RICE FIELDS AS SURROGATE WETLANDS: AVIAN DIVERSITY AND CONSERVATION INSIGHTS FROM NORTH SULAWESI, INDONESIA

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Abstract. The bird species diversity in Sulawesi Island includes both native and introduced species. One type of bird habitat found on Sulawesi is rice paddies. These areas provide habitat due to the abundant food resources in rice paddy ecosystems. In this ecosystem, rice cultivation has several distinct phases: land preparation, planting, vegetative, mature generative (ready-to-harvest) and post-harvest. The study categorized bird species observed during various rice planting stages to collect biodiversity index data. We identified 33 bird species in the rice paddy ecosystem of North Minahasa Regency, North Sulawesi, Indonesia. These species represent various bird families, including Passeridae, Estrildidae, Pycnonotidae, Columbidae, Alcedinidae, Apodidae, Accipitridae, Ardeidae, Rallidae, Scolopacidae, Corvidae, and Phasianidae. The results obtained through analysis with PAST produced a Shannon Index of 2.384, which concluded that the diversity of bird species visiting rice fields in North Minahasa Regency, North Sulawesi, Indonesia was included in the moderate category.
Keywords: *biodiversity, bird, North Minahasa, rice cultivation, Shannon index*

Introduction

Sulawesi, the largest island in the Wallacea region, is known for its rich biodiversity, particularly in birds, with many endemic species (Arini et al., 2023; Winarni et al., 2023). However, much of the island's natural wetlands have been degraded or converted for agriculture, making rice fields an increasingly important habitat for a variety of bird species. Rice fields, although managed for agriculture, serve as wetlands, offering food and shelter for birds (Zhang et al., 2021; Gleditsch et al., 2022). For certain places such as in various habitat types in Likupang SEZ, North Sulawesi. They found 69 bird species from 35 families and 3 bird species from 2 families that are found outside the location and observation hours (Migael et al., 2025). Meanwhile, in September 2022, observations made on the shores of Lake Linow found 45 species of birds from 20 families, including endangered bird species (Umbas et al., 2023). Sulawesi and several nearby islands are the largest contributors to endemic bird species in Indonesia, to be precise, 366 out of 510 species or 70.1% (Prawiradilaga, 2020). Some differences in numbers occur due to differences in species definitions or new discoveries or the emergence of introduced species.

The high diversity of bird species on Sulawesi Island is partly due to the variety of habitat types for birds. Birds have maintained a long-standing relationship with humans, serving important ecological functions such as seed dispersal and pollination. Beyond their ecological roles, birds are also valued as food sources, kept as pets, and hold significant cultural meaning in many societies (Rumanasari et al., 2017). One type of bird

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habitat is rice fields, which provide essential resources such as food and nesting areas across different growth phases. Similarly, recent research on butterfly diversity in North Sulawesi by Koneri et al. (2022) found that habitat heterogeneity—such as that found in agroforestry and riparian zones—supports high species richness. These parallels underscore how semi-managed landscapes like rice fields can function as important biodiversity reservoirs for multiple taxa, including birds and insects. Data from the Central Statistics Agency of North Sulawesi Province in 2023 stated that there were 13,939 irrigated rice fields spread across North Sulawesi (BPS Provinsi Sulawesi Utara, 2023). Paddy fields are land that is specifically used for rice farming activities. The use of this land can be made intensively throughout the year, where rice is the main crop that is planted sustainably. In addition, in some cases, paddy fields are also used in turns by planting other types of crops, such as secondary crops (Syachroni, 2020). Crop rotation in rice fields is an important method often applied by farmers to maintain soil fertility, prevent quality degradation due to continuous planting, and reduce the risk of pests and plant diseases (Suprihatin et al., 2021). In Southeast Asia by alternating the types of crops planted, this system helps maintain the balance of nutrients in the soil while maximizing land productivity. Rice fields themselves have a very vital role in meeting the food needs of the community, especially in areas that rely on rice as the main staple food. Rice fields are essential for rice production. Sustainable practices like crop rotation are crucial for maintaining optimal yields and ensuring food security (Sari et al., 2024). The term "paddy field" refers to land used for rice cultivation, not a formal soil taxonomy, but a general term in agriculture. Land use categories encompass various types, including forest land dominated by natural vegetation, plantation land used for commercial crops such as oil palm and rubber, and agricultural land designated for diverse farming activities (Jayathilake et al., 2023). Therefore, the term "paddy field" refers more to land use or functional classification than scientific categorization (Syachroni, 2020).

Rice fields, though primarily managed for rice production, play a crucial ecological role akin to natural wetlands, especially as habitats for birds. Rice fields provide vital resources such as insects, seeds, and aquatic organisms, supporting a range of bird species, including those of conservation concern. As natural wetlands are rapidly disappearing, rice fields have become critical for sustaining biodiversity, particularly for migratory and endemic bird species. These fields not only provide food resources such as insects, seeds, and aquatic organisms but also serve as temporary shelters and breeding sites for various species, especially during the wet phase of the cultivation cycle (Lukanov et al., 2023; Propper et al., 2023). As such, rice fields contribute significantly to local biodiversity (Rahmawasiah and Arnama, 2025), especially in regions where natural wetlands are declining. In North Sulawesi, where agricultural expansion has degraded natural wetland habitats, rice fields now serve as vital refuges for bird species. These fields not only support the diversity of avian species but also provide critical ecosystem services that contribute to the sustainability of local agriculture and biodiversity. Building on previous studies, this research aims to highlight the crucial role of rice fields in maintaining biodiversity, particularly for bird species, and provide new insights for effective conservation strategies. Extensive surveys across Peninsular Malaysia have demonstrated that rice fields support a substantial number of bird species, including both resident and migratory waterbirds, underscoring their ecological importance as alternative wetland habitats (Azman et al., 2019). Meanwhile Agroecological rice field management has been shown to enhance functional diversity and attract a wider range of avian species compared to conventional systems, as observed in Argentina (Lorenzón et al., 2020).

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As an ecosystem, rice fields are a habitat that has various biotic and abiotic factors that support the lives of many species of living creatures, even though there is a cycle of land cultivation whose main purpose is to be used as agricultural land for rice plants (Pathak et al., 2021; Lukanov et al., 2023). The rice field habitat also supports the life of several types of birds, although they are not birds that live in this habitat, but function more as a location for finding food (Aarif et al., 2025). By seeing that in rice fields there can be phases, namely the land processing phase, planting phase, vegetative phase, mature generative phase (ready to harvest), and post-harvest phase (Nayak et al., 2022; Agung et al., 2024). Each phase has different habitat conditions from other phases, both biotic and abiotic components (Nayak et al., 2022). By looking at the possibilities of each phase that occurs in the morning rice fields, the conditions that occur in the rice fields will cause the emergence of different types of natural food for birds so that there will be different variations of bird species in each phase. This study focuses on observing bird species in rice fields in North Minahasa, aiming to assess their diversity and the role of rice fields as critical habitats. By evaluating bird populations across different rice cultivation phases, the study will provide insights into how these fields contribute to local biodiversity.

By observing birds across various cultivation phases, we aim to identify species patterns and calculate biodiversity indices, providing a comprehensive understanding of the ecological value of rice fields for avian populations. This approach was chosen because each stage of rice field cultivation presents varying habitat conditions, for this reason observations were conducted across all rice field phases (Duan et al., 2025). The final objective of this study is to group the types of birds present in each phase of rice planting to obtain biodiversity index data that can be found.

Methods

Study area

July to October 2024 for 100 days. The research location is in Kalawat District, North Minahasa Regency, North Sulawesi Province, Indonesia. Observation points include two locations.

Location 1 with a radius of 100 m from coordinates 1°28’06.1”N 124°56’07.5”E.

Location 2 with a radius of 100 m from the coordinates 1°28’16.2”N 124°56’11.0”E.

The habitat observed was rice fields with all stages of cultivation, namely land management, planting, vegetative phase, mature generative phase (ready to harvest), and post-harvest.

The geographical position of the study sites in Kalawat District is illustrated in *Figure 1,* which shows the satellite image covering both observation points. Rice cultivation follows several distinct phases, each creating unique habitat conditions that influence the presence and behavior of various bird species. Each of these phases offers different ecological opportunities for birds, with some phases providing essential food sources, while others offer shelter and nesting sites. Understanding the habitat characteristics of each phase is crucial for assessing their role in supporting avian diversity. *Figure 2* illustrates the typical conditions found during the land processing, vegetative, and post-harvest phases of rice field cultivation.

Figure 2 presents the land conditions during different stages of rice cultivation. Panel (a) illustrates the land processing phase, where the field is overgrown with weeds and minimally irrigated, mimicking swamp-like conditions. This environment is conducive to wading birds and species that forage in muddy or weedy areas. Panel (b) represents the

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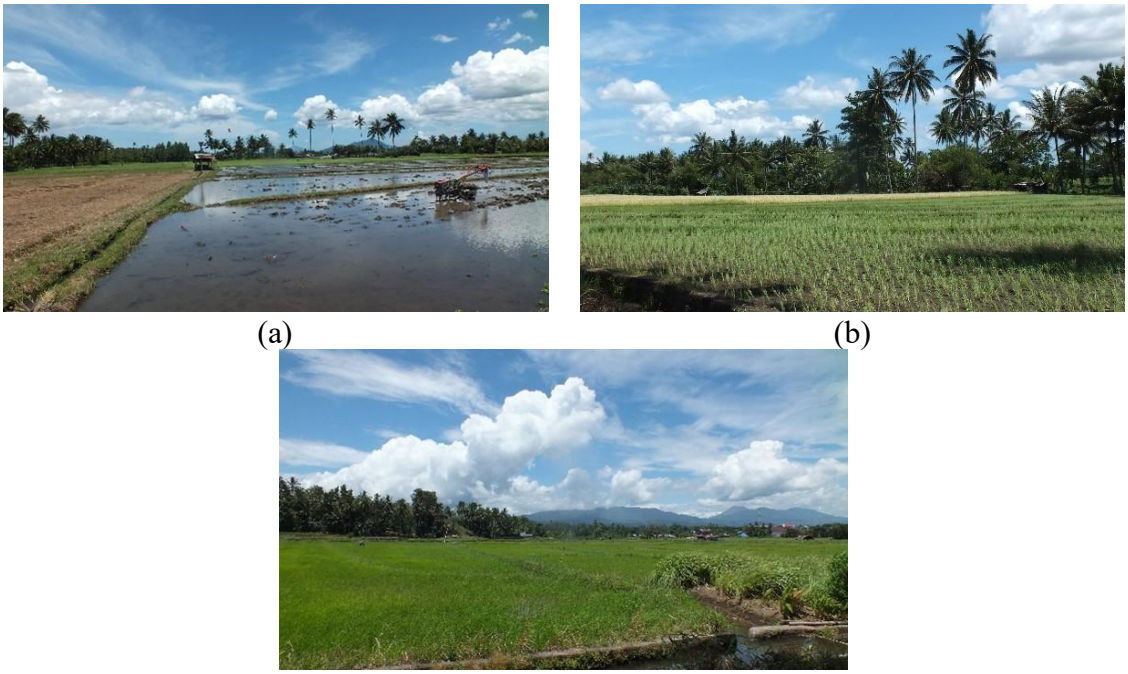
vegetative phase, where the rice plants are well-established, and the field is often flooded. This stage supports a variety of insectivorous species, as the vegetation provides both shelter and abundant food resources. Finally, panel (c) shows the post-harvest phase, where fields are left bare or sparsely covered with straw, attracting granivorous species that feed on leftover grains. These three phases demonstrate the dynamic nature of rice fields as habitats for diverse bird species, with each phase supporting different ecological niches.

Figure 1. *Satellite image of the research location*



(a) (b)

(c)

Figure 2. *Location condition for each phase: (a) land processing, (b) vegetative, (c) post-harvest*

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Observations were conducted across all stages of rice cultivation, which are crucial to understanding the varying ecological conditions and their impact on bird species. Rice cultivation follows several distinct phases, each creating unique habitat conditions that influence the presence and behavior of various bird species. These phases include land processing, planting, vegetative growth, mature generative (ready-to-harvest), and post-harvest.

From *Figure 3,* the conditions in each phase differ significantly, providing varying resources such as food and shelter for birds. Below are brief descriptions of each phase and its ecological characteristics:

(1) Land processing (July 2024)

During the land processing phase in July 2024, the rice field was in its initial preparation stage, characterized by overgrown weeds and minimal water. The fields had a swamp-like appearance due to limited irrigation. This phase created ideal conditions for wading birds and insectivores, which thrived in the moist, weedy areas. Species such as the Black-winged Stilt and Black-winged Kite were observed, taking advantage of the temporary wetland conditions.

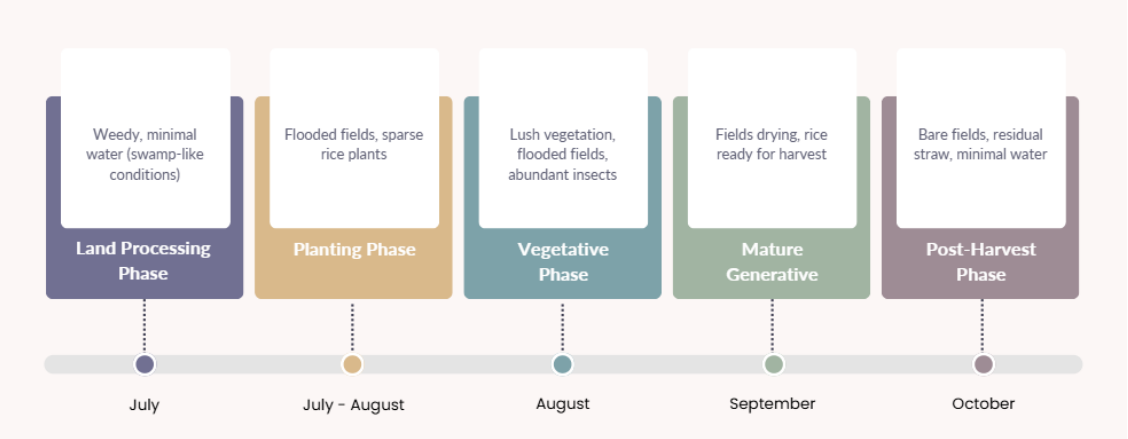

Figure 3. *Timeline and condition for each phase*

(2) Planting phase (July-August 2024)

The planting phase, occurring in late July to early August 2024, involved the sowing of rice seeds in the fields. During this stage, the fields were flooded, but there was still minimal vegetation growth, making it a critical time for aquatic birds and insectivores. The standing water, coupled with the sparse vegetation, provided a rich environment for species such as the Javan Pond Heron and the Chinese Egret. These birds foraged in the shallow water for insects, worms, and small aquatic animals. The combination of water and minimal rice plant cover created an optimal habitat for wading birds during this period.

(3) Vegetative phase (August 2024)

The vegetative phase in August 2024 saw rice plants fully established, with fields often flooded to support the growing crop. The lush vegetation provided cover for insectivores, such as the Olive-backed Sunbird and the Zitting Cisticola, which foraged for insects among the rice plants. This phase supported a significant increase in bird activity due to

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the abundance of both food and shelter. The dense plant cover also provided nesting sites for certain species, adding to the ecological richness of the rice field during this phase.

(4) Mature generative (ready-to-harvest) phase (September 2024)

The mature generative (ready-to-harvest) phase in September 2024 is when the rice plants began to mature, with grains forming and ripening. At this stage, the field was relatively dry, and most of the rice plants were tall and ready for harvesting. This phase provided a different type of habitat compared to the earlier stages, as it was characterized by dry, open fields that attracted species like the Zebra Dove and the Black-winged Kite, which hunted in the open field for smaller prey such as rodents and insects. The reduction in standing water and the abundance of mature rice plants drew granivores and some predatory species, marking a shift in bird diversity during this phase.

(5) Post-harvest phase (October 2024)

By October 2024, the post-harvest phase began, with fields left bare or covered only with residual straw. This stage was marked by a concentration of granivorous birds, such as the Eurasian Tree Sparrow and Scaly-breasted Munia, which fed on the leftover rice grains. The bare fields also provided foraging opportunities for birds like the Cattle Egret and the Black-winged Stilt, which walked through the fields, feeding on leftover insects and small animals. This phase demonstrates the role of rice fields as critical foraging grounds for seed-eating species, contributing to the overall avian diversity of the region. It also highlighted the importance of rice fields as habitats for migratory and resident species, especially those that rely on post-harvest leftovers as a primary food source.

Procedures

Surveys ran from July–October 2024 (100 days) at two sites. Each day included three 15-min sessions per site (morning, midday, afternoon), yielding 600 point-count sessions (3 sessions × 2 sites × 100 days) and a total of 150 observer-hours (9000 min).

Bird observations are carried out in the morning, afternoon and evening. Observations at Location 1 were conducted from 06:00 to 06:15, in the afternoon from 12.00 to 12.15, and in the afternoon from 16.00 to 16.15. Observations at location 2 were carried out in the morning from 06.30 to 06.45, in the afternoon from 12.30 to 12.45, and in the afternoon from 16.30 to 16.45. A survey of the type and number of individuals was observed for 15 min by walking along the rice field at a speed of around 1 km/h. If birds were observed, they were photographed with a digital camera for identification purposes, in addition to counting the number of individuals and the activities carried out by the birds. The points observed include the ground surface, rice plants, trees in the rice field area, as well as the space above the rice field area. Only birds that were present within or entered the observation zone during the time interval were counted present within or entering the observation area (15 min). Only birds actively using the rice fields—such as raptors hunting for prey—were counted. Researchers walked along the rice field embankments and recorded and photographed every bird seen. Observations were made using binoculars and then photographed using a digital camera. The data observed included bird species, sub habitats, and activities. Morphological characteristics used in identification Birds include estimates of body size, beak shape, leg shape, and feather color on typical body parts to facilitate identification. Identification of species is done using the Avibase-World Bird Database identification key for the Sulawesi Archipelago (Lepage, 2024).

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The bird diversity index used is the Shannon Index (Daly et al., 2018) which will be calculated using the Paleontological Statistics Software (PAST). The Shannon Weiner Diversity Index value usually falls between 1.5 and 3.5, rarely exceeding 4.5 (Abubakar et al., 2019). Within this research diversity analysis with Shannon index (H' = 2.384) was computed in PAST using total individuals per species pooled across all sessions.

Data analysis

The rice field habitat observed in this study is not a rice field that is cultivated simultaneously so that several types of sub habitats emerge, namely the land processing phase, planting, vegetative phase, mature generative phase (ready to harvest), and post-harvest. Each type of sub habitat has different characteristics (Supahan, 2022).

The initial land cultivation phase is characterized by land that is still overgrown with weeds, especially grass, and little irrigation, creating swamp-like conditions. The final cultivation phase is characterized by land that is inundated with water and free from weeds, so that its condition is like the edge of a swamp/lake (Yoganandham et al., 2023). The rice seed planting phase is characterized by land that is free from weeds with relatively little water, creating a swamp-like environment with short vegetation. The vegetation phase is characterized by little or much irrigation depending on irrigation activities, high rice plant vegetation, and free from weeds because of weeding activities. The final generative phase is characterized by relatively dry land, and rice that is ready to be harvested. The post-harvest phase is characterized by land that is temporarily left with or without straw, starting to be overgrown with weeds, and irrigation has not been carried out. The results of the observations obtained were the types and number of individual birds during the observations as presented in *Table 1*.

Table 1 provides a comprehensive summary of the bird species observed in the rice field habitats across different cultivation phases in North Minahasa. A total of 33 species were documented, representing various avian families and foraging strategies. These species included granivores (e.g., *Passer montanus*, *Lonchura punctulata*), insectivores (e.g., *Cisticola juncidis*, *Seicercus sarasinorum*), carnivores (e.g., *Elanus caeruleus*, *Haliastur indus*), and omnivores (e.g., *Corvus enca*). The high number of granivorous birds in the post-harvest phase highlights the importance of leftover grains as a key food source during this period.

Large flocks of *Lonchura punctulata*, *Lonchura malacca*, and *Passer montanus* were frequently observed after harvest, drawn to the leftover rice grains, demonstrating the importance of post-harvest rice fields for grain-eating birds. In contrast, insectivorous species like *Cinnyris jugularis*, *Cisticola juncidis*, and *Seicercus sarasinorum* were more active during the vegetative and planting stages, likely due to the abundance of insects when plant growth is at its peak.

Wading and aquatic birds such as *Egretta eulophotes*, *Ardeola speciosa*, *Bubulcus ibis*, and *Calidris ferruginea* were primarily found in waterlogged fields during early planting and land preparation. These wet conditions temporarily resemble natural wetlands, providing ideal feeding grounds for waterbirds. Notably, some observed species are of conservation concern, such as the endangered *Lonchura oryzivora* and the vulnerable *Aramidopsis plateni* and *Acridotheres javanicus*, underscoring the role of rice fields as vital fallback habitats, especially as natural wetlands are lost to development.

Predatory birds like *Elanus caeruleus* and *Circus assimilis* were also seen flying over the fields or resting nearby, suggesting a healthy food web supported by a steady supply of smaller birds and rodents. The shifting bird populations across different rice

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cultivation stages highlight the dynamic nature of these ecosystems. With bird-friendly farming practices, rice field management can support biodiversity and broader conservation goals.

Table 1. *Types and number of individuals visiting birds*

No.	Name & local name	Species & family	Phase of presence	Total amount	Activity
1.	Barred rail (Mandar-padi zebra)	Species: Hypotaenidia torquata (Linnaeus, 1766) Family: Rallidae	Vegetative, mature generative	31	Walking slowly among the weeds or rice plants to look for food
2.	Barn swallow (Layang-Layang Asia)	Species: Hirundo rustica (Linnaeus, 1758) Family: Hirundinidae	Planting	764	Actively fly low over rice plants or other planting phases to catch flying insects
3.	Black-headed munia (Bondol Rawa)	Species: Lonchura malacca (Linnaeus, 1766) Family: Estrildidae	Post-harvest	3002	Found in the post-harvest phase by forming flocks or associating with other munia species, eating the remains of rice grains
4.	Black-winged kite (Elang Tikus)	Species: Elanus caeruleus (Desfontaines, 1789) Family: Accipitridae	Planting, vegetative, mature generative, post-harvest	30	Flies over rice field habitat for long periods in small flocks (3 individuals) to catch mainly small birds
5.	Black-winged stilt (Burung Gagang-bayang Belang)	Species: Himantopus himantopus (Linnaeus, 1758) Family: Recurvirostridae	Land processing	205	Staying or waiting for prey in the habitat after land cultivation
6.	Blue-breasted quail (Puyuh Batu)	Species: Synoicus chinensis (Linnaeus, 1766) Family: Phasianidae	Mature generative	6	Walk slowly among the weeds or rice plants to look for seeds
7.	Blue-eared kingfisher (Raja-udang meninting)	Species: Alcedo meninting (Horsfield, 1821) Family: Alcedinidae	Planting	1	Waiting on the rice field embankment to catch insects or small animals
8.	Brahminy kite (Elang Bondol)	Species: Haliastur indus (Boddaert, 1783) Family: Accipitridae	Mature generative	1	Flying over rice field habitat to catch mainly small birds
9.	Cattle egret (Kuntul Kerbau)	Species: Bubulcus ibis (Linnaeus, 1758) Family: Ardeidae	Land processing, planting, vegetative	201	Forages by walking or standing still to capture insects, worms, lizards, or other small animals...
10.	Chinese egret (Kuntul Cina)	Species: Egretta eulophotes (Swinhoe, 1860) Family: Ardeidae	Land processing, planting, vegetative	4001	Forages by walking or standing still to capture insects, worms, lizards, or other small animals...
11.	Collared kingfisher (Cekakak Sungai)	Species: Todiramphus chloris (Boddaert, 1783) Family: Alcedinidae	Planting	9	Found on trees growing on the edges of rice fields, occasionally flying to catch insects or other small animals
12.	Common greenshank (Trinil Kaki-hijau)	Species: Tringa nebularia (Gunnerus, 1767) Family: Scolopacidae	Land processing	879	Forages by walking or standing still to capture insects, worms, frogs, or other small animals...
13.	Curlew sandpiper (Kedidi Golgol)	Species: Calidris ferruginea (Pontoppidan, 1763) Family: Scolopacidae	Land processing, planting, vegetative	920	Forages by walking or standing still to capture insects, worms, lizards, or other small animals...
14.	Eurasian tree sparrow (Burung Gereja)	Species: Passer montanus (Linnaeus, 1758) Family: Passeridae	Post-harvest	1440	Found in the post-harvest phase by forming flocks or associating with other munia species, eating the remains of rice grains
15.	Green-headed wagtail (Kicuit kerbau)	Species: Motacilla tschutschensis (Gmelin, JF, 1789) Family: Motacillidae	Land processing	301	Hops and walks in the rice fields in the initial land preparation phase
16.	Grey heron (Cangak Abu)	Species: Ardea cinerea (Linnaeus, 1758) Family: Ardeidae	Land processing, planting, vegetative	12	Forages by walking or standing still to capture insects, worms, lizards, or other small animals...
17.	Java sparrow (Gelatik Jawa)	Species: Lonchura oryzivora (Linnaeus, 1758) Family: Estrildidae	Post-harvest	78	Found in the post-harvest phase by forming flocks or associating with other munia species, eating the remains of rice grains

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No.	Name & local name	Species & family	Phase of presence	Total amount	Activity
18.	Javan myna (Kerak Kerbau)	Species: Acridotheres javanicus (Cabanis, 1851) Family: Sturnidae	Post-harvest	20	Hops actively to pursue insects, and perch in trees near rice fields
19.	Javan pond Heron (Blekok Sawah)	Species: Ardeola speciosa (Horsfield, 1821) Family: Ardeidae	Land processing, planting, vegetative	2250	Forages by walking or standing still to capture insects, worms, lizards, or other small animals...
20.	Lesser coucal (Bubut Alang-alang)	Species: Centropus bengalensis (Gmelin, JF, 1788) Family: Cuculidae	Planting	1	Swings and perches among the surrounding rice/grass to search for insects
21.	Lesser sand plover (Cerek pasir mongolia)	Species: Charadrius mongolus (Pallas, 1776) Family: Charadriidae	Land processing	410	Forages by walking or standing still to capture insects, worms, frogs, or other small animals...
22.	Olive-backed sunbird (Burung Madu Sriganti)	Species: Cinnyris jugularis (Linnaeus, 1766) Family: Nectariniidae	Vegetative, mature generative	5	Found perching from one plant to another to catch insects
23.	Scaly-breasted munia (Burung Bondol Peking)	Species: Lonchura punctulata (Linnaeus, 1758) Family: Estrildidae	Post-harvest	2890	Found in the post-harvest phase by forming flocks or associating with other munia species, eating the remains of rice grains
24.	Schrenck's bittern (Bambangan Coklat)	Species: Ixobrychus eurhythmus (Swinhoe, 1873) Family: Ardeidae	Land processing, planting, vegetative	205	Forages by walking or standing still to capture insects, worms, lizards, or other small animals...
25.	Slender-billed crow (Gagak Hutan)	Species: Corvus enca (Horsfield, 1821) Family: Corvidae	Post-harvest	21	Perching in trees on the edge of rice fields or flying over rice field habitats to catch mainly small birds
26.	Snoring rail (Mandar Dengkur)	Species: Aramidopsis plateni (Blasius, W, 1886) Family: Rallidae	Vegetative, mature generative	36	Walking slowly among the weeds or rice plants to look for food
27.	Sooty-headed bulbul (Cucak Kutilang)	Species: Pycnonotus aurigaster (Vieillot, 1818) Family: Pycnonotidae	Vegetative, mature generative	360	Found on trees growing on the edges of rice fields, occasionally flying to catch insects
28.	Spotted harrier (Elang-rawa tutul)	Species: Circus assimilis (Jardine & Selby, 1828) Family: Accipitridae	Vegetative	1	Flying over rice field habitat to catch mainly small birds
29.	Sulawesi leaf warbler (Cikrak Sulawesi)	Species: Seicercus sarasinorum (Meyer & Wiglesworth, 1896) Family: Phylloscopidae	Vegetative, mature generative	9	Small, perched on plants or electric poles, feeds on small insects
30.	Terek sandpiper (Trinil Bedaran)	Species: Xenus cinereus (Güldenstädt, 1775) Family: Scolopacidae	Land processing, planting, vegetative	308	Forages by walking or standing still to capture insects, worms, lizards, or other small animals...
31.	White-breasted woodswallow (Kekep Babi)	Species: Artamus leucoryn (Linnaeus, 1771) Family: Artamidae	Post-harvest	21	Found in the post-harvest phase by forming small groups of the same type
32.	Zebra dove (Perkutut Jawa)	Species: Geopelia striata (Linnaeus, 1766) Family: Columbidae	Post-harvest	78	Found in the post-harvest phase, eating the remains of rice grains
33.	Zitting cisticola (Cici Padi)	Species: Cisticola juncidis (Rafinesque, 1810) Family: Cisticolidae	Vegetative, mature generative, post-harvest	90	Found perching from one plant to another to catch insects

Results and discussion

Table 2 summarizes the distribution and characteristics of the bird species recorded during the study.

A total of 33 bird species from 21 families were identified across different stages of rice field cultivation. This number is higher than initially expected and reflects the ecological richness of the study area. The birds observed represent a wide range of feeding behaviors. Insect-eating species like *Cisticola juncidis* and *Seicercus sarasinorum*,

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seedeaters such as *Lonchura punctulata* and *Passer montanus*, and fish-eaters like *Ardea cinerea* were all present. Several of these species are of conservation concern. For example, *Lonchura oryzivora* is classified as endangered, while *Aramidopsis plateni* and *Acridotheres javanicus* are considered vulnerable. The presence of these birds shows that rice fields can serve not only as feeding grounds but also as temporary refuges for species facing habitat loss.

Table 2. *Ecological data on the types of birds found (Eaton et al., 2021; Author data, 2024)*

Species	Distribution	Status	Description
Artamus leucoryn (Linnaeus, 1771)	Indonesia, Philippines, Pacific, Australia (Invasive)	LC	Small-sized, forming large colonies, often seen in rice fields and grasslands, grain eaters
Passer montanus (Linnaeus, 1758)	Europe, Asia, Southeast Asia (Invasive)	LC	Small birds, able to adapt to human life, forming relatively small groups, eating seeds although sometimes also eating insects
Lonchura punctulata (Linnaeus, 1758)	South Asia, Southeast Asia (Invasive)	LC	Small-sized, forming large colonies, often seen in rice fields and grasslands, grain eaters
Lonchura malacca (Linnaeus, 1766)	South Asia, Indonesia (Invasive)	LC	Small-sized, forming large colonies, often seen in rice fields and grasslands, grain eaters
Lonchura oryzivora (Linnaeus, 1758)	Java (native), all of Indonesia, East Asia and in many countries (Invasive)	EN	This introduced bird is small in size, is a bird that forms colonies in quite large numbers and has a striking grey body color and a red beak, often seen in rice fields and grasslands, and eats seeds
Cisticola juncidis (Rafinesque, 1810)	Cosmopolitan, Africa, Europe, South Asia, Southeast Asia, East Asia, Indonesia, Pacific, Australia (Invasive)	LC	Small bird, small insect eater
Seicercus sarasinorum (Meyer & Wiglesworth, 1896)	Indonesia (Endemic)	LC	Small birds that prey on insects, moving from one plant to another
Cinnyris jugularis (Linnaeus, 1766)	South Asia, Southeast Asia, Philippines, Northern Australia (Invasive)	LC	A small bird that also sucks nectar from flowers, although it sometimes catches small insects
Pycnonotus aurigaster aurigaster (Vieillot, 1818)	Southeast Asia, Indonesia (Invasive)	LC	An introduced bird, medium-sized, forming small groups, able to adapt to various habitats, a fruit eater although it often also eats insects and small animals
Geopelia striata (Linnaeus, 1766)	Southeast Asia, Indonesia (Invasive)	LC	Introduced bird, medium sized, forms small flocks, seed-eating
Todiramphus chloris (Boddaert, 1783)	Southeast Asia, Indonesia, Pacific, Northern Australia (Invasive)	LC	Medium-sized, often solitary, eats insects and other small animals, prefers habitats around water
Alcedo meninting (Horsfield, 1821)	South Asia, Southeast Asia, Indonesia (Invasive)	LC	Relatively Small-sized, like other birds in the Alcedinidae family, it eats insects or other small animals
Centropus bengalensis (Gmelin, JF, 1788)	India, South Asia, East Asia, Indonesia, Philippines (Invasive)	LC	Medium sized, short flights and more often found among rice/grass thickets
Hirundo rustica (Linnaeus, 1758)	Latin America, South Africa, South Asia, Southeast Asia, Indonesia (Invasive)	LC	Small sized, often in groups or solitary, spends time flying and sometimes perching, insectivorous
Haliastur indus (Boddaert, 1783)	South Asia, East Asia, Pacific, North and East Australia (Invasive)	LC	Large sized, solitary flyers often hover slowly to watch for prey, feeding animals
Circus assimilis (Jardine & Selby)	Australia, Wallacea (Invasive)	LC	Medium-sized, solitary, carnivorous
Elanus caeruleus (Desfontaines, 1789)	Indonesia, Africa, East Asia, South Asia, Southeast Asia (Invasive)	LC	Relatively small in size, in small flocks, carnivorous
Ardea cinerea (Linnaeus, 1758)	Europe, Africa, South Asia, East Asia, Indonesia (Invasive)	LC	Large and tall, gray in color, often solitary, likes aquatic habitats, eats small animals

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Species	Distribution	Status	Description
Ardeola speciosa (Horsfield, 1821)	Thailand, Vietnam, Southern Philippines, Most of Indonesia (Invasive)	LC	Medium sized, blackish back and brownish chest, often forming colonies scattered in swamps or waters, feeds on aquatic animals
Egretta eulophotes (Swinhoe, 1860)	Parts of Indonesia, Philippines, East Asia (Invasive)	VU	Medium-sized, white in color, often forming colonies scattered in swamps or waters, eats aquatic animals
Ixobrychus eurhythmus (Swinhoe, 1873)	Indonesia, Philippines (Invasive)	LC	Medium-sized, brown striped color, solitary, eats small animals
Bubulcus ibis (Linnaeus, 1758)	Africa, South Asia, East Asia, Southeast Asia, Australia (Invasive)	LC	Slightly larger in size compared to Egretta eulophotes, yellow beak
Himantopus himantopus (Linnaeus, 1758)	South America, Africa, South Asia, Southeast Asia, Pacific, Australia (Invasive)	LC	Very long legs, prefers habitats with clear, stagnant water
Aramidopsis plateni (Blasius, W, 1886)	Sulawesi (Endemic)	VU	Medium-sized, often walks in thickets of plants, solitary, eats insects, small animals, or seeds
Hypotaenidia torquata (Linnaeus, 1766)	Sulawesi, Philippines, Northside Papua (Invasive)	LC	Medium-sized, often walks in thickets of plants, solitary, eats insects, small animals, or seeds
Xenus cinereus (Güldenstädt, 1775)	East African Coast, South Asian Coast, Indonesian Coast, Australian Coast (Invasive)	LC	Migratory bird, medium-sized, often in groups, preying on small animals in swamps or waters
Calidris ferruginea (Pontoppidan, 1763)	Africa, South Asia, East Asia, Southeast Asia, Indonesia, Australia (Invasive)	VU	Migratory bird, medium-sized, often in groups, preying on small animals in swamps or waters
Tringa nebularia (Gunnerus, 1767)	Africa, South Asia, Southeast Asia, Indonesia, Philippines, Pacific, Australia (Invasive)	LC	Medium sized, in groups with similar species or other species
Charadrius mongolus (Pallas, 1776)	Coast of South Asia, Southeast Asia, Indonesia, Philippines, Pacific, Australia (Invasive)	LC	Medium sized, in groups with similar species or other species
Corvus enca (Horsfield, 1821)	Indonesia, Philippines (Invasive)	LC	Quite large in size, often solitary or in small groups, black in color, carnivorous
Synoicus chinensis (Linnaeus, 1766)	South Asia, Southeast Asia, Indonesia, Australia (Invasive)	LC	Medium-sized, often solitary, walking slowly in plant thickets, seed-eating
Motacilla tschutschensis (Gmelin, JF, 1789)	South Asia, Southeast Asia, Indonesia, Philippines, Northern Australia (Invasive)	LC	Small-sized, in groups, walking along rice fields to eat small animals
Acridotheres javanicus (Cabanis, 1851)	Java, Bali, Introduced to Sulawesi (Endemic)	VU	Medium-sized, solitary walking in rice fields or perching in trees

LC = Least Concern, En = Endangered, Vu = Vulnerable, NT = Near Threatened

Some species, especially *Lonchura punctulata* and *Passer montanus*, were recorded in large numbers, particularly after harvest. Their abundance during this phase is likely due to leftover rice grains, which attract seed-eating birds. In contrast, earlier stages of cultivation, such as land preparation and the vegetative phase, were more frequently visited by wading birds and insectivores, including *Egretta eulophotes*, *Bubulcus ibis*, and *Tringa nebularia*. These patterns suggest that changes in the field's condition throughout the growing cycle strongly influence which bird species are present.

The calculated Shannon Index of 2.384 reflects a moderate level of bird diversity, likely shaped by the varied habitat conditions and human activities in the area. The sighting of raptors like *Haliastur indus* and *Elanus caeruleus* further indicates a functioning food chain, with enough prey to support predators. This balance underscores the role of rice fields as complex ecosystems capable of supporting diverse wildlife.

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This biodiversity also creates opportunities for bird-related tourism and education, especially in the post-harvest period when bird numbers are at their highest. Conservation strategies should recognize the importance of rice fields as substitute wetlands, particularly in areas facing rapid land-use changes.

Looking more closely at seasonal trends, different phases of cultivation were linked to shifts in bird communities. Insectivorous birds appeared more frequently during the vegetative stage, when insect populations were likely higher. Grain-eating birds, on the other hand, gathered in large flocks after harvest, attracted by leftover grains in the fields.

Bird diversity was especially high in fields where planting was not done simultaneously. In these areas, birds typically associated with wetland environments, like *Himantopus himantopus* and *Xenus cinereus*, were more commonly seen. This suggests that non-synchronized planting can help create a mix of habitat conditions that benefit a wider range of species.

Differences in flock size also offered clues about how birds used the fields. Small groups of raptors like *Elanus caeruleus* tended to appear in open, post-harvest areas, while solitary species such as *Ardea cinerea* and *Ardeola speciosa* showed clear preferences for specific habitats. These observations point to the ecological complexity that can develop even in managed agricultural settings.

To support this biodiversity, ongoing monitoring is essential. Combining field surveys with tools like remote sensing could help track changes over time and guide more effective land-use decisions. In regions like Wallacea, where agriculture and conservation often overlap, rice fields may play a growing role in protecting birdlife.

Discussion

The shifting bird populations across the different rice cultivation phases underscore the importance of each phase in providing distinct habitat conditions. The land processing phase (July) and planting phase (July-August) were dominated by insectivorous and aquatic species, with Cisticola juncidis and Egretta eulophotes being more abundant due to the wet conditions of the fields. The vegetative phase (August), with its dense rice growth, provided an optimal environment for insectivorous species such as Cinnyris jugularis, while the mature generative phase (September), where the rice plants were mature, saw an increase in granivorous birds like Passer montanus. The post-harvest phase (October) was particularly important for seed-eating species such as Lonchura punctulata and Scaly-breasted Munia, which fed on leftover grains, demonstrating the role of rice fields as essential feeding grounds.

Figure 4 displays the total bird count across the five rice paddy phases. The data reveals that various bird species are more prevalent during specific phases, with waterbirds like the Chinese Egret and Javan Pond Heron being most abundant in the wet Vegetative Phase. Meanwhile, seed-eating birds, especially the Scaly-breasted Munia, and Eurasian Tree Sparrow, are observed in large numbers during the Post-Harvest Phase, searching for the leftover grains.

These findings support the idea that rice fields serve as surrogate wetlands, providing critical habitats for various bird species, particularly in regions where natural wetlands are in decline. The variation in bird species across cultivation phases also highlights the need for sustainable rice farming practices that support biodiversity. By managing rice fields with bird-friendly approaches, such as maintaining wetland-like conditions during key phases, rice cultivation can play an important role in the conservation of local and migratory bird populations.

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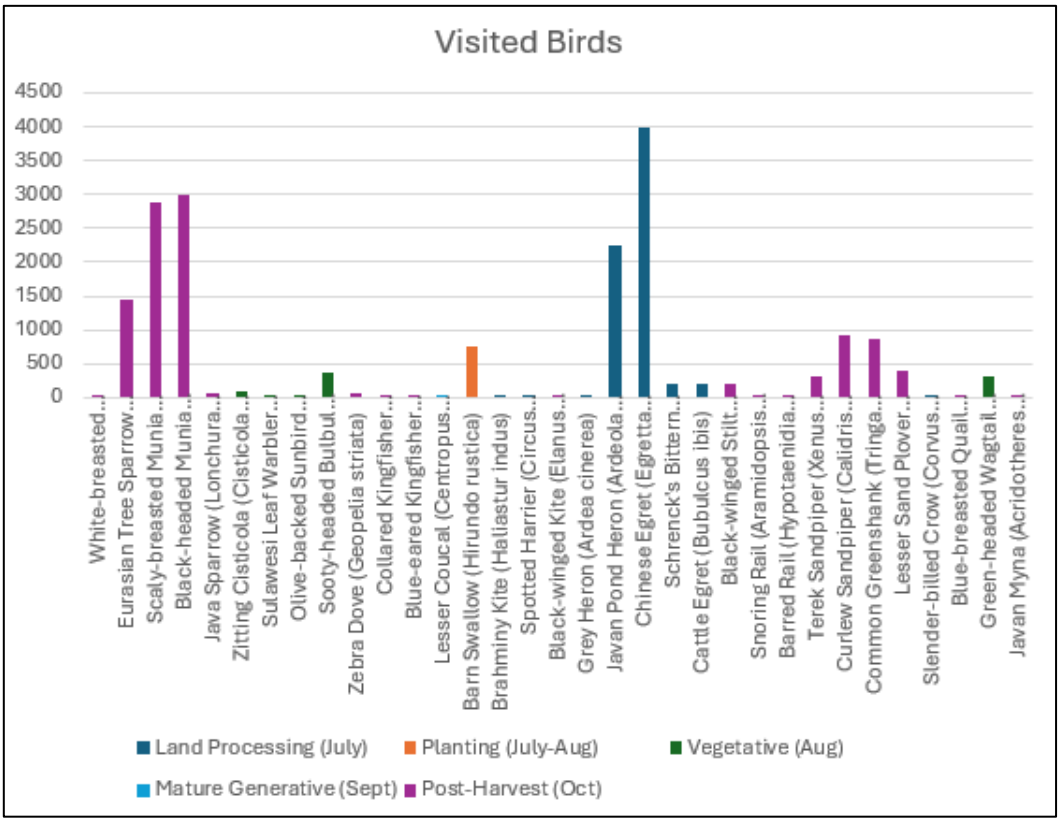

Figure 4. *Total visited birds*

The results of the observations obtained the types and number of individual birds during the observations as presented in *Table 1*. The distribution and other characteristics of each type are presented in *Table 2* with reference to Birds of the Indonesian Archipelago: Greater Sundas and Wallacea Books in grouping the types (Eaton et al., 2021). A total of 33 bird species from 21 families were documented in the rice fields of North Minahasa, as presented in *Table 1,* with a Shannon diversity index of 2.384, indicating moderate biodiversity. This diversity is notable for a region with such a high number of endemic species, including those of conservation concern. The presence of vulnerable and endangered species further emphasizes the role of rice fields as critical habitats. Additionally, these rice fields can serve various purposes, including birdwatching and education. As a result, they could be a valuable resource for ecotourism in the region, offering a sustainable means of raising awareness and providing economic opportunities. Protecting these areas from degradation, particularly from land conversion for housing, is essential to preserve their ecological value.

The study demonstrates that rice fields in North Minahasa Regency serve as important seasonal habitats for diverse bird species, including those with vulnerable and endangered status. With 33 species identified across all cultivation phases and a moderate Shannon diversity index, these managed agricultural landscapes play a dual role in biodiversity support and ecosystem service provision. Strategic conservation and sustainable agricultural practices, especially during post-harvest periods, are essential to maintain this balance. Promoting birdwatching tourism and integrating bird monitoring into local agricultural planning could further enhance the ecological and socioeconomic value of rice fields in the region.

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Data availability

All raw counts by species, phase, photographs, and site notes are available at sl.unsrat.ac.id/ricefieldbirds.

Conclusion

Rice fields in North Minahasa support diverse bird species, including several conservation concerns. Strategic management can enhance both biodiversity and local livelihoods. The documentation of 33 species from 21 avian families, including taxa of conservation concern, highlights the capacity of these managed agricultural landscapes to contribute meaningfully to regional biodiversity conservation. Temporal shifts in species composition, driven by rice phenology and habitat heterogeneity, reflect the dynamic nature of rice fields as surrogate wetlands within an increasingly human-modified environment. The moderate Shannon diversity index (2.384) further underscores the ecological value of this habitat mosaic in sustaining avian community structure. Sustainable agricultural practices that enhance habitat complexity, reduce disturbance during critical foraging periods, and support bird-friendly management can simultaneously promote both biodiversity and agricultural productivity. Additionally, integrating bird conservation with ecotourism initiatives may provide valuable socioeconomic incentives for local communities, fostering a more holistic approach to landscape management. Ongoing monitoring and adaptive management strategies will be essential to safeguard and enhance the ecological functions of rice fields in North Minahasa and similar tropical agroecosystems.

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