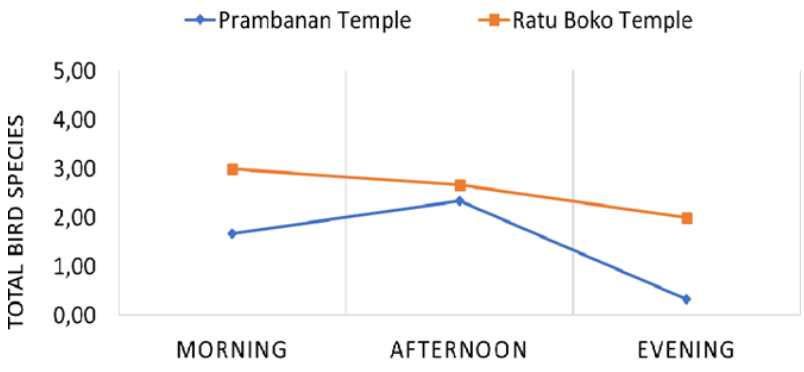
(a)



Location	NDSI			
	morning	afternoon	evening	**Mean**
Prambanan Temple	-0,19	-0,02	-0,01	**-0,07**
Ratu Boko Temple	0,65	0,27	0,1	**0,34**

(b)

Fig. 4.ACI (a) and NDSI score (b) in the Green Open Space Area of Prambanan Temple and Ratu Boko Temple



Location	Total bird species			
	morning	afternoon	evening	**Mean**
Prambanan Temple	1.67	2.33	0.33	**1.44**
Ratu Boko Temple	3.00	2.67	2.00	**2.56**

Fig. 5. Number of Bird Species Found Per Time

The average ACI and NDSI from point A (Prambanan Temple) and point B (Ratu Boko Temple) varied between the morning, afternoon and evening. The ACI chart pattern for location A, which was low in the morning and high in the afternoon (figure 4a), was predicted to increase anthropogenically, due to the increasingly greater number of motor vehicles during the day. Moreover data collection was also carried out on weekends. Negative NDSI values in the morning and afternoon supported high anthrophony and weakened the biophony portion. However, the increase in the NDSI value at location A from morning to afternoon (figure 4b), as well as the number of bird species from morning to afternoon at location A which also increased (figure 5), illustrated the presence of high bird activity amid traffic noise or other anthropogenic disturbances. According to Depraetere et al.[7], where environmental factors affect the performance of ACI. For example, in temperate climates, the correlation between biodiversity and ACI weakens along with increasing anthropogenic disturbance. Anthrophony and geophony that cause the complexity of sound noise to disturbances in the Prambanan Temple and Ratu Boko Temple areas are the presence of roads, villages around the location, and the sound of strong winds. The sound components of the landscape (such as noise and species richness) are directly related to landscape elements (topography, vegetation patterns, animal distribution). They are involved in sound production and dissemination[8]. Bird activity in the Prambanan Temple tourist park is supported by a river providing resources for fish-eating specialist birds. Future research is expected to take sound recording points in the temple park area, which is far from the highway and closer to the river, to reduce anthropogenic noise disturbance and increase IKB, NDSI and the number of bird species, particularly specialist birds.

4. Conclusion

Based on the study results, it can be concluded that the environmental quality in the GOS of Ratu Boko Temple is better with the medium category than the Prambanan Temple area, which is classified as low environmental quality. Road noise disturbance and other anthropogenic activities make the ACI value in the Prambanan Temple area relatively high with a negative NDSI value. On the other hand, the Ratu Boko Temple area is far from the highway, has a higher topography, and has denser trees, making more bird species present in the Ratu Boko Temple area with a positive NDSI value above one. This acoustic index analysis helps describe the scenery from the sounds of complex landscapes and can be related to the composition of animals that live in that environment.

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