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Avian diversity and conservation value in Tram Chim Ramsar site, Mekong Delta, Vietnam

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Abstract. *Kieu LD, Ban LN, Nguyen PQ. 2026. Avian diversity and conservation value in Tram Chim Ramsar site, Mekong Delta, Vietnam. Biodiversitas 27 (5): d270504. https://doi.org/10.13057/biodiv/d270504*. Tram Chim National Park is a Ramsar site in the Mekong Delta, Vietnam, which is important for the conservation of bird species in Vietnam and migratory species worldwide. This study assessed the biodiversity, conservation value, and population structure of birds in the Tram Chim National Park Ramsar site using direct observation of 23 transects, conducted monthly throughout 2022. The survey recorded 139 bird species across 49 families and 17 orders. The bird community showed high biodiversity and uniformity, which was relatively stable between the dry and rainy seasons ($p>0.05$), with d, H' and J' values 8.14-11.97, 2.24-3.38 and 0.52-0.75, respectively. However, the biodiversity of the bird community continued to decline significantly in both richness and uniformity during the transitional months (June, July, November and December). The presence of numerous migratory and endangered bird species, as listed in the IUCN, CITES, and the Vietnam Red Book, confirms that the Tram Chim Ramsar Site is a crucial link in the global conservation of bird species. The structure of migratory birds, forest/water birds, and feeding groups fluctuated seasonally. The results of this study suggest that maintaining biodiversity resilience requires appropriate hydrological management informed by seasonal ecological information, ensuring the long-term conservation function of the global bird migration network.

Keywords: Avian diversity, inland wetlands, Mekong Delta, migration status categories

INTRODUCTION

Highly productive inland wetland ecosystems (Mandal et al. 2021) are vital habitats for many endangered species, playing a key role in maintaining global biodiversity (Delgado et al. 2017; Finlayson et al. 2018; Lorenzón et al. 2019; Kakati et al. 2021), balancing ecosystems and regulating climate (Xu et al. 2020). Ramsar sites are wetlands of international importance that not only provide abundant food and shelter but also serve as irreplaceable stopovers and wintering grounds along global migration routes for numerous migratory birds, notably the East Asia-Australia Flight Route (EAAF) (Chaleekarn et al. 2022; Navedo and Piersma 2023). Bird communities in wetland ecosystems served as sensitive bioindicators, accurately reflecting the health and service value of the ecosystem and changes in its environmental quality (Santosa et al. 2018; Araneda et al. 2025). Bird community structures, which are not static, constantly change with ecological cycles. Seasonal fluctuations in meteorological and hydrological factors directly regulated the availability of ecological niches and food resources of bird species (Mandal et al. 2021; Ullah et al. 2024). Therefore, understanding the dynamics of seasonal bird communities is an indispensable scientific basis for the conservation of bird species and wetland ecosystems (He et al. 2025).

Tram Chim National Park is an inland Ramsar site and a typical example of the Dong Thap Muoi ecosystem in the Mekong Delta region of Vietnam. This National Park boasts diverse habitats and flora and fauna, serving as an essential habitat and stopover point on the migration routes of many bird species, most notably Sarus crane (*Grus antigone*). The natural hydrological regime of Tram Chim is characterized by two distinct seasons: the dry season from December to April of the following year, and the rainy season from May to November (Cuong 2011). The dynamics of the Tram Chim ecosystem are regulated by seasonal flooding (flood season months are August-November), creating habitat diversity ranging from deep and shallow flooding to dry grasslands (Cuong 2011), as well as the variability of biological community structure, food group differentiation, and habitat selection behavior of bird species. Seasonal climate and hydrological changes will affect the presence of bird species in inland wetlands in South Asia and East Asia (Asawra et al. 2025; Ullah et al. 2025), such as changes in migratory bird groups (Crosby et al. 2025; Takekawa et al. 2023), and functional foraging groups (Wan et al. 2025). These responses are important for management because they indicate when habitats provide critical resources for resident and migratory birds. This situation highlights the urgent need for a detailed assessment of the interactions within the seasonal bird community in this protected area.

Given its exceptional biodiversity and importance, numerous studies have been conducted on the ecosystem and biodiversity of this Ramsar site. However, recent studies on avian biodiversity in Tram Chim National Park have only focused on recording species composition and

those prioritized for conservation (Cuong 2011; Tran and Barzen 2016; Tran et al. 2018), without detailed analyses of changes in biodiversity status, structural differentiation and functional groups across months and seasons of this community. This study was conducted to fill the aforementioned knowledge gap by evaluating in detail the seasonal dynamics of the bird fauna in the Tram Chim Ramsar site. We put forward the following scientific hypotheses: (i) The transition between hydrological phases between the dry and rainy seasons will lead to changes in species richness and bird community structure, (ii) With seasonal fluctuations in bird communities, Tram Chim National Park still maintains a diverse functional group structure and supports globally threatened species, affirming its role as an important ecological link in the conservation of bird species in the region.

MATERIALS AND METHODS

Study area

Tram Chim National Park was recognized by the Vietnamese Government in 1998 as the most important model of the Dong Thap Muoi inland wetland ecosystem. In 2012, the Ramsar Convention recognized Tram Chim National Park as a wetland of international importance, making it Vietnam's 4th Ramsar site and the first in the Mekong Delta (Cuong 2011). Tram Chim National Park has geographical coordinates of 10°40′ to 10°47′ North latitude and 105°26′ to 105°36′ East longitude, with a total core area of 7,313 ha (Cuong 2011). Tram Chim National Park is located in a tropical monsoon climate zone with two distinct seasons: the rainy season from May to November and the dry season from December to April of the following year. The average annual rainfall is 1,350 mm to 1,680 mm, mainly concentrated in the rainy months, and the air temperature fluctuates between 27-29°C (Lee and Dang 2020). The habitat in Tram Chim National Park is characterized by Melaleuca forests, open water bodies, and grasslands with many unique habitats such as Wild rice (*Oryza rufipogon*), Torpedo grass (*Panicum repens*), Purple spikerush (*Eleocharis dulcis*), Needle grass (*Eleocharis ochrostachys),* Muraina grass (*Ischaemum rugosum*), Hippo grass (*Vossia cuspidata*), Water-lily (*Nymphaea* sp.), Indian lotus (*Nelumbo nucifera*) (Cuong 2011; Tran and Barzen 2016). This Ramsar site supported over 130 plant species, 150 fish species, and many rare bird species, especially migratory waterbirds (Tran et al. 2018; BirdLife International 2020). The flood season in the area begins from August (July in the lunar calendar) to November (October in the lunar calendar) (Cuong 2011), so the water level in the reserve also rises and reduces the area of grassland ecosystems, which can affect the activity areas, food sources, and habitats of birds.

Survey time and methods

The survey of avian diversity in Tram Chim National Park was conducted monthly from January to December 2022 at five sub-zones (A1-A5). A total of 23 survey routes were conducted: 15 walking routes (2-4 km each) and 8 boat routes (2-11 km each), as shown in detail in Table 1 and Figure 1. Then, methodological workflow figure to synthesize the study design (see Figure 2).

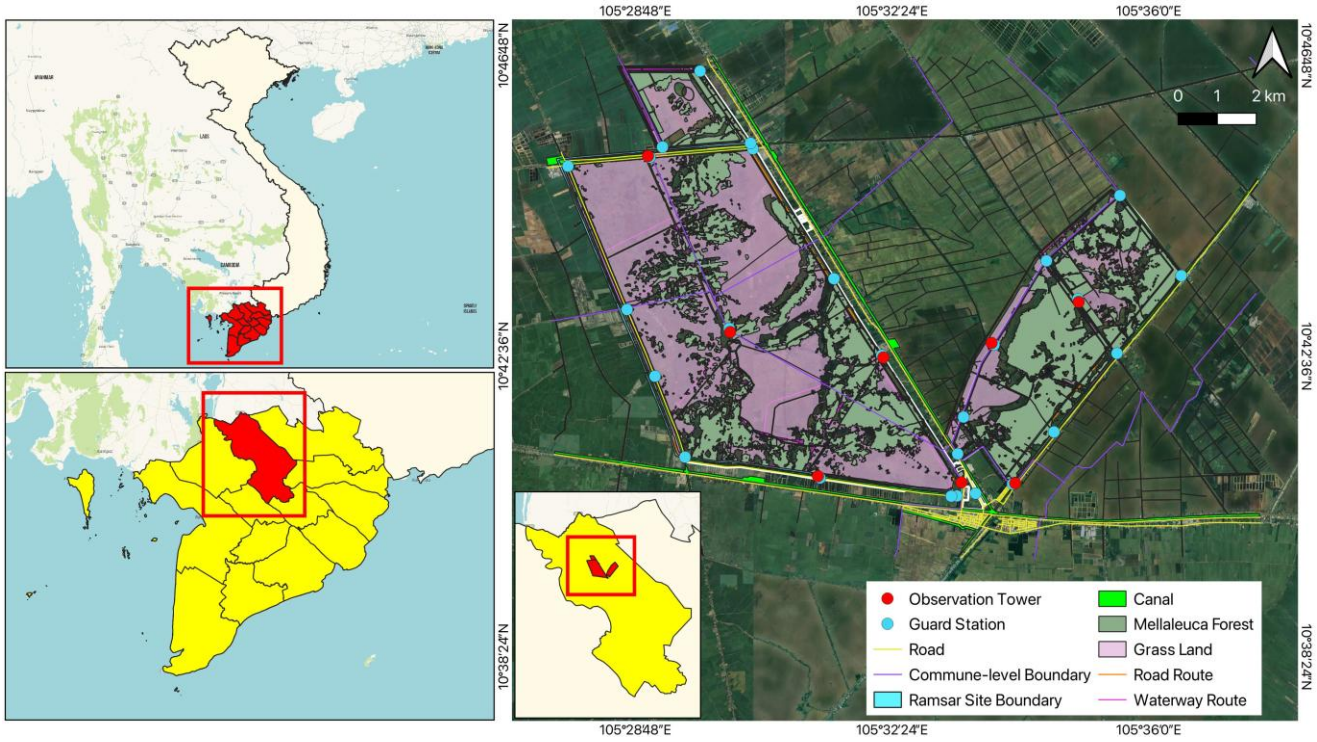

Figure 1. Biodiversity survey route of bird communities in Tram Chim National Park, Vietnam, in 2022

Table 1. Distribution of survey transects by functional zone and major habitat in Tram Chim National Park, Vietnam

Sub-area	Area (ha)	Function	Survey route	Main habitat
A1 (North of Muoi Nhe Canal-An Binh Canal)	4,187.1	Strict protection	Walking: 2, 3, 4, 5, 6, 7, 8, 9 Boat: 2, 3, 4	Melaleuca forest, wild rice, purple spikerush, needle grass, torpedo grass, muraina grass, lotus and water lily.
A1 (Triangle Area)	746.4	Ecological restoration	Walking: 1, 10 Boat: 1	Melaleuca forest, wild rice, purple spikerush, needle grass, torpedo grass, lotus and water lily.
A2	1,122.7	Ecological restoration	Walking: 11, 12, 13 Boat: 8	Melaleuca forest, purple spikerush, lotus and water lily
A3	44.5	Service and administrative area	Boat: 7	Melaleuca forest, purple spikerush, torpedo grass, lotus and water lily.
A4	731.9	Ecological restoration	Walking: 14 Boat: 5	Melaleuca forest, purple spikerush, needle grass, torpedo grass.
A5	440.5	Ecological restoration	Walking: 15 Boat: 6	Melaleuca forest, purple spikerush, needle grass, torpedo grass.

All transects were surveyed simultaneously at two peak bird activity times (5:30-7:00 AM and 5:00-6:30 PM) on the same day of the month to ensure representativeness and minimize errors. The survey staff maintained a steady speed of 1.0-1.5 km/h, briefly stopping when necessary to identify species, but the average speed remained unchanged (Bibby et al. 2000; Ullah et al. 2025). The research team did not use distance software to run a distance-function model; however, adjacent survey transects were spaced at least 100 m apart, and a strict one-way movement principle was followed for all transects to eliminate duplicate counting. The survey method combined visual observation, binoculars (Canon EOS 1200D KIT 18-55 IS II), hearing, and sound recording (identification through songs/calls) to avoid missing reclusive species. The number of small, slow-moving flocks was counted individually, while for large, fast-moving flocks an estimation method was used: groups of 50 individuals were counted, then multiplied by the flock size. The survey team consists of 31 personnel (reserve staff and experts with over 10 years of field experience), assigned to each transect: one person per walking transects and two people per boat transect, fixed for 12 months. They had received standardized training in species identification based on morphological and vocalization characteristics. In addition, the research team also performed inter-observer calibration and consistency checks after each survey. The main field guides used were the Vietnamese Bird Book (Cu et al. 2000; Bao et al. 2025) and Guide to the Birds of Southeast Asia (Robson and Allen 2009). All survey activities and the publication of biodiversity results from Tram Chim National Park in this article have been authorized by the Tram Chim National Park Management Board.

Methods for classifying and assessing the diversity of bird communities

Bird species were identified and classified (Order, Family, and Species) based on morphology and bioacoustics. Conservation value, population status globally and the distribution of the species in Vietnam and the world were determined based on the International Union for Conservation of Nature (IUCN) Red List of threatened Species (https://www.iucnredlist.org), and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (https://checklist.cites.org/#/en); and in Vietnam according to the Vietnam Red Book (2007) (http://vnredlist.vast.vn/ accessed on 08/12/2025).

Bird residence status was classified as: Resident species (R) are those present in the National Park year-round and typically breed within the protected area (Bezzalla et al. 2019; Chanyandura et al. 2025); Migratory species (M): Species that move in seasonal cycles (wintering, summering or reproductive migration) between breeding grounds and the protected area (Siri et al. 2019). Resident and migration (R, M) (Partial migration) refers to some individuals within a population that migrate while others remain in the protected area year-round (Chanyandura et al. 2025). Determining the migration status of species in Tram Chim National Park is based on global population trend data reports from conservation organizations such as BirdLife International (Nagy et al. 2022), IOC World Bird List v15.1 (Gill et al. 2025), documents on bird species in Vietnam (Cu et al. 2000; Bao et al. 2025), eBird of Tram Chim National Park hotspots (https://ebird.org/hotspots), and actual records of bird populations in the protected area in 2022. For new records, migration labeling is not automatically assigned; it is assessed based on regional biological cycle data from eBird and BirdLife International to distinguish true migratory birds from random stray birds.

The bird community in Tram Chim National Park was divided into three main ecological groups (forest birds, terrestrial birds and waterbirds) based on ecological interactions and the dependence of bird populations on the environment (Nugroho et al. 2023), according to Convention on Wetlands (2025), international standards of IUCN (2026), and field observations. The waterbird group includes species that are ecologically dependent on wetlands for at least part of their life cycle (Convention on Wetlands 2025); Forest birds include species that depend on the canopy or understory of woody ecosystems, from evergreen forests to regenerating forests (Siri et al. 2019); Terrestrial birds are species that prefer non-flooded habitats such as dry grasslands, agricultural land, or urbanized areas (Nugroho et al. 2023; IUCN 2026). Bird species present various habitat types were grouped according to the

"predominant habitat" rule, which was the species' population habitat with the highest frequency of occurrence during field surveys (Navedo and Piersma 2023).

The functional feeding groups of bird species were classified according to the rule of primary diet (>50% of the diet) based on authoritative literature on bird populations in Vietnam and the region (Cu et al. 2000; HBW Alive 2021; Bao et al. 2025) and survey results during the study period. Species with mixed diets without a dominant food source were classified as omnivores (Nugroho et al. 2023; Shafie et al. 2023). Based on these criteria, the species in the bird community of Tram Chim National Park were classified into 9 food groups and remained stable over the 12-month survey period, including insectivores, fishivores, carnivores (vertebrates and carrion), herbivores (grass, leaves and shoots), omnivores, molluscs, nectarivores, seedivores and fruitivores (Olabamiyo and Akinpelu 2017; Pan et al. 2025).

The distribution status of bird populations at Tram Chim National Park in 2022 was evaluated based on the frequency of occurrence across 12 monthly survey events (n: 12 field trips) and assessed using the methods of Mazumdar (2019) and Makwana et al. (2024). Each "field trip" encompasses all data collected from all transects within that month. In which, the status of the distribution of common bird species (C) is recorded in 80-100% of field trips, uncommon species (U) is 50-79.9%, occasionally occurring species (O) is 20-49.9%, and rare species (R) is less than 20%. The data were then analyzed using index analysis biodiversity indicators, including Margalef Species Richness Index (d) (Margalef 1958):

$$d = \frac{S-1}{lnN}$$

Shannon-Wiener Species Diversity index (H' Index) (Shannon and Weaver 1949):

$$H' = -\sum_{i=1}^{S} p_i * lnp_i$$

Pielou's Evenness Index (J' ranges from 0 to 1) (Pielou 1966):

$$J' = \frac{H'}{lnN}$$

The Gini-Simpson index (1−λ):

$$1 - \lambda = 1 - \sum_{i=1}^{S} p_i^2$$

The Gini-Simpson index was used to estimate the probability that two randomly selected individuals belong to different species, helping assess the stability of the community (Simpson 1949; Bibi and Ali 2013; Kunakh et al. 2023). Where: pi: n_i/N, n_i is the number of individuals of each bird species; N is the total number of bird individuals surveyed in the community; and S is the total number of bird species surveyed in the community.

Data analysis

Biodiversity data of surveyed bird species in the Tram Chim Ramsar site in 2022 were analyzed using $d_{Margalef}$, H', and J' biodiversity indices with Primer 5 software. Linear Mixed Models (LMM) were applied to assess the seasonal impact on bird biodiversity; biodiversity data from consecutive months were evaluated for temporal dependence using a first-order autoregressive (AR1) covariance structure. The Chi-square ($\chi 2$) test was used to assess the relationship between months and the ratio of bird groups. In cluster analysis (CA), indices were Z-score normalized before applying the Ward method. Diversity indices were analyzed using Primer v5, and other statistical analyses were performed in IBM SPSS 22.0.

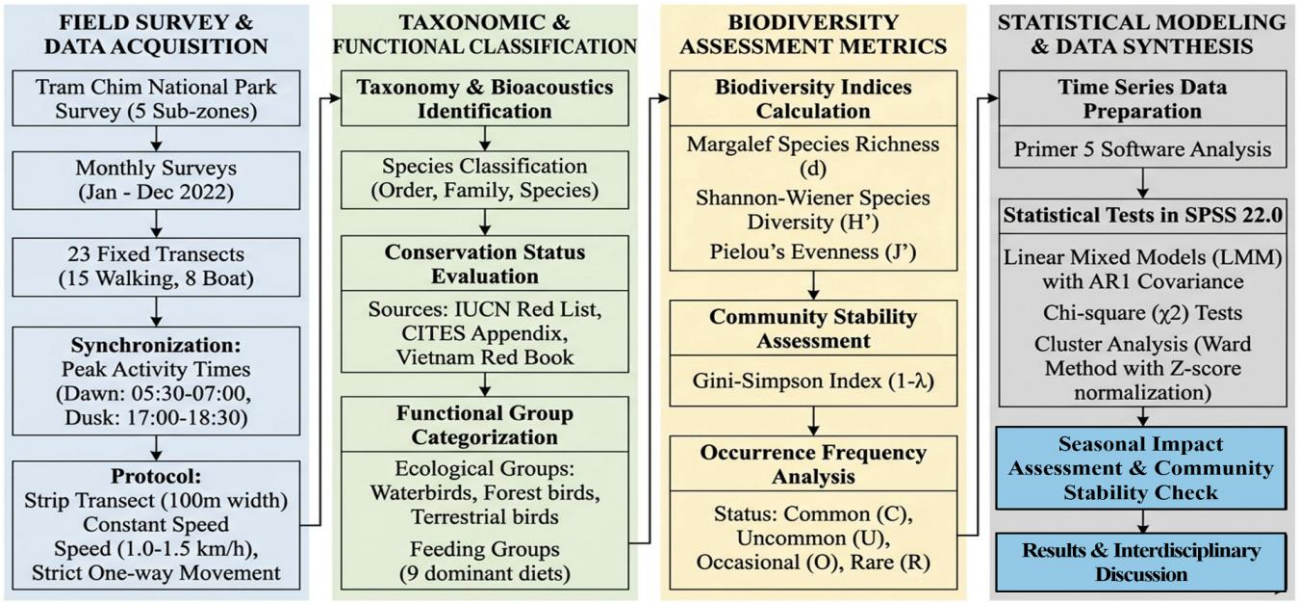

Figure 2. Methodological workflow figure to synthesize the study design

RESULTS AND DISCUSSION

Results

The results of a survey and analysis of bird diversity theo IOC World Bird List v15.1 in the Tram Chim National Park Ramsar site from January to December 2022 showed that 139 bird species belonging to 49 families and 17 orders. Of these, 9 orders have only one family, 4 have two, and 2 have three. Many orders of high ecological importance in the National Park have only one family, and within that family, only one species, such as the Apodiformes order with only Apodidae, the Caprimulgiformes order with only Caprimulgidae, the Podicipediformes order with Podicipedidae, and the Psittaciformes order with Psittacidae. Furthermore, 19 families have only one species, 13 families have two species, and only the Ardeidae family shows the highest species diversity with 12 species. However, the Passeriformes order has the highest family diversity with 22 families and 52 species, accounting for 37.41% of the total number of species recorded in 2022 at the Tram Chim Ramsar site (Table 2).

Analysis of biodiversity indices of bird communities in Tram Chim National Park showed that the average values of d, H', J', and 1-λ indices of the bird community during the dry season were 9.6±1.71, 3.04±0.39, 0.68±0.07, and 0.91±0.04, and the rainy season with average values of the above indices of 9.28±0.58, 2.83±0.41, 0.64±0.09, and 0.86±0.07. The results of the Linear Mixed Models (LMM) analysis showed that the biodiversity indices of the bird community did not differ significantly between the dry and rainy seasons ($p>0.05$). The autocorrelation coefficient (AR1 rho) of the biodiversity indices between months ranged from -0.39 to 0.31, reflecting compensatory fluctuations and a low level of inheritance of the current diversity status of the bird community from month to month; however, these fluctuations did not form a clear seasonal trend. The d value in all months of the year was always greater than 8; the J' value of the bird community in Tram Chim National Park was also greater than 0.5; and the value of the 1-λ index was always greater than 0.8. The H' value of the bird community in March, June, July, November, and December rang from 2.24 to 2.91, các tháng còn lại đều có the H' value was greater than 3 (Table 3). The results of the CA (Ward's method) analysis of the diversity and richness of the bird community in the National Park for each month of the year based on biodiversity indices showed that at a distance of 5, the bird communities in January and April (dry season months) had high species richness and diversity and were evenly distributed, followed by 6 months with both dry and rainy seasons. The group with the lowest level of biodiversity was in the transitional months between the two seasons (June, July, November and December). This result once again confirmed changes in the structure of bird communities in the reserve throughout the year, especially at transitional times between seasons (Figure 3).

Conservation value assessment results showed that many bird species in Tram Chim National Park are threatened in Vietnam and worldwide. *Nettapus coromandelianus* is listed as endangered (EN), and 7 species are listed as vulnerable (VU) in the Vietnam Red Book (2007), all of which are experiencing population declines. According to the IUCN red list (2026), 3 (2.16% of the total species surveyed in Tram Chim) belong to the near threatened (NT) group: *Ploceus hypoxanthus*, *Limosa limosa* and *Alcedo hercules*; 1 species (0.72%) belongs to the Vulnerable (VU) group: *Halcyon pileata*; and 95.68% of the species belong to the least concern (LC) group. In addition, *Mycteria leucocephala* is listed in Appendix I, and 11 bird species are listed in Appendix II of the CITES Convention. Of the 20 rare bird species, 9 are experiencing population decline, while only 5 are showing population increase globally (IUCN 2026); and these mainly belong to the rare (9 species) and occasional (3 species) groups present in Tram Chim National Park in 2022 (Table 4). The 2022 bird population survey in Tram Chim National Park did not record the presence of the Sarus crane, a species representative of the health of the inland wetland ecosystem.

The bird community in Tram Chim National Park has an ecological structure ranging from species dependent on wetlands (waterbirds) to forest birds. The number of forest bird species varied from 37 to 62 species (accounting for 53.42 to 61.11% of the total species surveyed each month), higher than the number of waterbird species, which ranged from 30 to 40 species (accounting for 37.78 to 46.58%). Regarding migration patterns, the number of resident and migratory bird species in Tram Chim National Park also fluctuated throughout the year. The highest number and proportion of resident bird species ranged from 41 to 64 species, accounting for 61.2-70.7% of the total bird species for the month. The number of partially migratory bird species in 2022 ranged from 15 to 21, accounting for 18.4-22.4% of the total number of bird species in that month. These species had migratory behaviors that only partially represent the population, with the remainder being resident year-round in the Tram Chim Ramsar site.

Table 2. Family and species diversity of bird orders in the Tram Chim National Park, Vietnam

Name of order	Number of family	Number of species
Apodiformes	1	1
Caprimulgiformes	1	1
Podicipediformes	1	1
Psittaciformes	1	1
Ciconiiformes	1	2
Anseriformes	1	4
Columbiformes	1	5
Gruiformes	1	5
Cuculiformes	1	7
Piciformes	2	3
Strigiformes	2	4
Suliformes	2	4
Pelecaniformes	2	14
Accipitriformes	3	9
Coraciiformes	3	15
Charadriiformes	4	11
Passeriformes	22	52
Total	49	139

Table 3. Avian diversity in Tram Chim Ramsar site, Vietnam, in 2022

Season	Month	S	N	d	J'	H'	1-λ
Dry	January	103	12879	10.78	0.72	3.33	0.93
	February	81	7460	8.97	0.71	3.14	0.93
	March	67	3303	8.15	0.69	2.91	0.91
	April	99	3591	11.97	0.73	3.38	0.94
	December	71	6127	8.14	0.57	2.42	0.83
	Mean±std	84.2±16.2	6672.0±3882.3	9.6±1.71	0.68±0.07	3.04±0.39	0.91±0.04
Rain	May	82	5051	9.50	0.75	3.30	0.93
	June	79	7173	8.79	0.55	2.42	0.81
	July	77	4824	8.96	0.59	2.55	0.81
	August	82	4677	9.59	0.69	3.04	0.92
	September	87	6191	9.85	0.70	3.13	0.92
	October	90	8035	9.90	0.69	3.10	0.90
	November	73	5446	8.37	0.52	2.24	0.75
	Mean±std	81.4±5.8	5913.9±1280.8	9.28±0.58	0.64±0.09	2.83±0.41	0.86±0.07
Sig. (Season)		0.712	-	0.652	0.898	0.666	0.537
Linear mixed models							
AR1 rho (Month)		-0.224	-	-0.393	0.217	0.23	0.312

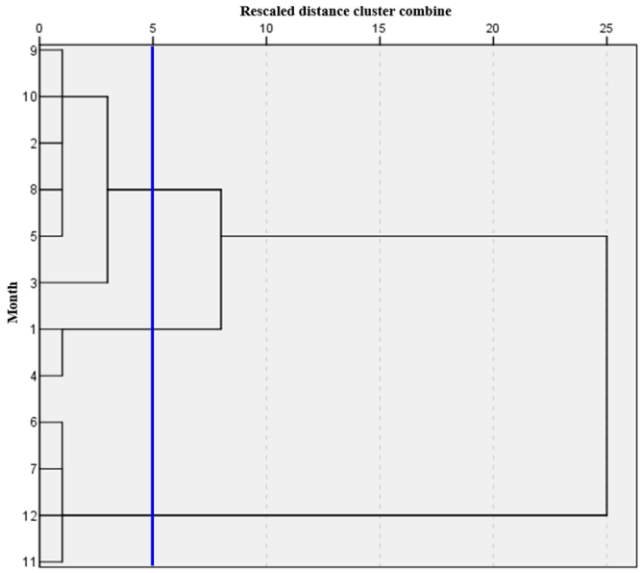

Figure 3. The dendrogram illustrates the results of monthly CA analysis of the bird community using the Ward method. Biodiversity index data were Z-score normalized to ensure weight homogeneity. The dashed vertical line at a normalized distance of 5 delineates three main clusters in the bird community, supported by a significant jump in agglomeration coefficients (from 8.52 to 19.19)

The number of migratory bird species ranged from 7 to 18, accounting for 8.6-17.5% of the total number of bird species in each month (Figure 4). Among these, forest/ terrestrial bird species mainly belonged to the resident group (63.3-79.5%), followed by migratory species (17.6-25.0%), and the lowest percentage was for partial migration species (4.3-11.7%) of the total number of forest bird species in the surveyed months. Waterbird species exhibit a predominantly partial migratory status, with partial migration species accounting for 50.0-62.5% of the total number of waterbird species each month, followed by resident species at 25.0-44.7%, and the lowest being migratory birds at 2.7-16.7% of the total number of waterbird species each month (Figure 5). The differences in migration status between waterbird and forest/terrestrial birds monthly are statistically significant according to the Chi-square test (χ^2: 18.38-31.19; df: 2; p: 0.000; 2x3 contingency table).

The distribution of waterbird species in Tram Chim National Park also differed among bird groups. Commonly distributed species in the reserve accounted for 41.7% of the total species surveyed in 2022, while uncommonly distributed species accounted for only 17.3%, occasionally occurring species account for 15.1%, and rarely occurring species accounted for 25.9%. The proportion of commonly distributed species among resident and partial migration birds was 42.9% and 64.5%, respectively, while only 16.1% of migratory species were commonly distributed. Conversely, the proportion of rarely present migratory bird species in Tram Chim National Park was highest at 45.2%, more than twice as high as the proportions of rare species in resident and partial migration groups (20.8% and 19.4%, respectively) (Figure 6).

The diversity of bird orders, families and species in Tram Chim National Park influenced the diversity of bird species groups according to food sources. The results of the bird species composition analysis in Tram Chim National Park according to the feeding guild showed that insectivorous birds (insectivores) were the most dominant group with 31.2-33.2% of the total number of species, fishivores birds at 17.8-21.0%, omnivores at 14.4-15.6% and carnivorous birds at 7.6-11.5%. The proportions of frugivorous, molluscivores, seedivores, nectarivorous and herbivores birds were relatively low. The fishivores and insectivores' birds increased sharply in the rainy season, while the carnivorous and molluscivores birds increased in the dry season (Figure 7).

Table 4. Conservation status of bird species in Tram Chim National Park according to IUCN, CITES, Vietnam Red Book

Order	Family	Scientific name	1	2	3	4	5	6
Accipitriformes	Accipitridae	*Aviceda leuphotes*	M	LC	II		D	R
		Circus melanoleucos	M	LC	II		D	O
		Circus spilonotus	M	LC	II		S	U
		Milvus migrans	R	LC	II		S	U
		Pernis ptilorhynchus	R, M	LC	II		D	R
		Spilornis cheela	R	LC	II		D	R
	Elanidae	*Elanus caeruleus*	R	LC	II		S	C
	Pandionidae	*Pandion haliaetus*	M	LC	II		I	R
Anseriformes	Anatidae	*Nettapus coromandelianus*	R, M	LC		EN	U	U
Charadriiformes	Scolopacidae	*Limosa limosa*	M	NT			D	R
Ciconiiformes	Ciconiidae	*Anastomus oscitans*	R, M	LC		VU	I	C
		Mycteria leucocephala	R, M	LC	I	VU	I	O
Coraciiformes	Alcedinidae	*Alcedo hercules*	R	NT		VU	D	O
		Halcyon pileata	M	VU			D	C
Passeriformes	Ploceidae	*Ploceus hypoxanthus*	R	NT		VU	D	R
Strigiformes	Strigidae	*Otus sunia*	R, M	LC	II		S	R
	Tytonnidae	*Tyto alba*	R	LC	II		U	R
	Tytonnidae	*Tyto longimembris*	R	LC	II	VU	D	R
Suliformes	Anhingidae	*Anhinga melanogaster*	R	LC		VU	I	C
	Phalacrocoracidae	*Phalacrocorax carbo*	R, M	LC		VU	I	C

Note: 1. Migration status: R: Resident, M: Migrant, R, M: Resident-migrant; 2. Conservation Status: Categorized according to the IUCN Red List (2026): VU: Vulnerable, NT: Near Threatened, LC: Least Concern; 3. International Trade Protection: Species listed under the Appendices of CITES: I: Appendix I, II: Appendix II; 4. Conservation Status: Categorized according to the Vietnam Red Data Book (2007): EN: Endangered, VU: Vulnerable; 5. Global Population Trends (IUCN 2026): U: Unknown; D: Decreasing; S: Stable; I: Increasing; 6. Population distribution in Tram Chim National Park: C: Common, U: uncommon, O: Occasional; R: Rare

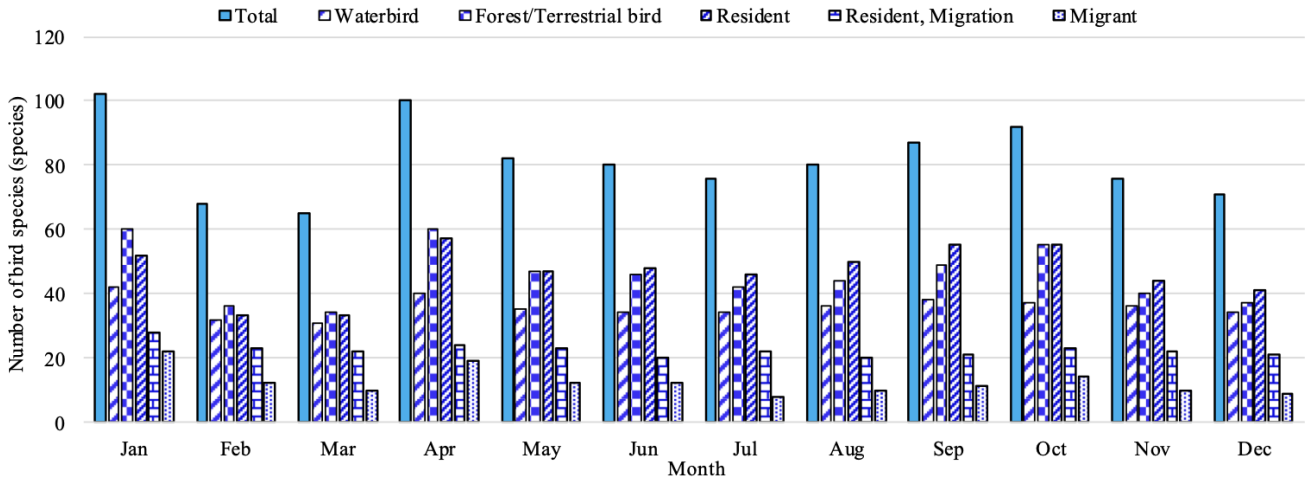

Figure 4. Number of bird species by habitat and migration status from January to December 2022

Discussion

Many bird species surveyed in Tram Chim National Park in 2022 were unique within their families and orders, a situation also observed in numerous studies on bird communities in wetlands (Ramlah et al. 2021; Malaki et al. 2022; Gill et al. 2025). Monospecificity within orders and families led to a lack of support from closely related species in maintaining populations, making them vulnerable to decline and extinction when the environment changes (Nurrofik et al. 2021), and the loss of such species will result in the loss of an important evolutionary branch of the Aves class (Siddiq et al. 2023; Gill et al. 2025) and the structural stability of bird communities in an ecosystem (Garg 2015; Tu et al. 2020; Mandal et al. 2021; Bianchini and Tozer 2023). Therefore, conservation efforts for bird populations in Tram Chim National Park should focus not only on total species (species diversity) but also on protecting unique representatives of orders and families. The Passeriformes order, with the highest diversity of families and species in the Tram Chim Ramsar site, is the youngest evolutionarily but also the most diverse, accounting for the majority of families and species in bird biodiversity reports (Yarys et al. 2024; Gill et al. 2025).

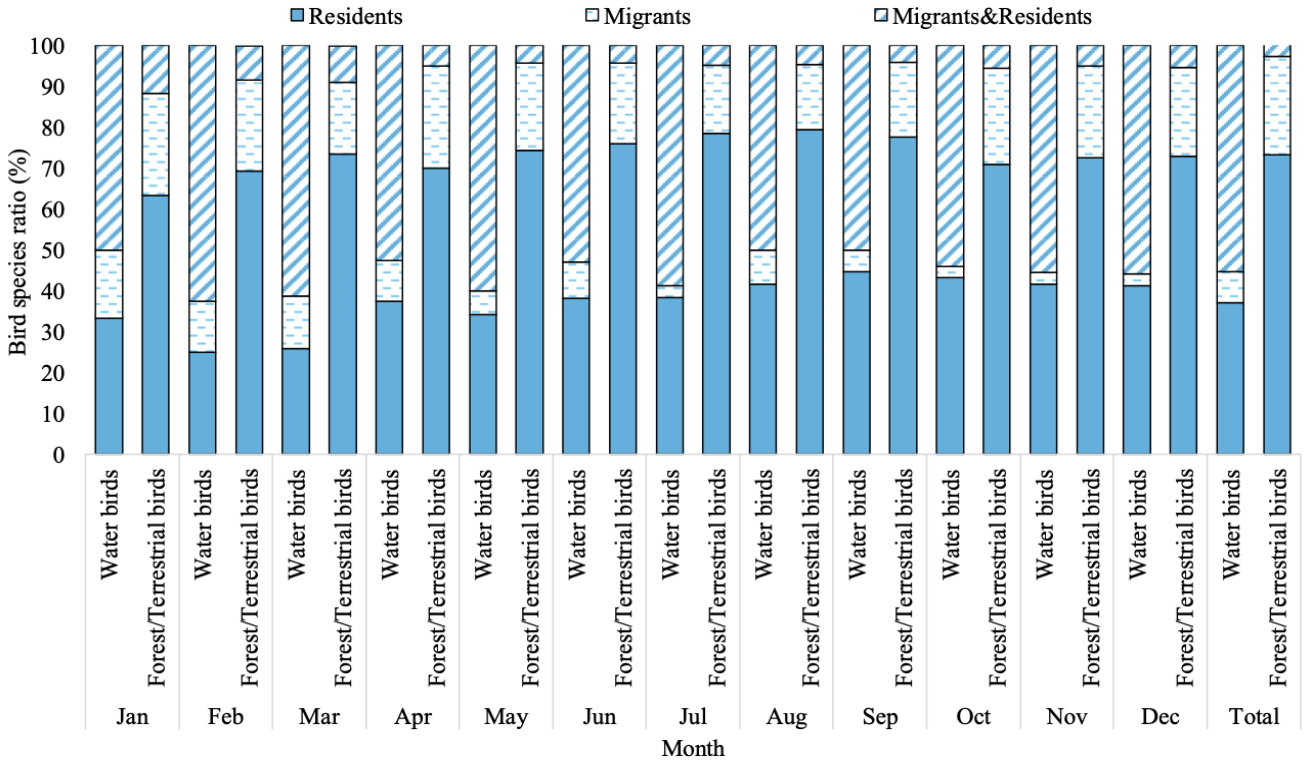

Figure 5. Fluctuation of resident and migratory waterbird species in the Tram Chim Ramsar site, Vietnam, from January to December 2022

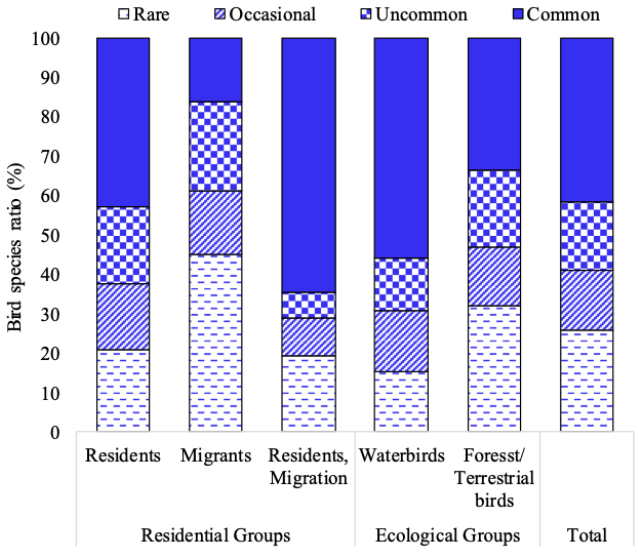

Figure 6. Presence of bird species in Tram Chim National Park, Vietnam, from January to December 2022

The species diversity of the Ardeidae family in Tram Chim National Park was similar to that in the Chariganga and Arpara Beel wetlands in Nadia, West Bengal (Mandal et al. 2021). The species diversity in this family reflected the richness of the canal system and the food sources in the wetland (Thongsoulin et al. 2019; Purify et al. 2020; Santosa et al. 2018; Pan et al. 2025). However, the dependence of this group of species on mudflats and shallow waters made them sensitive to human-controlled hydrological changes, so natural hydrological management solutions were needed to ensure the conservation of birds in this family.

The high values of d, H' and 1-λ of the bird community in Tram Chim National Park reflect the characteristics of a bird community in a natural wetland ecosystem of international importance, and may also indicate that habitat in the Ramsar area is at a minimum level (Ludwig and Reynolds 1988; Iglesias-Rios and Mazzoni 2014; Rajpar et al. 2022; Wan et al. 2025), so the values of these indices do not differ statistically between the dry and rainy seasons. Furthermore, the bird community in the Tram Chim Ramsar area is capable of maintaining a balanced structure and is not dominated by a few species with high population densities (J'>5, Table 3) (Simpson 1949; Pielou 1966; Khan et al. 2024; Kunakh et al. 2023; Wan et al. 2025). Nevertheless, during transitional months such as June, July, November and December, certain fluctuations in species diversity still occur, as evidenced by a decrease in biodiversity indices (d, H' and 1-λ) and an uneven distribution of individuals within the community (decline in J' value). The stability of population structure was significantly affected during transitional months, as clearly shown in the CA analysis results, with June, July, November, and December exhibiting low biodiversity and uniform population distribution. This could be due to seasonal hydrological changes characteristic of the Mekong Delta region and to the seasonal migration of bird species.

Because high water levels during the rainy season bring in more whitefish (Truong et al. 2022), attracting large waterbirds of high conservation value (Cui et al. 2024; Guzzo et al. 2025), while sudden environmental changes cause low water levels at the beginning and end of the rainy season. The flooding level in core area habitats such as sedges, reeds, lotus ponds, and swamps in Tram Chim Ramsar site was 2.5 to 7.5 times lower during the dry season compared to the rainy season (Ly et al. 2023). Therefore, long-term studies and assessments are needed on seasonal hydrological and fisheries variability and its impacts on bird biodiversity, especially during transitional months, to propose the most appropriate solutions for bird biodiversity conservation, particularly in the context of changing hydrology and the environment due to human impacts and climate change.

The presence of migratory birds such as *Limosa limosa*, *Gallinago gallinago* and *Spatula querquedula* demonstrated the important role of Tram Chim National Park on one of the most important and threatened bird migration routes globally-the EAAF (Crosby et al. 2025). In addition, there were resident and migratory bird groups, such as *Anastomus oscitans*, *Plegadis falcinellus*, *Dendrocygna javanica* and *Mycteria leucocephala*, that migrate in search of food through the wetlands of the Mekong River basin (Cambodia-Vietnam). In addition, the presence of 3 endangered bird species belonging to the VU and NT groups and experiencing population decline worldwide (IUCN 2026), 8 bird species listed in the Vietnamese Red Book (EN, VU), and 12 species listed in the CITES appendix (2025) was evidence of the international value of the Tram Chim National Park Ramsar site in conserving rare and threatened bird species in Vietnam and the world (Amano et al. 2018). This result also demonstrated the Vietnamese Government's efforts to fulfill international commitments to the conservation of migratory waterbirds and wetlands of international importance (VPM 2025). The absence of the Sarus crane in the Tram Chim Ramsar site may be due to the rapid decline in the number of Sarus crane in the region and worldwide (Sharma et al. 2024); and the decline in natural wetland area (Yoezer et al. 2026), changes in hydrological regimes due to water resource management in the Mekong River, impacts of climate change and hydrological management of protected areas (Sharma et al. 2024; Wan et al. 2025), in addition to increased agricultural intensity and pollution in the buffer zone (Sharma et al. 2024; Asawra et al. 2025; Dai et al. 2025).

The bird community structure in wetlands of international importance (Ramsar sites) was maintained by complex interactions between bird groups characteristic of diverse ecological environments and with different sedentary and migratory behaviors. The number of forest bird species in Tram Chim National Park was higher than the number of water bird species in all months of the year because the Melaleuca Forest habitat in Tram Chim National Park accounts for up to 35% of the protected area. Forest areas played a crucial role in maintaining the habitat for sedentary and migratory forest bird species, as these birds' habitats did not experience significant seasonal changes (Chaleekarn et al. 2022). Resident bird species consistently accounted for the highest proportion of all bird species in all surveyed months of 2022. Next, the group of partially migratory birds will help stabilize the structure of the bird community at the Tram Chim Ramsar site. In contrast, migratory birds increased the structural diversity and biodiversity of the reserve, especially during months with abundant food sources and during winter migration. Resident birds also accounted for the highest proportion of forest bird species, thus playing a key role in stabilizing the structure of this bird community. This research result was similar to that of studies by Ullah et al. (2025). However, waterbirds had the highest proportion of partially migratory species and significantly influenced stability and resilience to environmental changes (Chen et al. 2025). Therefore, conservation efforts for waterbirds in protected areas need to place greater emphasis on the management of hydrology and waterbird habitats, especially for rare species at risk of population decline in protected areas worldwide, including Vietnam.

The role of bird groups in stabilizing the structure of bird communities in the Tram Chim National Park Ramsar site was also demonstrated through their distribution patterns. The proportion of partial migratory and resident bird species was higher in the reserve compared to migratory bird groups. Furthermore, the proportion of waterbird species was higher than that of forest birds. In addition, the proportion of waterbird species was higher than that of forest birds. These results confirmed the significant role of resident, partial migratory, and waterbird species in maintaining the stability of bird community structure in Tram Chim National Park (Chan 2001).

The composition of bird functional feeding guilds in Tram Chim National Park highlights the structural diversity of the community and reflects the ecological complexity of the wetland environment. Insectivorous and fishivores species dominated the assemblage and increased during the rainy season, consistent with studies in other wetland systems (Hathurusinghe et al. 2020; Chaleekarn et al. 2022), likely due to high biological productivity in mudflats and vegetation, as well as the complexity of canopy and forest structure. Fishivores and carnivorous birds, represented mainly by Alcedinidae and Ardeidae, function as top predators, indicating the abundance of aquatic resources and the integrity of the trophic network (Sergio et al. 2005; Miranda-García et al. 2021; Shafie et al. 2023). Omnivorous species exhibited high adaptability to environmental variability and anthropogenic disturbance, reflecting flexible resource use in dynamic wetland systems (Ullah et al. 2024).

Collectively, fishivores, carnivorous, molluscivorous, and insectivorous groups accounted for approximately 66% of all species, markedly higher than reported for comparable systems such as the Indus River Basin (47.5%) (Ullah et al. 2024). Herbivorous birds, primarily waterfowl, were associated with grassland habitats and contributed to seed dispersal (Boros et al. 2023). In contrast, nectarivores and frugivorous species were relatively scarce, likely due to the limited availability of fruiting plants and seasonally variable nectar resources in Melaleuca-dominated habitats.

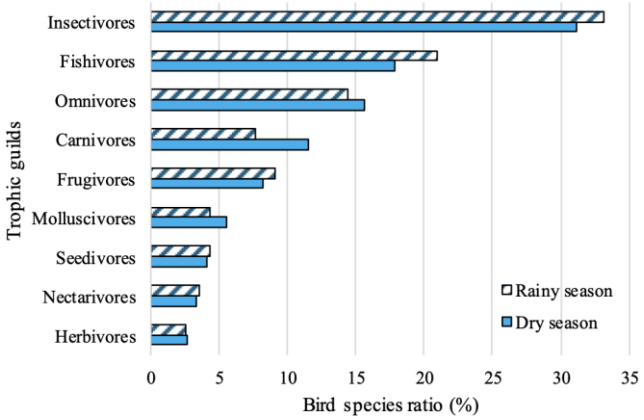

Figure 7. Proportion of bird species by food group in Tram Chim National Park from January to December 2022

Overall, the distribution of feeding guilds underscores the central role of hydrological dynamics, habitat heterogeneity, and resource availability in shaping bird community structure and maintaining biodiversity in this Ramsar wetland. The bird feeding groups exhibited seasonal changes, with fishivores and insectivorous birds increasing in the rainy season, following increased biological productivity and the migration of fish into inland areas driven by floodwaters (Cuong 2011; Mandal et al. 2021). Conversely, carnivorous and molluscivorous birds increased in the dry season, as mudflats and food sources in shallow, narrow water became abundant (Ullah et al. 2024; Wan et al. 2025). The results demonstrated the flexible adaptation of bird communities in the Tram Chim Ramsar site to seasonal hydrological conditions, ensuring the stable functioning and ecological resilience.

The study on avian diversity in Tram Chim National Park found that the bird community structure in this Ramsar site remained relatively stable. However, certain fluctuations in the diversity index were still observed during the transitional months (June, July, November and December), as well as monthly variations in the functional ecological groups of the bird community. Although this study does not directly assess hydrological and environmental variability, previous studies on hydrological conditions and fisheries resources in protected areas and studies in similar wetlands have shown that hydrological conditions are a major determinant of food sources, activity space, and breeding conditions for birds (Byrne et al. 2025; Wan et al. 2025), especially for habitat specialists sensitive to environmental changes (Kingsford et al. 2017; Yoezer et al. 2026). Therefore, the management of the Tram Chim Ramsar site should focus on proactive hydrological management (water level regulation) to maintain habitat diversity (Ferrarini et al. 2024) and restore the habitats of specialized bird groups that are highly sensitive to environmental changes, especially measures to prevent extreme drought or excessive flooding to protect bird feeding and nesting grounds (Byrne et al. 2025; Wan et al. 2025). These management strategies need to be built upon integrated monitoring programs that simultaneously measure and assess bird community dynamics alongside accurate hydrological parameters, environmental quality, habitat diversity, and seasonal food sources to ensure the sustainability of the Tram Chim ecosystem.

In conclusion, the study confirmed that the Tram Chim National Park Ramsar site was an essential center of avian diversity with 139 bird species belonging to 49 families and 17 orders, and had a high proportion of monotypic orders and families. The bird community maintained a balanced and stable structure with high diversity indices: Margalef (d: 8.14-11.97), Shannon-Wiener (H': 2.24-3.38), Pielou (J': 0.52-0.75) and Gini-Simpson (1−λ: 0.75-0.94). The bird community did not fluctuate significantly between the rainy and dry seasons; however, a decline in biodiversity and species uniformity indices was observed in the transitional months (June, July, November, and December). The presence of numerous migratory and globally threatened species (according to IUCN, CITES, and the Vietnam Red Book) confirmed that Tram Chim National Park was a crucial link in the global conservation of bird species. The community structure showed that forest birds are dominant in terms of species, but waterbirds were more prevalent, playing a stabilizing role in the ecosystem. The diverse and seasonal shifts in bird feeding groups reflected the tropical inland wetland ecosystem, creating a sustainable food web. Conservation of bird communities in the Tram Chim Ramsar site required proactive hydrological management based on natural hydrological pulses and enhanced monitoring of sensitive species and environmental variability to maintain functional connectivity for the international migratory bird network.

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