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Terrestrial vertebrate fauna in a multifunctional landscape in Gabaldon, Nueva Ecija, Philippines

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Abstract. *Gojo-Cruz PHP, Caldito JC, Catubig YDL, Cornes HM, Corpuz JS, Maniquiz SS, Matunan KGE, Pascual FJ, Miguel ESS, Siguancia GC, Turqueza DC, Madlao JP, Cruz CF, Merculio JG. 2024. Terrestrial vertebrate fauna in a multifunctional landscape in Gabaldon, Nueva Ecija, Philippines. Biodiversitas 25: 583-597.* This study was done to document the vertebrate fauna in a multifunctional landscape at the foothills of Mt. Mingan, Gabaldon, Nueva Ecija. The inventory of wild vertebrate fauna associated with the different habitat types in the area will be valuable in creating suitable management programs to reduce the impact of human activities in the area without affecting local economic activities. Standard survey techniques, including day and night transect walks, opportunistic surveys, mist-netting, and cage trapping, were employed to document vertebrate fauna in the agro-forest, around built-up areas, forest edges, lowland forest, grassland, and riparian habitats. A total of 79 species of vertebrate fauna were recorded, including 7 species of mammals, 13 species of reptiles, 9 species of amphibians, and 50 species of birds. Thirty-three (33) species were endemic to the Philippines. Regarding conservation status, eight (8) species were listed in the higher threat status under DAO 2019-09. Species richness was observed to be highest in lowland dipterocarp forests. On the other hand, species composition varies between habitats, with endemic species being more common in complex habitats such as lowland dipterocarp forests than in simpler habitats like agricultural areas. The high species richness and the presence of endemic and threatened species in the multifunctional landscape of the area highlight the need for management plans considering habitat heterogeneity and connectivity.

Keywords: Biodiversity, multifunctional landscape, vertebrate

INTRODUCTION

Multifunctional landscapes (MFL) are areas used for production, extraction, recreation, and conservation. Multifunctional landscapes provide critical benefits such as support of climate regulation, ecosystem services and community resilience, which are essential for human well-being (Meerow and Newell 2017; Fagerholm et al. 2020; Feit et al. 2021; Gonçalves et al. 2021). Such multifunctional landscapes are characterized by mosaics of semi-urban areas, heavily modified production lands and degraded native vegetation cover, occasionally interspaced or beside high-quality remnant habitat (Mendenhall et al. 2014). Due to this, a variety of habitats exists within MFLs due to the varied land use, creating a matrix of habitats that can support a diverse assemblage of vertebrate fauna that may utilize different microhabitats and resources present in adjacent habitat types, with more complex landscapes supporting greater biodiversity (Estrada-Carmona et al. 2022). According to Tuanmu and Jetz (2015), habitat heterogeneity, or the presence of different habitats in an area, has long been recognized as a key landscape characteristic determining biodiversity patterns, with landscapes having multiple and complex habitat types harboring more species due to a broader niche space. Additionally, ecotones formed between connected habitats provide additional possibilities for species coexistence (Hamm and Drossel 2017). The biodiversity associated with the different habitats in the multifunctional landscape also provides the basis for local livelihoods, where the diverse benefits are the key to their subsistence (Bridhikitti and Khadka 2020; Diansyah et al. 2021), making multifunctional landscapes environmentally and economically valuable (Kremen 2020). Further, biodiversity in multifunctional landscapes enhances ecosystem multifunctionality on local, or patch, scales as the presence of many functionally distinct species ensures complementary and efficient resource use (Angelini et al. 2015).

In the Philippines and other developing Asian countries, consolidating economic growth, human development, and environmental sustainability remains a challenge (Bridgewater et al. 2015; Martinico-Perez et al. 2018; Horigue et al. 2023), especially in underdeveloped areas where the community must rely on resource production (e.g., production of valuable crops) and extraction (e.g., logging, harvesting of firewood for charcoal-making) from biologically-diverse habitats for sustenance. Resource extraction and conversion of forest land into agricultural lands often collide with biodiversity conservation (Verdade et al. 2022), with agricultural expansion into natural ecosystems being recognized as a threat to the unique biodiversity in many tropical landscapes (Grass et al. 2019). The conversion of forests and adjacent habitat types into agricultural lands will not only threaten the forest and its biodiversity, but also threaten the lives of humans, especially those living close to forests, who are most dependent upon these habitats (Diansyah et al. 2021). Reconciling the varying land use and biodiversity conservation in multifunctional landscapes is therefore important. Therefore, conservation and development needs should be addressed together for sustainable land use (Dewi et al. 2013). Therefore, it is important to identify the different species in various habitats in a multifunctional landscape to integrate resource utilization and biodiversity conservation. This information will be valuable in determining species-habitat association, population levels, and the threats to species in the area. Research on biodiversity management on multifunctional agricultural landscapes should also help society perceive and solve problems cost-effectively (Verdade et al. 2022).

Multifunctional landscapes are common in the Philippines, especially in rural areas where the community utilizes habitats and associated resources for various purposes, including agriculture, resource extraction, recreation, and reforestation. One such MFL exists at the foothills of Mt. Mingan, Gabaldon, Nueva Ecija. Mt. Mingan, part of the Sierra Mountain Range, is characterized by lowland dipterocarp forest at about 559 meters above sea level (masl) to mossy forest at 1,785 masl and reforestation and agroforestry site surrounded by agricultural lands in the lower elevations (about 100 m) (Balete et al. 2011). Additionally, the area is being promoted as an eco-tourism site, with Danglan River, Gabaldon Falls, and Mingan Trails as the major tourist attractions. The multifunctional landscape and the area's associated biodiversity potentially promote biodiversity conservation and socio-economic development if sustainable programs (e.g., community-based forest management and sustainable tourism programs) are developed and implemented. Biodiversity surveys are therefore important, considering that conservation strategies in the Philippines, primarily identifying critical habitats and protected areas (Tabora et al. 2023), rely on the availability of up-to-date information on the species in the area.

Additionally, despite the areas' conservation significance and potential for socio-economic development, no detailed reports on the areas' vertebrate diversity are available except for Balete et al. (2011) work documenting mammals in this part of Mt. Mingan. This study was therefore conducted to document the vertebrate fauna in a multifunctional landscape in Gabaldon, Nueva Ecija. The data on the vertebrate fauna associated with the various habitats in the area is crucial in creating suitable conservation programs and management plans to protect the area's biodiversity while ensuring continued socio-economic growth through sustainable development.

MATERIALS AND METHODS

Study site

The survey site is at the foothills of Mt. Mingan, Gabaldon, Nueva Ecija, Philippines (Figure 1). Mt. Mingan, with a maximum elevation of 1,901 masl, is part of the Central Sierra Madre between Nueva Ecija and Aurora provinces. Based on the study of Corporal-Lodangco and Leslie (2017), this part of Luzon falls under cluster 4 of the Philippine Climate Zone, characterized by relatively dry months from January to April with 70-90 mm of rainfall, with a significant increase starting in May and continuing until July (the wettest month), with rainfall ranging from 270 mm to 480 mm. Rainfall gradually and monotonically decreases from August to October, further dropping in November and December.

Areas around Gabaldon Eco-Park (15.45125°N, 121.34238°E) within the Nueva Ecija University of Science and Technology-Gabaldon Campus were surveyed in this study. The sites were visited twice, in January and April 2023, with surveys lasting 3-5 days. The terrain is mostly flat, ranging from 190 to 227 masl elevations. The area, measuring 66.63 hectares, is composed of open grasslands, agricultural areas including rice agro-ecosystems, coconut and coffee plantations, reforestation sites, lowland dipterocarp forest, and built-up areas including the University compound, the Eco-Park, and residential areas. Two rivers border the survey area, Danglan River and Asan River, providing important water sources for the communities. Plants common in the area include *tibig* (*Ficus nota* (Blanco) Merr.), *ipil-ipil* (*Leucaena leucocephala* (Lam.) de Wit), *akasya* (*Samanea saman* (Jacq.) Merr.), bamboo (Arecaceae), and dipterocarps (Dipterocarpaceae). Major economic activities in the area include agriculture, with areas planted with coconut, rice, ornamental plants, and coffee. The area also serves as a tourist destination, with the Gabaldon Eco-Park being one of the drop-off points for tourists going to the Gabaldon Falls and the Mingan Trails leading to the peak of Mt. Mingan.

Survey techniques

Mammals

Mist nets with a mesh size of 36 mm and heights and lengths of 3m x 6m were used to assess volant mammals. Eight (8) mist nets were placed in areas where bats were known to congregate, such as ridge tops, footpaths, stream channels in the forest, and near fruit trees (Rickart et al. 2016). The mist nets were left up for 3-5 consecutive nights and maintained twice daily, before sunrise at (04.00-07.00 h) and at night (18.00-22.00 h) for a total of 64 net nights.

A total of 26 cage traps were used to document non-volant mammals during the surveys, totaling 208 traps days/nights. Cage traps were placed on the ground surface under root tangles, at burrow entrances, along runways, besides, or even on top of fallen logs on horizontal branches, crossed vines, or overhanging lianas (Rickart et al. 2016) to survey small non-volant mammals. Cage traps were baited with coconut/peanut butter. The traps were checked twice daily, in the early morning (after sunrise, 07.00 h) and late afternoon (before dusk, 17.00 h). Captured bats were carefully removed from the nets, photographed, and fed a sugar solution before release after relevant information such as ear length, hindfoot length, tail length, forearm length, and overall length were measured. Captured rodents were also carefully removed from the traps, photographed, and measured before release on-site.

The identification of the volant and non-volant mammals was based on the publications of recent studies conducted in Luzon, primarily the works of Balete et al. (2011) on the mammals of Mt. Mingan and Ingle and Heaney (1992) for the bats. Nomenclature is based on the Synopsis of Philippine Mammals (Heaney et al. 2010).

Herpetofaunal surveys

Transect lines were established along trails and rivers to document herpetofauna. Opportunistic sampling, visual encounter survey, and acoustic survey were used to assess and collect the amphibian species in the area (Plaza and Sanguila 2015). Searches involving 7 individuals were done in the morning between 0700 h and 1100 h for reptiles and 1500 h and 2300 h for amphibians and nocturnal reptiles, for 448 man-hours. All accessible microhabitats within each habitat where animals may be lodged were examined by raking the forest floor litter, probing epiphytes and tree hollows, upturning rocks and logs, and cracking apart rotten logs (Gojo Cruz et al. 2018). Specimens were photographed and released on-site.

Identification of species was aided by published works, including Diesmos et al. (2015) for the frogs, Welton et al. (2014) for varanid lizards, Linkem and Brown (2013), and Siler et al. (2014, 2016) for the identification of skinks, and Leviton et al. (2018) and Weinell et al. (2019) for the snakes. Nomenclature is based on the Amphibian Species of the World (Frost 2023) for amphibians and the Reptile database by Uetz et al. (2023) for reptiles.

Birds

Three transects measuring 1000 m each were established to document the birds in the area. Transects were situated along the Danglan River, Asan River, and within the campus grounds to document birds associated with human habitation. Bird surveys were conducted from 0530 h to 1000 h in the morning and between 1530 h and 1730 h in the afternoon, when the birds are usually most active. Surveys were aided with binoculars (Bushnell 20×50) and a camera (Canon Powershot XS70). Bird calls were also noted to aid in documenting and identifying species by comparing them with available data from xeno-canto.org. Additionally, mist nets used to document volant mammals were also used to capture birds, with each net checked regularly throughout the day for a total of 68 net days/nights. Birds caught in the nets were carefully removed, photographed, and released on-site.

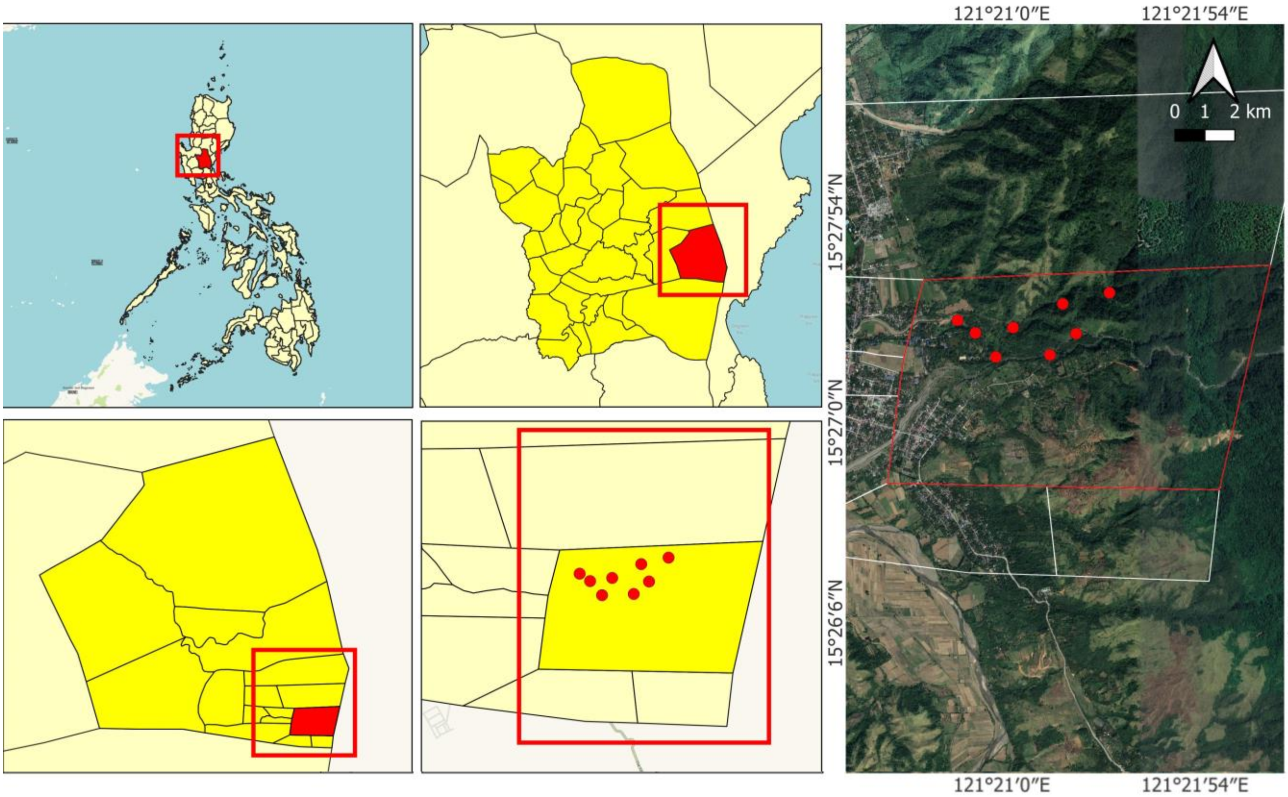

Figure 1. Location of the survey area in the foothills of Mt. Mingan, Gabaldon, Nueva Ecija, Philippines. The red circle marks the location of the sampling points around Gabaldon Eco-Park within the Nueva Ecija University of Science and Technology-Gabaldon Campus. Land cover map of the survey area based on ESRI Sentinel-2 Land Cover Time Series. Note: Green areas include the lowland dipterocarp forest, reforestation sites, and agricultural areas planted with coconut.

Birds were identified in situ with the aid of field guides by Allen et al. (2020), and Fisher and Hicks (2020). Birds were classified into feeding guilds based on their dietary requirements (insectivore, frugivore, nectarivore, carnivore, or a combination of these) and their foraging layer (terrestrial, understory, arboreal) (Duco et al. 2020). In cases where no literature was found on the foraging habit of certain species, the species were classified based on their nearest relative species (Pabico et al. 2020). The nomenclature of the recorded bird species is based on the Wild Birds Club of the Philippines (Brinkmann et al. 2023).

Conservation Status of species

The Philippine Red List of Threatened Wildlife Fauna (Department Administrative Order 2019-09) and the International Union for the Conservation of Nature (IUCN 2022) Red List served as the basis for the conservation status of species. Both databases were included in this study to determine differences in species conservation status between national (DAO 2019-09) and international (IUCN) Red Lists.

RESULTS AND DISCUSSION

Species accounts

A total of 79 species of vertebrate fauna were recorded from Gabaldon, Nueva Ecija survey sites. Information on the recorded wild vertebrate fauna, including species' scientific names, common names, and species status (residency, IUCN Red List, and DAO 2019-09) are presented in Table 1. Birds are the most species-rich vertebrate group, with 50 species. This is followed by reptiles with 13 species, amphibians represented by 9 species, and mammals with 7 species. Of the recorded vertebrates, 41.77% are endemic to the Philippines.

Profile of selected vertebrate fauna recorded in the area

Mammals

Cynopterus brachyotis. (Figure 2.A). This species is the most common species of bat documented in the area. Specimens were captured from lowland agroforest and forest edges along the two rivers, where numerous *Ficus* and other fruiting trees were observed.

Haplonycteris fischeri (Figure 2.B). The pygmy fruit bat is widely distributed and endemic to the Philippines. The species occurs in forest edges along Asan River, where many fruiting *Ficus* trees are present. It was observed that no specimen was recorded in areas along Danglan River, which is characterized by stronger water flow and fewer, widely dispersed *Ficus* trees.

Otopteropus cartilagonodus (Figure 2.C). The Luzon fruit bat is restricted to Luzon Island, where the species occupy a variety of habitat types at various elevations. Balete et al. (2011) reported that the species were most common in the higher-elevation mossy forest of Mt. Mingan, while the specimens in this study were documented in the primary forest at 229 masl.

Ptenochirus jagori (Figure 2.D). This medium-sized species of fruit bat is endemic to the Philippines except in the Palawan Faunal Region. Specimens were captured in primary forests and agricultural areas where coffee plants were grown.

Reptiles

Bronchocela marmorata (Figure 2.E). The Marbled Crested Lizard is recognized for its distinct features of green and black color patterns. It is endemic in the Philippines, including Luzon Island. Most individuals were observed at night when they rested among the trees covered in vines or in bamboo thickets.

Draco spilopterus (Figure 2.F). The Philippine flying dragon is most active during the early morning and late afternoon when they are observed gliding from tree to tree. Individuals were recorded in the Eco-Park and forest edges where tall trees like coconut (*Cocos nucifera*) and acacia (*Samanea saman*) occur.

Brachymeles ilocandia (Figure 2.G). The species is primarily terrestrial, living on the forest floor and under leaf litter, and feeds on small invertebrates such as insects and spiders. Distribution models by Siler et al. (2016) showed that this species, which was first discovered in Northern Sierra Madre, may also occur in Central and Southern Sierra Madre. The single specimen documented in the study area provides a significant range extension for this species. The specimen recorded in this study was captured from a rotting log in an area planted with mahogany (*Swietenia macrophylla* G.King).

Eutropis borealis (Figure 2.H). During the day, this species was commonly seen scampering in grasslands, agricultural areas, and forest edges. The species feeds on various small invertebrates, such as insects and spiders.

Eutropis cumingi (Figure 3.A). Another locally abundant species, *E. cumingi*, occurs in sympatry with other *Eutropis* species. They were commonly observed in agricultural lands, grasslands, or forest edges along river banks and streams.

Lamprolepis smaragdina philippinica (Figure 3.B). An arboreal species of skink, *L. smaragdina philippinica*, was observed in areas around the Eco-Park, with a few individuals inhabiting denuded trees within the forest interiors. Individuals were more active during the early morning when they could be seen basking or scampering along tree trunks.

Pinoyscincus jagori (Figure 3.C). The Filipino skink is endemic to the Philippines, where the species has been recorded in various habitat types. Compared to other species of skinks in the area, *P. jagori* were more often encountered among grasses near aquatic habitats, scampering under the vegetation once disturbed.

Gekko gecko (Figure 3.D). This large, nocturnal lizard was observed to be common around human habitation, where they can be seen or heard calling from ceilings or tree holes. Their distinctive calls can also be heard from tall trees along forest edges and riparian habitats.

Table 1. Checklist of vertebrate wildlife species recorded in the multifunctional landscape of Gabaldon River, Nueva Ecija, Philippines, showing the habitat where the species was recorded, the species distribution status, and conservation status

Species	Common name	Habitat					Status		
		BUA	LDF	RS	AA	OG	Distribution status	IUCN Red List	DAO 2019-09
Mammals									
Muridae									
Rattus tanezumi Temminck 1844	Asian house rat	+		+	+		Introduced	LC	OWS
Pteropodidae									
Cynopterus brachyotis (Muller 1838)	Lesser short-nosed fruit bat		+	+	+		Native	LC	OWS
Haplonycteris fischeri Lawrence 1939	Pygmy fruit bat		+				Endemic	LC	OWS
Macroglossus minimus (E. Geoffroy 1810)	Lesser long-tongued fruit bat		+	+			Native	LC	OWS
Otopteropus cartilagonodus Kock 1969	Luzon fruit bat		+				Endemic	LC	OWS
Ptenochirus jagori (Peters 1861)	Greater musky fruit bat		+				Endemic	LC	OWS
Viverridae									
Paradoxurus hermaphroditus philippinensis (Pallas 1777)	Philippines palm civet		+	+			Native	LC	OWS
Amphibians									
Bufonidae									
Rhinella marina (Linnaeus 1758)	Cane toad	+		+	+		Introduced	LC	OWS
Ceratobatrachidae									
Platymantis dorsalis (Dumeril 1853)	Common forest frog		+	+			Endemic	LC	OWS
Dicroglossidae									
Limnonectes macrocephalus (Inger 1954)	Luzon fanged frog		+				Endemic	NT	OTS
Occidozyga laevis (Gunther 1858)	Common puddle frog		+				Native	LC	OWS
Microhylidae									
Kaloula pulchra Gray 1831	Asian painted frog	+		+			Introduced	LC	OWS
Ranidae									
Hylarana erythraea (Schlegel 1837)	Green paddy frog	+		+	+		Introduced	LC	OWS
Pulchrana similis (Günther 1873)	Laguna del bay frog		+				Endemic	LC	OWS
Sanguirana luzonensis (Boulenger 1896)	Luzon stream frog		+				Endemic	LC	OWS
Rhacophoridae									
Polypedates leucomystax (Gravenhorst 1829)	Common tree frog	+	+	+	+		Native	LC	OWS
Reptiles									
Agamidae									
Bronchocela marmorata Gray 1845	Marbled crested lizard		+		+		Endemic	LC	OTS
Draco spilopterus (Wiegmann 1834)	Philippine flying dragon	+		+	+		Endemic	LC	OWS
Scincidae									
Brachymeles ilocandia Siler et al. 2016	Ilokano slender skink			+			Endemic	LC	OWS
Eutropis borealis (Brown and Alcala 1980)	Northern two-stripe mabuya	+	+	+	+	+	Endemic	LC	OWS
Eutropis cumingi (Brown and Alcala 1980)	Cuming's mabuya	+	+	+	+	+	Endemic	LC	OWS
Eutropis multifasciata (Kuhl 1820)	Common sun skink	+	+	+	+	+	Native	LC	OWS
Lamprolepis smaragdina philippinica (Mertens 1928)	Emerald tree skink	+	+	+	+		Endemic	LC	OWS
Parvoscincus sp.	-		+				-	-	-
Pinoyscincus jagori (Peters 1864)	Filipino's skink		+				Endemic	LC	OWS
Gekkonidae									
Gekko gecko (Linnaeus 1758)	Tokay gecko	+	+	+	+		Native	LC	OTS

Hemidactylus frenatus Dumeril and Bibron, 1836	Common house gecko	+		+			Native	LC	OWS
Colubridae									
Boiga dendrophila divergens Taylor 1922	Mangrove snake		+				Endemic	LC	OTS
Lycodon capucinus Boie 1827	Wolf snake	+					Native	LC	OWS
Birds									
Accipitridae									
Butastur indicus (Gmelin 1788)	Grey-faced buzzard		+				Migrant	LC	OWS
Haliastur indus (Boddaert 1783)	Brahminy kite		+				Native	LC	OWS
Spilornis holospilus Vigors 1831	Philippine serpent eagle		+		+	+	Endemic	LC	OWS
Alcedinidae									
Alcedo atthis (Linnaeus 1758)	Common kingfisher		+	+			Migrant	LC	OWS
Halcyon gularis (Kuhl 1820)	Brown-breasted kingfisher		+	+			Native	LC	OWS
Apodidae									
Collocalia marginata Salvadori 1882	Grey-rumped swiftlet	+	+	+	+	+	Endemic	LC	OWS
Hirundapus celebensis (Sclater 1866)	Purple needletail		+				Native	LC	OWS
Ardeidae									
Ardea purpurea (Linnaeus 1766)	Purple heron	+			+		Native	LC	OWS
Butorides striata (Linnaeus 1758)	Striated heron	+			+		Native, Migrant	LC	OWS
Artamidae									
Artamus leucorynchus (Linnaeus 1771)	White-breasted woodswallow	+		+	+		Native	LC	OWS
Bucerotidae									
Penelopides manillae (Boddaert 1783)	Luzon hornbill		+	+			Endemic	LC	VU
Campephagidae									
Coracina striata (Boddaert 1783)	Bar-bellied cuckooshrike	+		+	+		Native	LC	OWS
Lalage nigra (Pennant 1781)	Pied triller	+		+	+		Native	LC	OWS
Pericrocotus divaricatus (Raffles 1822)	Ashy minivet	+	+	+			Migrant	LC	OWS
Columbidae									
Geopelia striata (Linnaeus 1766)	Zebra dove	+			+	+	Native	LC	OWS
Macropygia tenuirostris Bonaparte 1854	Philippine cuckoo-dove		+				Near endemic	LC	OWS
Phapitreron leucotis (Temminck 1823)	White-eared brown dove		+		+		Endemic	LC	OWS
Spilopelia chinensis (Scopoli 1876)	Spotted dove	+	+				Native	LC	OWS
Corvidae									
Corvus macrorhynchos Wagler 1827	Large-billed crow	+		+	+		Native	LC	OWS
Cuculidae									
Dasylophus cumingi (Fraser 1839)	Scale-feathered malkoha		+	+			Endemic	LC	OWS
Dasylophus superciliosus Dumont 1823	Rough-crested malkoha		+	+			Endemic	LC	OWS
Eudynamys scolopaceus (Linnaeus 1758)	Asian koel	+		+	+	+	Native	LC	OWS
Dicaeidae									
Dicaeum australe (Hermann 1783)	Red-keeled flowerpecker	+	+	+	+	+	Endemic	LC	OWS
Estrildidae									
Lonchura atricapilla (Vieillot 1807)	Chestnut munia	+			+	+	Native	LC	OWS
Falconidae									
Microhierax erythrogenys (Vigors 1831)	Philippine falconet		+				Endemic	LC	OWS
Hemiprocnidae									
Hemiprocne comata (Temminck 1824)	Whiskered treeswift		+				Native	LC	OWS
Laniidae									
Lanius cristatus Linnaeus 1758	Brown shrike	+		+	+	+	Migrant	LC	OWS
Meropidae									

Merops philippinus Linnaeus 1766	Blue-tailed bee-eater	+		+	+	+	Native	LC	OWS
Monarchidae									
Hypothymis azurea (Boddaert 1783)	Black-naped monarch		+		+		Native	LC	OWS
Motacillidae									
Motacilla cinerea Tunstall 1771	Grey wagtail		+				Migrant	LC	OWS
Muscicapidae									
Copsychus mindanensis (Boddaert 1783)	Philippine magpie-robin	+	+	+	+		Endemic	LC	OWS
Muscicapa griseisticta (Swinhoe 1861)	Grey-streaked flycatcher	+					Migrant	LC	OWS
Nectariniidae									
Cinnyris jugularis (Linnaeus 1766)	Olive-backed sunbird	+		+	+	+	Native	LC	OWS
Leptocoma sperata (Linnaeus 1766)	Purple-throated sunbird		+				Endemic	LC	OWS
Oriolidae									
Oriolus chinensis Linnaeus 1766	Black-naped oriole	+		+	+		Native	LC	OWS
Paridae									
Pardaliparus elegans (Lesson 1831)	Elegant tit		+	+	+	+	Endemic	LC	OWS
Passeridae									
Passer montanus (Linnaeus 1758)	Eurasian tree sparrow	+			+		Introduced	LC	OWS
Phylloscopidae									
Phylloscopus examinandus Stresemann 1913	Kamchatka leaf warbler		+				Migrant	LC	OWS
Picidae									
Yungipicus maculatus (Scopoli 1786)	Philippine pygmy woodpecker	+	+		+		Endemic	LC	OWS
Psittacidae									
Bolbopsittacus lunulatus (Scopoli 1786)	Guaiabero	+	+				Endemic	LC	OWS
Loriculus philippensis (Müller 1776)	Philippine hanging parrot	+	+				Endemic	LC	CR
Pycnonotidae									
Hypsipetes philippinus (Forster 1795)	Philippine bulbul	+	+	+	+	+	Endemic	LC	OWS
Pycnonotus goiavier (Scopoli 1786)	Yellow-vented bulbul	+		+	+		Native	LC	OWS
Rallidae									
Poliolimnas cinereus (Vieillot 1819)	White-browed crake	+					Native	LC	OWS
Rallina eurizonoides Lafresnaye 1845	Slaty-legged crake	+					Native	LC	OWS
Rhipiduridae									
Rhipidura nigritorquis (Vigors 1831)	Philippine pied fantail	+		+	+		Endemic	LC	OWS
Sturnidae									
Sarcops calvus (Linnaeus 1766)	Coleto		+	+			Near endemic	LC	OWS
Turdidae									
Geokichla cinerea (Bourns and Worcester 1894)	Ashy thrush	+					Endemic	VU	VU
Zoothera aurea (Holandre 1825)	White's thrush	+		+			Migrant	LC	OWS
Zosteropidae									
Zosterops nigrorum Tweeddale 1878	Yellowish white-eye	+		+	+		Endemic	LC	OWS

Notes: BUA: built-up areas; LDF: Lowland dipterocarp forest; RS: Reforestation Site; AA: Agricultural areas; OG: Open grassland. CR: Critically Endangered; VU: Vulnerable; NT: Nearly Threatened; OTS: Other Threatened Species; OWS: Other Wildlife Species

Amphibians

Platymantis dorsalis (Figure 3.E). This endemic and leaf litter frog is widespread throughout Luzon. This species is a direct-developer, bypassing the tadpole stage commonly observed in other frog species. Most individuals were seen on leaf litter on the forest floor and along the river bank.

Limnonectes macrocephalus (Figure 3.F). These large fanged frogs were encountered in all habitat types, in vegetation and rock crevices around water sources. They were referred to as fanged frogs because they generally have extremely big teeth that are absent or very small in other frog species. This frog species is known to be consumed for its meat in other parts of Luzon (Gojo Cruz et al. 2018). It is classified as Near Threatened (NT) under the IUCN and OTS under DAO 2019-09, with habitat loss and hunting as major threats to the species.

Pulchrana similis (Figure 3.G). This species of stream frog, characterized by the presence of two yellow dorso-lateral lines on a brown dorsum is found all over Luzon (Diesmos et al. 2015), in undisturbed streams and rivers in forests at various elevations (McLeod et al. 2011). Individuals were encountered in vegetation and rocks around streams and rivers, especially in areas with slower water flow.

Birds

Butastur indicus (Figure 3.H). This species is one of the eight migratory bird species recorded in the area during the survey. The species is evaluated by the IUCN as Least Concern and as OWS under the Philippine Red List. It is a long-winged brownish raptor with a grey head with pale supercilium, white throat with dark mesial streak, brown upperparts and breasts, and whitish belly with brown bars. Individuals were observed during the early morning and in the early afternoon, soaring above the canopy in areas around rivers and the agroforest, likely in search of prey.

Figure 2. Representative photographs of documented wild vertebrate fauna. A. Lesser short-nosed fruit bat; B. Lesser long-tongued fruit bat; C. Luzon fruit bat; D. Greater musky fruit bat; E. Marbled crested lizard; F. Philippine Flying Dragon; G. Ilokano Slender Skink; and H. Northern two-stripe Mabuya

Alcedo atthis (Figure 4.A). This species is a fairly common visitor recorded throughout the Philippines. The species is classified as Least Concern under the IUCN and OWS in the Philippine Red List (PRL). Individuals were observed perched on small branches or hanging vegetation around streams or pools of water.

Penelopides manillae (Figure 4.B). This species is endemic to the Greater Luzon Faunal Region, corresponding to the Luzon Pleistocene Aggregate Island Complex (PAIC), composed of islands linked in the past due to Pleistocene sea level fall during glacial periods (Vallejo 2014) with a faunal assemblage distinct from the rest of the Philippines. *P. manillae* was evaluated as Least Concern by the IUCN and Vulnerable under the PRL. Individuals were often seen perched on exposed branches of trees.

Macropygia tenuirostris (Figure 4.C). This medium-large pigeon is fairly common and widespread resident. The species is considered as Least Concern in the IUCN and OWS in the Philippine Red List. Individuals were common in areas around Asan River with large *Ficus* trees.

Dasylophus superciliosus (Figure 4.D). This species of malkoha is smaller and glossier than *L. cumingi*. Its distinctive red hair-like eyebrow crest can distinguish it from its congener. Individuals were active in the early morning around Asan River, where they can be seen flying from tree to tree. This bird is classified as Least Concern in the IUCN and OWS in the Philippine Red List.

Figure 3. Representative photographs of documented wild vertebrate fauna. A. Cuming's Mabuya; B. Emerald Tree Skink; C. Filipino's Skink; D. Tokay Gecko; E. Common forest frog; F. Luzon fanged frog; G. Laguna del Bay frog; and H. Grey-faced Buzzard

Muscicapa griseisticta (Figure 4.E). This monotypic species of flycatcher is a common winter visitor in the Philippines. These small grey flycatchers were commonly encountered in areas with leafless trees or cable wires. The species can be easily distinguished by its grey-streaked underparts, hence its name.

Loriculus philippensis (Figure 4.F). The Philippine Hanging parrots, also called Colasisi, are endemic species that are common and widespread throughout the Philippines but absent in Palawan and Sulu archipelago. These small parrots are evaluated as Least Concern by the IUCN but are considered Critically Endangered in the Philippine Red List due to hunting for the wildlife trade. They are predominantly green and have a distinctive red patch on their head and rump with an orange bill. Individuals were common around Danglan River and were also observed in human-modified habitats with tall trees.

Geokichla cinerea (Figure 4.G). This shy grey, black, and white thrush was found around vegetation along roads in human-modified habitat, where they were seen together with other birds, notably with zebra doves (*G. striata*). It is evaluated as vulnerable in both IUCN and the Philippine Red List due to habitat loss.

Zosterops nigrorum (Figure 4.H) This yellowish-olive white eye occurs in large numbers even in human-disturbed areas such as around the coffee plantations and the EcoPark. Most individuals were seen during the day when they formed flocks with other birds, such as flowerpeckers (*D. australe*), warblers (*P. examinandus*), and monarchs (*H. azurea*).

Figure 4. Representative photographs of documented wild vertebrate fauna. A. Common kingfisher; B. Luzon hornbill; C. Philippine cuckoo-dove; D. Rough-crested malkoha; E. Grey-streaked flycatcher; F. Philippine hanging parrot; G. Ashy thrush; and H. Yellowish white-eye

This study documented the vertebrate fauna in the different habitats in Gabaldon EcoPark, Nueva Ecija, which is part of the Mingan Mountains, providing baseline information on the areas' species composition. Conducting biodiversity studies in multifunctional landscapes is important in documenting species and their distribution in different habitat types. The result of biodiversity studies in multifunctional landscapes is a key component in identifying habitat types that require spatial prioritization, i.e., the identification of priority areas for conservation action, that is needed for decision-making at various levels (Klimek et al. 2014; Gonzalez-Maya et al. 2016; Kujala et al. 2017). For instance, information on the occurrence of species, in particular endemic and threatened species in an area, had been instrumental in identifying critical conservation areas in Ilocos Norte in Luzon (Batuyong et al. 2020); Palawan in the Western Philippines (Supsup et al. 2023), and Cotabato in Central Mindanao (Tabora et al. 2023).

Comparisons with other studies

In terms of species richness compared to adjacent areas in the Caraballo and Sierra Madre, the study recorded fewer vertebrate fauna species. In the case of herpetofauna, a higher number of species of amphibians and reptiles were documented by Gojo Cruz et al. (2018) in the Pantabangan-Carranglan Watershed in the Caraballo, with 59 species of herpetofauna. Additionally, Pabico et al. (2020) recorded 92 species of birds, also in the Pantabangan-Carranglan Watershed. Balete et al. (2011) reported 35 species of mammals in parts of the Mingan Mountains. The difference in the number of species detected is due to the difference in the survey duration, with the aforementioned studies involving multiple and longer site visits covering a wider range of habitats at various elevational ranges. Also, the methods employed in this survey may not be adequate to document all the species in the area. Moreover, additional methods may provide a more comprehensive list of species in an area (Budka et al. 2022; Bolitho et al. 2023). For instance, documenting insect bats and nocturnal non-volant mammals in an area may require specialized equipment like harp-traps and camera traps, respectively. The use of pitfall traps to capture fossorial and leaf-litter herpetofauna and the use of canopy nets to capture birds that occupy the higher strata of the forest should also be done to document species that occupy these layers of the forest. According to Supsup et al. (2020), comparison of species richness amongst sites/studies is only possible if systematic and intensive surveys have been completed, accounting for the potential effects of variable environmental conditions, hence the need for continuous and more extensive surveys. However, despite the shorter survey duration and the limited survey methods employed in this study, it can already be observed that the multifunctional landscape of Gabaldon, Nueva Ecija, is home to a wide variety of vertebrate fauna, with species composition comparable to that observed in other parts of the Caraballo (Alviola et al. 2011; Gojo Cruz et al. 2018; Pabico et al. 2020) and Sierra Madre Mountain Ranges (Balete et al. 2011; Brown et al. 2013; Duco et al. 2021; Duco et al. 2023). It can be expected that the number of species that may occur in the area will increase as more surveys covering different seasons and elevational ranges are conducted.

Species abundance, endemicity, and conservation status

A total of 1,043 individuals representing 79 species were recorded in the different habitats in the survey area. The most abundant mammal in the area is the lesser short-nosed fruit bat (*C. brachyotis*), with 239 individuals documented. This species thrives in diverse types of habitats, even in disturbed lowland habitats such as agricultural and residential areas. Among the amphibians, the Luzon stream frog (*S. luzonensis*) recorded the highest number of individuals (n=36), with most of the individuals observed perched on rocks along the Asan River. On the other hand, skinks, in particular, the common sunskink (*E. multifasciata*) and the emerald tree skink (*L. smaragdina philippinica*), are the most common reptile seen in the area with 26 and 20 individuals, respectively. Most of the individuals were observed around built-up areas and agricultural areas during the early morning when they could be seen basking in large rocks or fallen logs. Among birds, the family Columbidae had the highest number of species, with 4 representative species. However, the most abundant birds in the area were the grey-rumped swiftlet (*C. marginata*) and Philippine bulbul (*H. philippinus*), which were observed in all habitat types. In terms of bird feeding guild, arboreal insectivore-frugivore is the most dominant feeding guild in the study, with 10 species belonging to this group.

The vertebrate fauna of the surveyed areas included endemic, native, and introduced species. Among mammals, three species, pygmy fruit bat (*H. fischeri*), Luzon fruit bat (*O. cartilagonodus*), and the greater musky fruit bat (*P. jagori*), are known to be endemic to the Philippines. These species are often found in areas where there is an ample number of fruiting trees. Only one species, the Asian house rat (*R. tanezumi*), was introduced and captured around human habitation and agro-forest. Out of the 9 species of amphibians recorded from the survey areas, 4 species are endemic: Common forest frog (*P. dorsalis*), Luzon fanged frog (*L. macrocephalus*), Laguna del bay frog (*P. similis*), and Luzon stream frog (*S. luzonensis*). Additionally, introduced species, including the common toad (*R. marina*), Asian painted frog (*K. pulchra*), and the green paddy frog (*H. erythraea*), were also documented in areas around human habitation. Among reptiles, eight (8) of the documented species are endemic to the Philippines, while 18 of the documented birds are Philippine endemics.

Most of the species recorded in the area were evaluated to be in the lower threat status based on the IUCN Red List (2022), with the exemption of the Luzon fanged frog (*L. macrocephalus*) and Ashy thrush (*G. cinerea*), which were evaluated as near threatened and vulnerable, respectively. On the other hand, under DAO 2019-09, four species of herpetofauna, namely Luzon fanged frog (*L. macrocephalus*), marbled crested lizard (*B. marmorata*), tokay gecko (*G.gecko*), and mangrove snake (*B. dendrophila divergens*) were evaluated as other threatened species (OTS), with hunting as the common threats to these species. Several bird species were also at the higher threat status, including the Philippine hanging parrot (*L. philippinensis*), evaluated as critically endangered, and Luzon hornbill (*P. manillae*) and Ashy thrush (*G. cinerea*) listed as vulnerable species. The presence of several threatened species (e.g., *L. macrocephalus, B. marmorata, P. manillae, L. philippinensis, G. cinerea*) even in human-modified habitats showed that the maintenance of biodiversity corridors is potentially important in allowing local populations of these species to move between forested and non-forested sites (White and Smith 2018).

Species occurrence among habitat types

The varied habitat types in the area support diverse vertebrate fauna due to broader niche space and more resources following the habitat heterogeneity hypothesis concept (Stein et al. 2014; Hamm and Drossel 2017). Among the different habitats, the lowland dipterocarp forest has the greatest number of species, with 49 species recorded. This is followed by built-up areas and reforested sites with 44 and 42 species, respectively. The open grassland has the lowest number of species, with only 14 species, mostly birds, observed in this habitat type. The higher species richness in areas with complex vegetation structure and lower levels of disturbance was also observed in other studies throughout the Philippines (e.g., Decena et al. 2020; Duco et al. 2020; Supsup et al. 2020; Senarillos et al. 2021). The proximity of the lowland dipterocarp forest, built-up areas, and reforestation sites create ecotones that may serve as suitable habitats for generalist and specialist species. Danglan and Asan Rivers may also serve as corridors, allowing species to move from one habitat to another, likely resulting in comparable species richness between habitats. Maintaining the heterogeneity and connectivity of the habitat types in the multifunctional landscape will be important in maintaining species diversity.

Although species richness is not markedly different among habitat types, species composition still varies based on the result of this study. This variation in species composition results from the differences in vegetation structure, canopy height, and plant density that affect the available microhabitats, microclimatic conditions, and resources (Terán-Juárez et al. 2021; Thiel et al. 2021; Bitani et al. 2023). Variation in species composition in areas with multiple habitat types and along disturbance gradients had also been observed for herpetofauna (Gojo Cruz et al. 2016, 2019; Sanguila et al. 2020; Supsup et al. 2020); birds (Amoroso et al. 2018; Pabico et al. 2020; Duco et al. 2021), and mammals (Rickart et al. 2021; Woodgate et al. 2023). In this study, endemic species are often encountered within forested areas, along forest edges, and less disturbed sites. On the other hand, it was observed that native and introduced species of amphibians (*R. marina* and *H. erythraea*) and mammals (*R. tanezumi*) are more common in built-up areas than in more intact forests since these species are more adaptable or can tolerate varying levels of habitat modifications. Decena et al. (2020) and Reginaldo and Ong (2021) also observed that *H. erythraea* and *R. tanezumi* were strongly associated with open habitats. Consequently, the proliferation of these invasive species in areas adjacent to forests could result in the displacement of native and endemic fauna (Pili et al. 2019) through competition, direct predation, or the introduction of diseases. Some species (e.g., *C. brachyotis, E. multifasciata, E. borealis, H. philippinus, O. chinensis*) were observed in almost all habitat types since these species are considered habitat generalist.

Species and habitat conservation

The high species richness and several endemic and threatened vertebrate fauna highlight the need for the conservation of the areas' various habitats. Despite the short sampling period, the survey showed that the lowland dipterocarp forest is a potential critical habitat, considering that this habitat harbors numerous endemic species (n=30) and several species of conservation significance. In this regard, maintaining the lowland dipterocarp forest, the surrounding habitat types, and the two rivers that may potentially serve as biodiversity corridors in the area should be prioritized to conserve the area's biodiversity.

Increasing biodiversity can be done by changing to low land-use intensity or by changing landscape structure by increasing habitat heterogeneity and connectivity (Maskell et al. 2019). The successful management of multifunctional landscapes may require a combination of land-sharing and land-sparing measures, taking into consideration the maintenance of large, connected habitats to reduce the effect of habitat fragmentation (Pfeifer et al. 2017; Grass et al. 2019; Verdade et al. 2022). Strict conservation areas and biodiversity corridors in multifunctional landscapes could allow species, especially those that can be adversely affected by edge effects or small habitat size, to move from one area to another. Area-based conservation targets should include large-scale networks that include connectivity between protected areas, protection of endangered and threatened species or ecosystems, and ecologically intact wilderness areas (Woodley et al. 2019). Integrating biodiversity data in improving conservation and management strategies is important (Sanguila et al. 2021; Supsup et al. 2023), especially in creating land use plans in a multifunctional landscape. The baseline data on the vertebrate fauna and their occurrence in the different habitat types in the multifunctional landscape of Gabaldon, Nueva Ecija, will be valuable in identifying conservation areas and areas that can be utilized for socio-economic activities. With this information, the Local Government Unit (LGU) will be able to identify critical habitats that are key to species survival by integrating the data in their land use plan and identifying local conservation areas. Additionally, the information generated in this study will be valuable in developing the area's eco-tourism program through the development of information, education, and communication (IEC) materials, which are important in increasing biodiversity awareness and socio-economic development. The baseline data generated in this study will also be useful in monitoring future changes in species composition, diversity, and distribution concerning habitat and land use changes brought about by human activities in the area. Therefore, it is recommended that additional and regular surveys be done in the area.

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