BIODIVERSITAS
Volume 25, Number 1, January 2024
Pages: 186-196

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d250121

Understanding the impact of munia birds (Aves: Passeriformes: Estrildidae) on rice farming: Behavior, distribution, and bioacoustic parameters

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Manuscript received: 6 November 2023. Revision accepted: 21 January 2024.

Abstract. *Kurnianto AS, Dewi N, Haryadi NT, Arma WA, Maulana R, Sari YH, Hamidah W, Magvira NL, Kadafi AM. 2024. Understanding the impact of munia birds (Aves: Passeriformes: Estrildidae) on rice farming: Behavior, distribution, and bioacoustic parameters. Biodiversitas 25: 186-196.* Munia birds represent a significant challenge in rice farming. This study investigates the role of Munia birds (Aves: Passeriformes: Estrildidae) within rice agroecosystems. Utilizing point count observation methods in Desa Rowosari, Jember, across two farming models (organic and conventional), we assessed the behavior, population distribution, and bioacoustic parameters of Munia species. A total of 3820 Munia individuals were documented: 2187 Javan Munia (*Lonchura leucogastroides* Moore, 1858), 1214 Scaly-breasted Munia (*Lonchura punctulate* Linnaeus, 1758), and 419 White-capped Munia (*Lonchura ferruginosa* Sparrman, 1789). Bioacoustic recordings were conducted using the TASCAM DR 60D recorder, complemented by statistical tests in SPSS 16.0 and visual data representations via Matplotlib and Seaborn libraries. Findings revealed that Munias inflict damages ranging from 10.85% to 30% on rice crops. Notably, JM's bioacoustic bandwidth displayed adaptability between organic and conventional cultivation environments (P value=0.0129). In terms of population distribution, SbM has the highest population density on conventional (density=22.38), JM has the highest density on organic (density-32.55). Passing through activity is more observed in both types of organic and conventional management models. Scaly-breasted Munia dominates in three time groups, both in the morning ($\bar{x}$ = 224.75), mid day ($\bar{x}$ = 163.75), and afternoon ($\bar{x}$ = 198.25). However, PCA depiction indicates that the activity of passing through is dominated by JM. JM and SbM are depicted gathering in the center, indicating a similar average relationship between populations. While Munias pose potential threats as pests, their absence could surge insect populations, underscoring their ecological significance. This study accentuates the importance of an informed management strategy, considering Munia's multifaceted impact on agroecosystems.

Keywords: Bioacoustic parameters, management strategy, munia behavior, point count, population distribution

Abbreviations : JM: Javan Munia; SbM: Scaly-breasted Munia; WcM: White-capped Munia

INTRODUCTION

Munia birds, belonging to the Estrildidae family and classified under the Passeriformes order, represent a significant challenge in agricultural ecosystems, particularly in rice farming (Ranjith et al. 2023). These birds exhibit a unique duality as both agricultural pests and natural predators, adding a layer of complexity to their impact in these environments. The extent of damage they inflict on rice crops. Noteworthy, Sayuthi et al. (2020) reported losses ranging from 10.85% to 30% in each planting season. This considerable impact on crop yields underscores the urgent need for effective management strategies to mitigate their effects. Munias primarily feed on seeds and insects, making rice fields an ideal habitat for them. Their feeding activities start at the planting of rice seedlings and continue until harvest, leading to substantial losses in yield, damage to plant stems, and shedding of unripe grains (Pramudihasan et al. 2019; Dwijayanti et al. 2021). The significance of Munias as agricultural pests in rice cultivation has been highlighted by Dwijayanti et al. (2021), emphasizing the necessity for more efficient pest control methods. The intelligence and adaptability of these birds pose a significant challenge in their management. As Emery (2016) suggested, Munias have cognitive abilities comparable to mammals, enabling them to adapt to various environmental changes and control strategies. This adaptability underscores the need for more advanced and nuanced management approaches.

The dynamics of Munia populations in agricultural settings are influenced by various factors, including trophic interactions, microclimatic conditions, and human agricultural practices. These elements contribute to the variability in Munia population dynamics across different planting seasons. The behavioral patterns of Munias, especially concerning their intelligence and adaptability, are subjects of several scientific research (Pandian 2021; Kumar et al. 2023). Studies by several authors explore these aspects, yet much remains to be discovered about these intriguing birds (Fawcett et al. 2014; Weiss et al. 2014; Suzuki et al. 2016; He et al. 2019).

Researchers have been studying bird behavior dynamics using various methods, including population dynamics (Rushing et al. 2016), ecosystem dependency (Herrando et al. 2016), and vocalization patterns (Wimmer et al. 2013). A focus on Munia vocalizations aims to understand their communication for developing better management strategies, particularly concerning Munia predation on rice crops. The objective is to analyze Munia interactions in rice agroecosystems and their vocal communication patterns. This research is vital for reducing agricultural losses and promoting sustainable practices and wildlife conservation, striking a balance between the economic needs of farmers and the ecological importance of Munia birds. Understanding the impact of Munias on rice cultivation requires a multidisciplinary approach, encompassing biology, ecology, and agricultural science. Studying their behavior, including feeding, reproduction, and community dynamics, is essential for developing effective control strategies. Examining the environmental impacts on Munia populations helps to understand their response to agricultural practices, aiding in creating sustainable interventions. This research can be foundational in mitigating the negative impacts of Munias on rice cultivation and enhances our overall understanding of ecosystem dynamics, contributing to broader ecological research and conservation efforts.

MATERIALS AND METHODS

Study area

To observe Munia preferences covering and contrasting different rice management techniques, two management models were selected: organic and conventional. Both locations are 700 meters apart. The organic field has received certification from the Seloliman Organic Certification Institute (LeSOS) with certificate number 379-LSO-005-IDN-20 since November 15, 2015, and uses the Ciherang variety (70 Days After Planting (DAP)). The conventional field also uses the Ciherang variety (80 HST) and is managed with additional chemical inputs: Urea (200 kg/Ha, at 20 and 30 HST plant age), KCL (100 kg/Ha, at 30 HST plant age) and SP.36 (100 kg/Ha, 7 days before planting). The pesticide used by farmers is one with the active ingredient Isoprocarb under the trade name (Mipcinta 50 WP), at doses ranging from 0.5-4 kg/Ha depending on the level/intensity of pest attacks on the rice plants. This research was conducted in Desa Rowosari, Jember. Behavioral observation and bioacoustic recordings were carried out at the same point. There were three observation area spaced 500 meters apart, with five distinct repetition points 100 meters apart, arranged using the Point Count method (Figures 1 and 2; Bayne et al. 2016). Representative point placements were determined in a preliminary study.

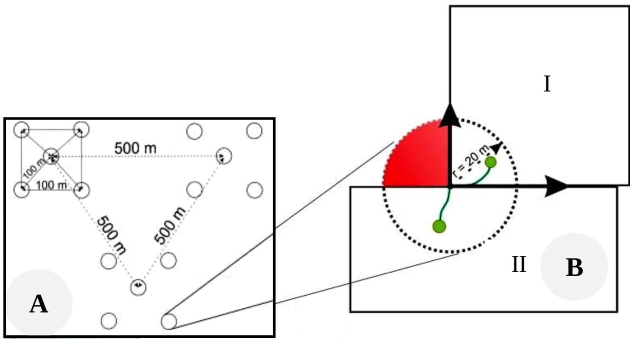

Figure 2. A. Placements of the three observation locations repeated five times. B. A schematic of the Point Count method facing two agroecosystems (I and II). In Figure B, the green line represents microphone placement; the red area indicates regions without an agroecosystem or unobserved areas; the dashed black line denotes the observation radius; and the black arrow indicates the cardinal direction

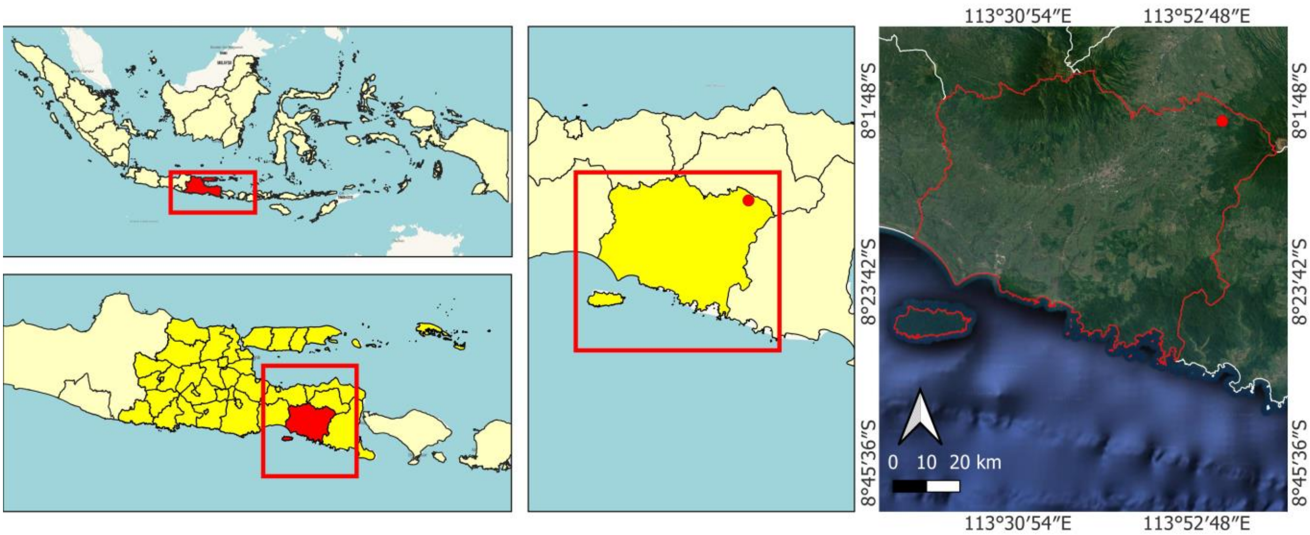

Figure 1. Depicts the research map and layout. A map showing the research location in Jember, East Java, Indonesia

The initial data collection involves counting the population of birds engaging in visitation activities in the observation area using the Point Count method. This method is employed to determine the overall number of pest birds visiting the field at each sample point. Two observers are stationed in the observation area. Observer 1 uses binoculars to observe birds perched or in motion within the observation area in a clockwise direction. Observer 2 is responsible for recording all birds with the naked eye. At the end of the observation, the number of individuals is recapitulated, where birds flying to the left before being observed by Observer 1 will be added, and those flying to the right of Observer 1 will be subtracted.

Procedures

Three types of Munia are commonly found in Java and play significant roles in attacks on rice agriculture: Javan Munia (*Lonchura leucogastroides* Moore, 1858 code=JM), Scaly-breasted Munia (*Lonchura punctulate* Linnaeus, 1758 code=SbM), and White-capped Munia (*Lonchura maja* Linnaeus, 1766 code=WcM) (Kurnianto and Kurniawan 2013). Each behavior was observed using NIKON ACULON A2117x50 binoculars. Behavior classifications were grouped into: foraging (FR) and passing through (PT). Passing through behavior is a bird that moves within the radius of the observation plot and Foraging is a bird that perches or eats grains of rice in the observation area. Each observation point was monitored for 10 minutes. To provide a preference overview regarding time, the three species were observed during three-time slots: morning (06.00-08.00 AM), mid day (11.00-01.00 PM), and mid day (03.00-05.00 PM). To support behavioral record explanations, light intensity was recorded using the Luxmeter Lutron LX-107, while temperature and humidity were measured using the Higrometer UNI-T UT3333. Environmental physical factor measurements were taken in three locations for each management type to ascertain their averages (Table 1). The organic field has a denser vegetation component and its location at the foot of a mountain results in lower light intensity and higher humidity compared to the conventional field.

Bioacoustic sampling was conducted integrating digital camera systems and recorders. The TASCAM DR 60D recorder, combined with a Parabolic microphone X8, was used to capture bird sounds from a distance. Recording commenced when the focal subject (sf) opened its beak. The session ended when the sf flew away or ceased vocalizing for 20 seconds. If the sf resumed vocalization after a 20-second silence, calls were recorded as a new session (Kondo et al. 2010). The period/inter-call interval was measured based on the duration between the end of the first call and the commencement of the second, while duration was gauged by the difference between a vocal's start and finish. Bandwidth represented the difference between the highest and lowest frequencies (Figure 3). Each call's occurrence was visualized as amplitude rises and falls (120 mV), sequentially, using RAVEN LITE 2.0 (Coffey et al. 2019).

Data analysis

The Shapiro-Wilk normality test was employed to compare the population distributions of each sample acquired from the two locations. The entire sample population inter-call was also compared between the two behavioral classifications and tested using the non-parametric Mann-Whitney U test. All these statistical tests were executed using SPSS 16.0 (Nordstokke et al. 2011). Graphs like the Principal Component Analysis (PCA; the input is data on individual records classified into species and behavior, as well as bioacoustic parameters), Heat MAP, Bar Chart, and Boxplot were created using the Matplotlib and Seaborn libraries (Lemenkova 2020) to portray the preventive behavior against biplot parameters.

Table 1. Presents the average observations of environmental physical factors, detailing the observation point, light intensity, temperature, and humidity for both conventional and organic management types

Location	Observation points	Light intensity (Lux)	T (ºC)	Humidity (%)
Conventional	1	70177.8	28.7	71.6
	2	64622.2	28.7	70.1
	3	89466.7	29.2	71.3
Organic	1	73289.2	29.6	50.8
	2	128041.7	29.0	54.6
	3	142883.3	29.5	53.3

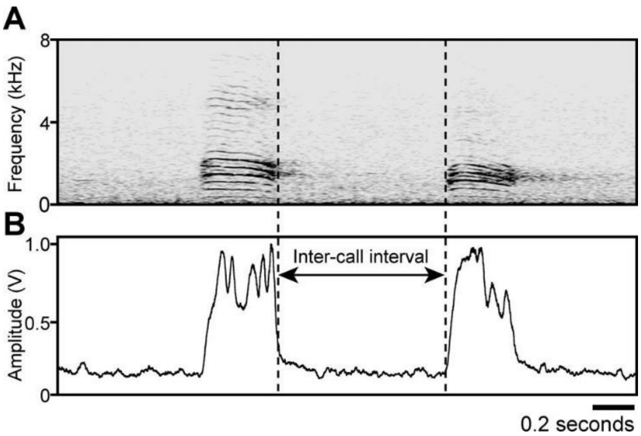

Figure 3. A. Provides an example of a sonogram visualization output. B. envelope curve that recorded two focal subjects (sf). The inter-call interval is the silent period between the first call and the commencement of the second call by a different individual indicated by arrows (Kondo et al. 2010)

RESULTS AND DISCUSSION

Bioaccoustic parameters

A total of 3820 Munia individuals were observed, comprising 2187 JM, 1214 SbM, and 419 WcM. The conventional region had a recording duration of 1596 seconds, while the organic region had 1049 seconds. Differential analysis results indicated that only JM's Bandwidth displayed significant differences (P Value = 0.0129) between organic and conventional farming. Neither the species nor other parameters showcased any significant variations (Table 2). Data distribution revealed that bandwidth records in conventional areas were lower than in organic regions (Figure 4). There exists evidence of bandwidth development in Munias occurring under different environmental conditions. However, there is no development of other vocal morphologies, especially regarding period and call duration.

Bandwidth describes the average magnitude of sound in species specifically. This indicates that there are differences in behavior, up to the suspected physiological differences that occur in 2 different management locations. Foraging activity in SbM has a significant difference in the Conventional Zone (Figure 5). The length of the Call Duration and period has a stronger impact on the SbM species. SbM notes with foraging behavior are more widely distributed and are supported by the Bandwidth biplot formation. Foraging SbM provides a larger overview of bioacoustic parameters, more than passing through behavior. Other species or behaviors do not show significant visualization differences in PCA. Only JM with Foraging behavior is slightly wider, indicating the magnitude of the attachment of these data to bioacoustic parameters.

The management of agroecosystems does not significantly differentiate the vocalization forms in all types of munia, except for the Bandwidth in Javan Munia. This highlights the potential effectiveness of specific sound interception in controlling bird pests that use call duration or periods specifically. The lack of strong evidence of differences between the two locations suggests that vocal interception can be widely used. Other studies have shown that the use of vocal interception has significantly influenced the scope of communication disturbances in birds (Lazerte et al. 2016). Specifically, bird grouping activity has resulted in communication complexity that remains uniform within an agroecosystem. The bandwidth difference in JM once again illustrates the potential adaptation of this species to a new environment. Bandwidth differences, although not fully depicting the potential differences in vocal morphology, can illustrate communication adaptation. Bandwidth, in communication, is essential for recognizing threats or revealing different potentials in different ecosystems toward animal communities (Luther et al. 2016; Robert et al. 2021).

Table 2. Differences between each species at 2 different locations (organic and conventional rice fields). The test difference used the Mann-Whitney U (*significantly different)

Species	Call duration	Period	Mode/bandwith
JM	U = 134, P Value = 0.9575	U = 140, P Value = 0.7899	U = 61.5, P Value = 0.0129*
SbM	U = 290, P Value = 0.4615	U = 283, P Value = 0.5619	U = 169.5, P Value = 0.0536
WhM	U = 26, P Value = 0.2403	U = 23, P Value = 0.4848	U = 7, P Value = 0.0931

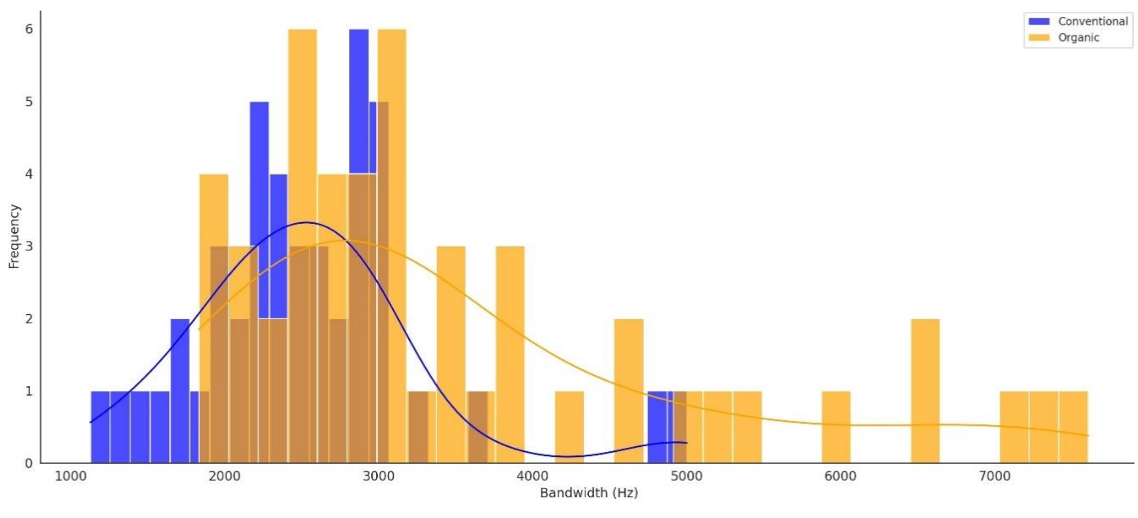

Figure 4. Data distribution of JM Bandwidth at two locations

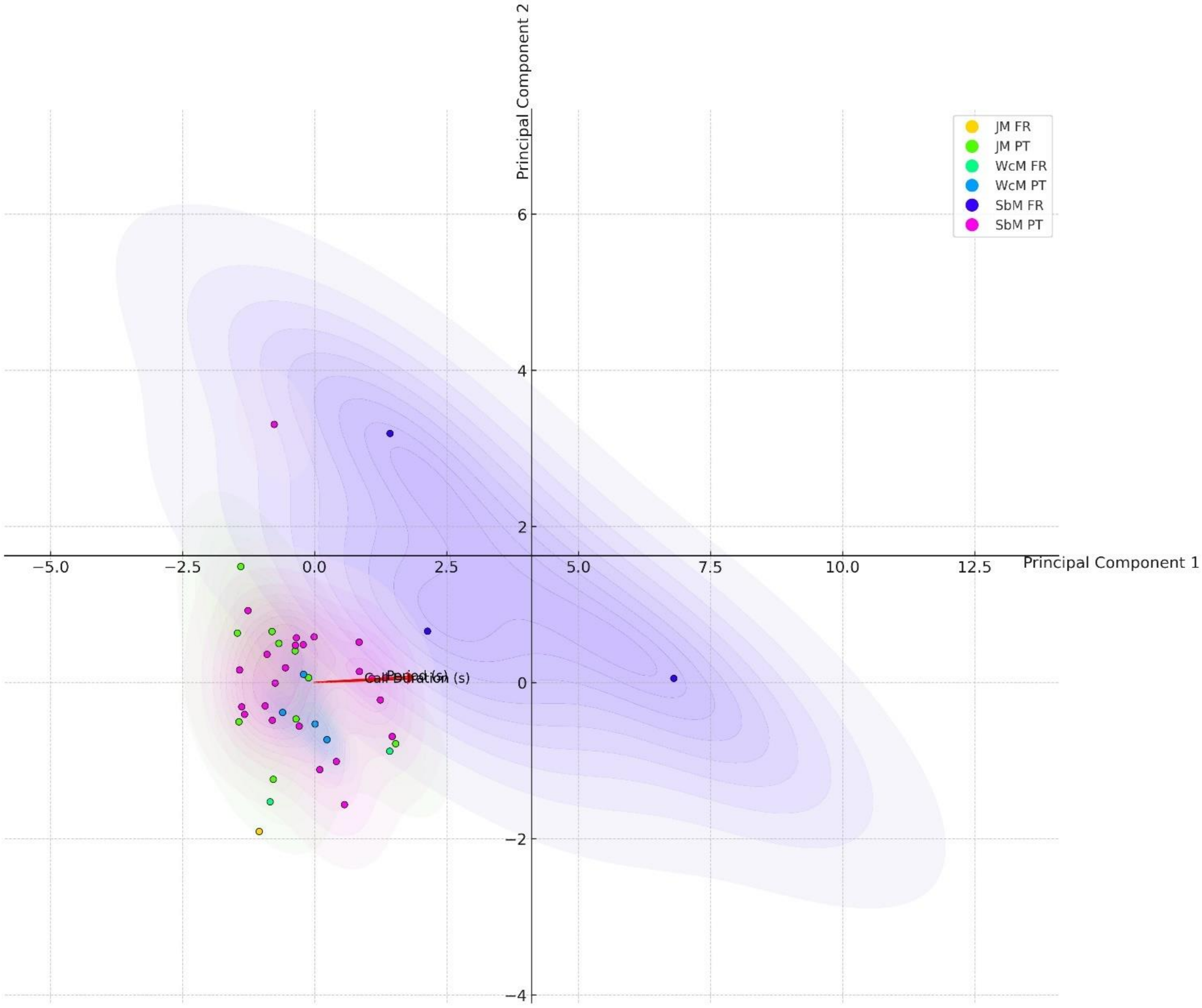

Figure 5. PCA chart by KDE (Kernel Density Estimation) color with species and behavior grouping preferences, and a bioacoustic parameter biplot for findings in the Conventional Area

In organic farming, it is known that the data distribution is more complex and mixed. JM becomes a dominant species that comes out of its group compared to other species groups (Figure 6). However, foraging behavior in JM shows more differences than passing through behavior. The same is also shown by the dominance of Foraging behavior data records in SbM. Both species have a small preference for bioacoustic parameters.

Complexity of population

The behavioral analysis results show significant differences in visits shown by each species. Passing through activity is more observed in both types of organic and conventional management models (Table 3). This activity is crucial to show the secondary interaction of munia towards a holistic rice agroecosystem. Munia concentrates a lot in area 1 (Figures 6 and 7), with higher edge vegetation density compared to other areas. Vegetation density affects the shade of the place, which is proven by the average measurement results of environmental physical factors. This proves that there is greater potential for damage to the rice field edges than the middle part. The difference in Scaly-breasted Munia visits is more concentrated in Area 1, while in area 2, Javan Munia. Statistically, WcM shows all significant differences in findings in the conventional area, except for no significant difference between areas 1 and 3. This happens because the population observation results have similarities with a large number in both species (SbM and JM). Area 1 in conventional land shows the highest population density compared to areas 1 and 3 in SbM, while JM follows after (Figure 7). This is because area 2 has a shady environment, allowing each species to visit area 2 (Table 1). Munia tends to prefer rice planting land that has shady or not too hot conditions, and bird species will come in groups because there are several types of trees in the observation area that have a wide canopy shape, such as *L. leucocephala* trees, which can be used by Munia to perch. An environment that is shady or not hot also allows Munia to rest.

Table 3. Mean and standard deviation of foraging and passing through behaviors in conventional and organic management

Type	Behavior	Area	JM mean	JM std	SbM mean	SbM std	WcM mean	WcM std
Conventional	Foraging	1	3.5	2.73	9	6.61	0.75	1.75
		2	4.25	5.31	1.25	0.89	0.75	1.16
		3	3.62	3.38	3.75	4.5	0	0
	Passing through	1	28.25	10.11	35.75	17.04	8.12	5.94
		2	34.38	16.67	37.12	13.39	7.5	6.02
		3	20.88	8.97	25.38	12.06	9.5	4.66
Organic	Foraging	1	22	13.31	7.62	7.54	7.5	4.24
		2	16.25	10.74	2.5	2.2	5.62	4.37
		3	12.75	9.53	3.5	4.24	6.75	7.83
	Passing through	1	41.62	13.64	10.75	16.12	2.75	3.2
		2	48.75	23.21	9.62	4.98	1.75	2.43
		3	37.12	20.36	5.5	4.87	1.38	2.33

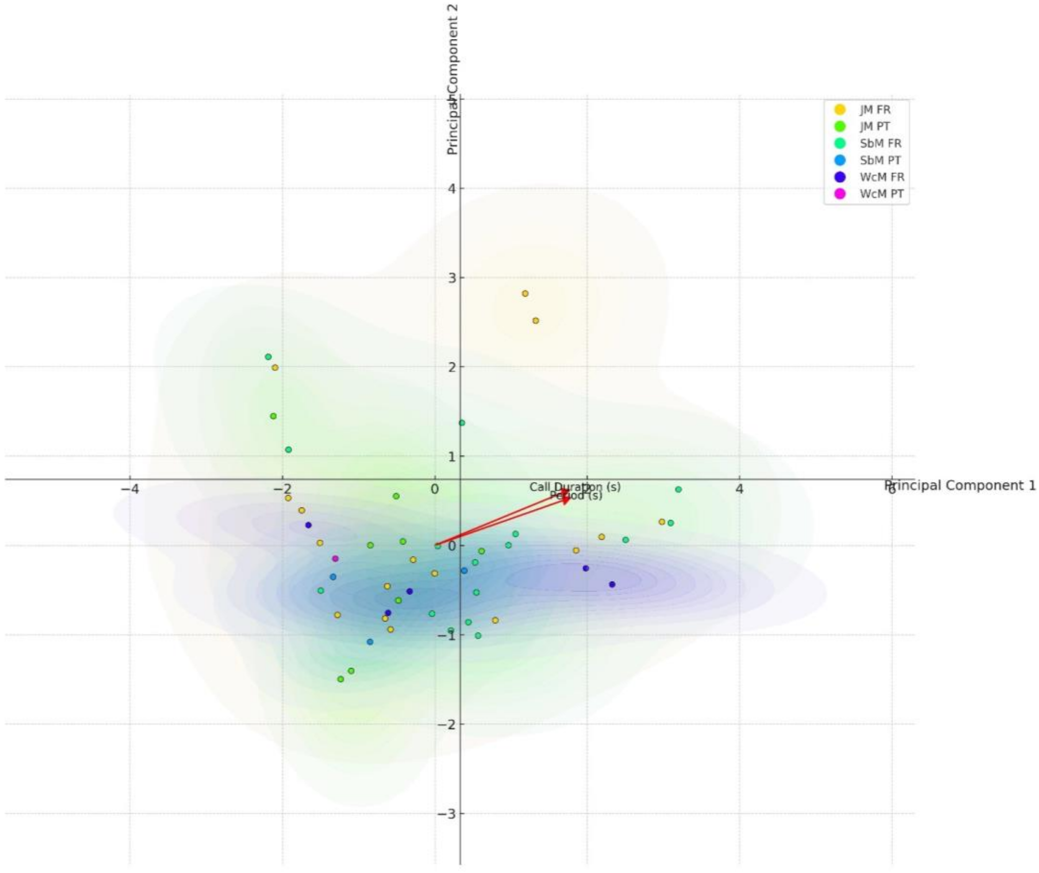

Figure 6. PCA chart by KDE color with species and behavior grouping preferences, and a bioacoustic parameter biplot for findings in the organic field

Area 2 in the Organic land of Rowosari shows the highest population density compared to areas 1 and 3 for the Javan-Munia species, while the Scaly-Breasted Munia and White-Headed Munia are found in area 1 (Figure 8). This is because area 2 has fairly shaded conditions along its edges. Meanwhile, area 1 has many fern-type plants that Munia can use to perch or roost.

The dynamics of the findings are illustrated by their attraction to environments that support life, holistically. The density of population records in shaded areas provides evidence that the potential destruction due to Munia is located in shaded areas, undisturbed by direct sunlight. We observed vegetation impacting bird presence, as has been evidenced in previous research. Birds are attracted to the availability of food, shelter, perching sites, and various vegetation benefits to sustain reproductive behavior (Narango et al. 2017; Jones 2018). Agricultural land with a complete vegetation structure, especially trees with canopies like woody plants, sugarcane, and bamboo, will have an abundance of bird species. In area 3, there are not many trees. A lack of trees and other vegetation will have a degradative impact on perching bird populations (Blinkova and Shupova 2017).

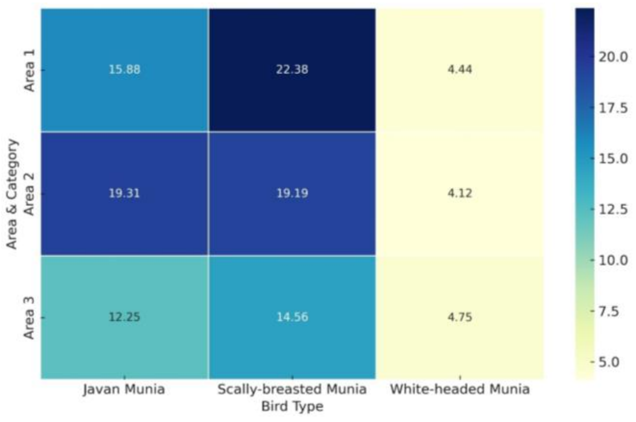

Figure 7. Average heatmap visit of munia in conventional land. The numbers inside the colored boxes represent population density, and gradient of color represents density values from small (lighter) to large (darker)

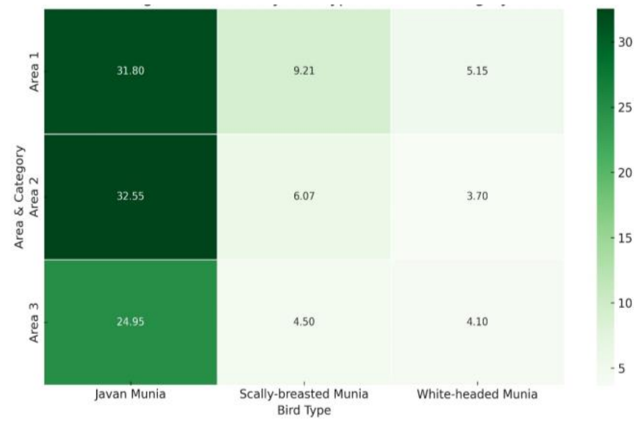

Figure 8. Average heat map visit of munia in organic land. The numbers inside the colored boxes represent population density, and gradient of color represents density values from small (lighter) to large (darker)

Time

Observations of 3 times show significant differences in notes in each time group. Scaly-breasted Munia dominates in three time groups, indicating the highest potential visit by this species throughout the day, both in the morning ($\bar{x}$= 224.75), mid day ($\bar{x}$=163.75), and afternoon ($\bar{x}$=198.25) (Figure 9). Javan Munia, although in total its population is not more than ScM, has a huge potential to attack rice plant populations significantly. This also affects the potential level of plant destruction due to its foraging activity (Figure 10). Javan Munia gives a fairly high population overview in three time sessions, even though SbM is significantly higher. WcM is a visitor with a low population at all times ($\bar{x}$=53.58), indicating its low potential for destruction in the rice area. Diurnal birds exhibit behaviors that show a preference for higher humidity, which varies among species, and for moderate light intensity. Therefore, most diurnal birds are highly active in the morning and evening, as observed in all three species. This pattern has led bird observation methods to focus on these two times as the most optimal for watching birds (Rohman et al. 2020).

Qualitatively, the PCA depiction indicates that the activity of passing through is dominated by JM (red area of Figure 10). The SbM population has records with a highly variable range, and tends to merge with the WcM population. JM moves away from WcM and SbM, which are separated into groups with a small population count. This suggests that the mobilization of Javan Munia is very high, and is quite different from WcM.

However, during foraging activity, the JM and SbM groups are depicted gathering in the center, indicating a similar average relationship between populations and lower than the passing through behavior. The potential for damage is built up by SbM and JM, which have a larger group size. This size is built by larger individual records compared to WcM (Figure 11). Munia's behavior reveals a new fact that the actual foraging is smaller compared to passing through activity, which is a new insight, showing that not all the presence of munia in rice agroecosystems potentially leads to direct destruction. Munia's interest is more depicted towards rice agroecosystems, and not just the presence of grains

Qualitatively, the PCA depiction indicates that the temporal distribution is dominated by the Javan Munia population, both in the morning, mid day, and the following afternoon, followed by the Scaly-Breasted Munia population which has records over a variable range (Figure 12). The Javan Munia and scaly-breasted munia species move away from WcM, which is separated into groups with a smaller population. This suggests that the mobilization of Javan Munia and SbM is evenly distributed in the morning, midday, and afternoon, which is different from the WcM population that is separate from these three time periods.

Microclimate is directly influenced by vegetation conditions in an ecosystem. Temperature affects daily activities because birds have a thermoregulatory system, where bird resting behavior increases as the temperature in rice planting habitats also rises (Clement and Castleberry 2013; Pérez-Ordonez et al. 2022). Birds do not develop a complex heat disposal system like humans. They use throat holes to slowly release body heat. This is one of the reasons for the minimal bird activity in areas that are hot and directly exposed to sunlight (Czenze et al. 2020). Physiological differences in Munia will affect the abundance of Munia species, where trophic mismatches are the primary cause of Munia species population dynamics (Etterson et al. 2017; Pejchar et al. 2018).

On average, JM is the most frequently encountered bird in all land types. This is influenced by gaps in vegetation structure complexity and canopy cover stratification (Subasinghe et al. 2014; Blinkova and Shupova 2017; Hakim et al. 2020). Some plants, like bamboo, whose leaves or branches can be used as materials for bird nest construction (Kurnianto and Kurniawan 2013).

Javan Munia has a high adaptability to various habitats, where they are more active in foraging compared to other species (Bari et al. 2021). JM's adaptation to a wide temporal preference also increases its potential for destruction. Most birds prefer activity times in the morning or afternoon (Frątczak et al. 2020). However, once again, the adaptive ability of birds, like JM, has provided a complete picture of how species have an incredible adaptation rate, adjusting between life needs and the existence of available resources. JM has evolved from an endangered endemic species due to its degraded habitat (Harris et al. 2014; Ramesh et al. 2017; Vale et al. 2018), to an adaptive species using various urban materials as nests (Kurnianto and Kurniawan 2013), and evidence of a broader temporal range and point. Javan Munia is typically found in pairs or small groups, or sometimes found mingling with other munia species like SbM. Munia groups only consist of a few individuals, but as harvest season approaches, these groups can consist of hundreds of individuals (Dwijayanti et al. 2021). WcM might follow some members of Ploceidae, like the Streaked Weaver (*Ploceus manyar* Horsfield, 1821) and (*Ploceus hypoxanthus* Sparrman, 1788), which historically have attacked rice in large waves. However, both are under threat due to hunting for songbirds (Iskandar et al. 2016).

The ambiguity of munia's presence in agroecosystems becomes clearer. Passing through activity, much larger than Foraging, is tangible evidence that the connection of munia lies in agroecosystems, not in the existence of grain as food. The presence of munia not only plays a significant role as pests but also has a potential impact on the collapse of the ecosystem's trophic structure. A drastic decline in munia populations will increase the potential for herbivorous insects, which also serve as bird food (Railsback and Johnson 2014; Milligan et al. 2016; García et al. 2018; Affandi 2023). This indicates that munia attacks can be anticipated by reducing edge vegetation, which besides disturbing rice physiology, also provides enough sunlight to block the interaction between munia and rice.

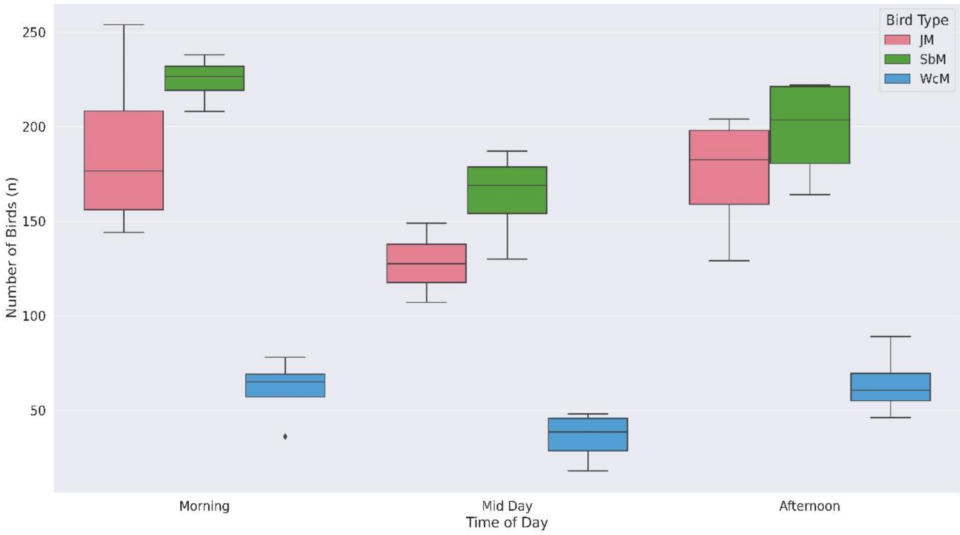

Figure 9. Temporal distribution of munia (Total number of birds) Across three time groups. See methods for details

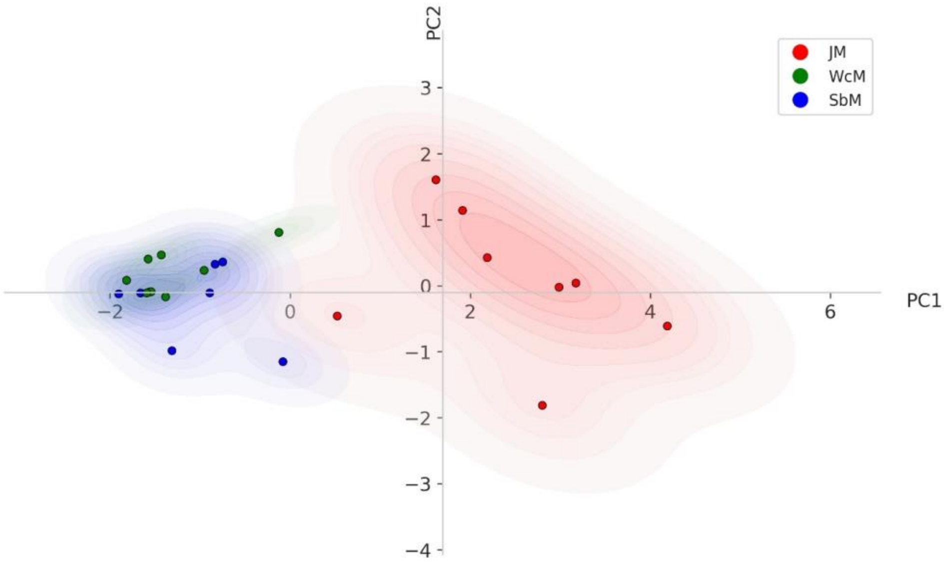

Figure 10. PCA analysis chart of passing through munia

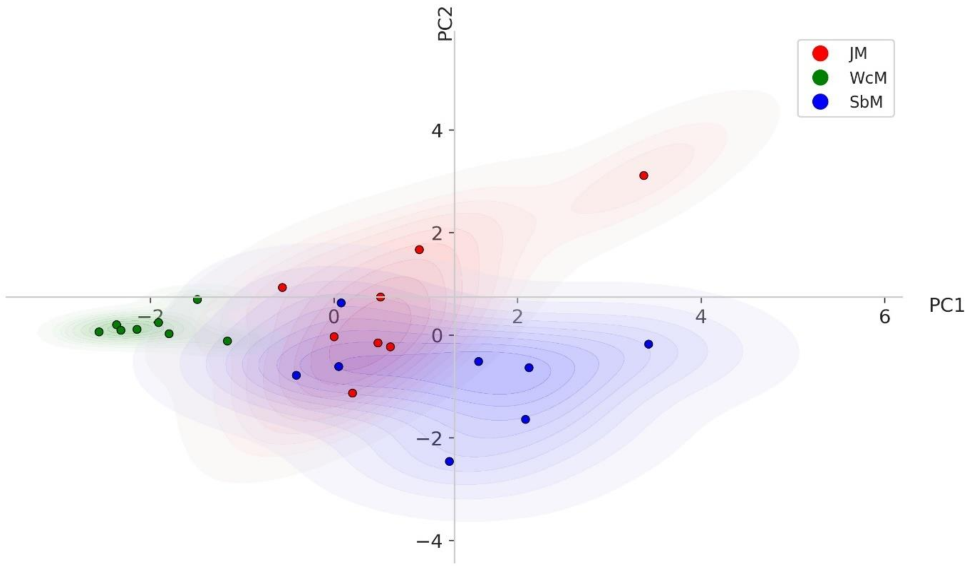

Figure 11. PCA analysis chart of foraging munia

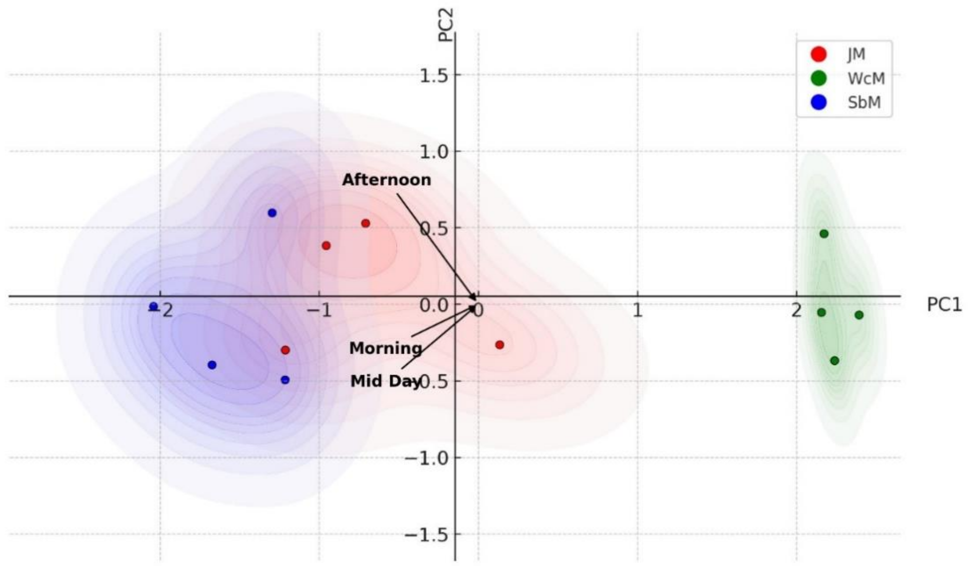

Figure 12. PCA analysis chart of temporal distribution of munia

In conclusion, munia's presence on land tends to be destructive, but Munia's intelligence and adaptability make them difficult to control in this ecosystem. Furthermore, JM bandwidth, which is a critical aspect of their communication, has shown adaptability to different environmental conditions. Notably, the Javan Munia (JM) species exhibit high adaptability across various habitats, displaying an expansive temporal preference and significant potential for crop destruction. Research shows that the damage potential of SbM and JM is higher compared to WcM. The mobilization of Munia Jawa and SbM is evenly distributed in the morning, midday, and afternoon, in contrast to the number of WcM residents who are separated in these three time periods. Thus, the relationship between munia and rice agroecosystems is complex. The birds' interactions with the environment, including their preference for shaded areas, could provide insights into how to manage their impact. In sum, while Munia can pose threats as pests, they also play a vital role in the trophic dynamics of the ecosystem, and their complete removal might have unintended consequences.

ACKNOWLEDGEMENTS

The author would like to thank Rudi (Tani Jaya II Farmer Group) Sumberjambe for granting research permission. The author also expresses gratitude to LPPM

Universitas Jember, Indonesia for the *Penelitan Dosen Pemula* Grant (Grant No: 023.17.2.677562/2023). The author is also thankful for the assistance of Fadlul Laili, Dea Ayu, and the 2023 Proposal group who have supported this research in the field.

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