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Communication

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Avian species richness in traditional rice ecosystems: a case study from upper Myanmar

Steven G. Platt [1], Myo Min Win [2], Naing Lin [3], Swann Htet Naing Aung [4], Ashish John [5] & Thomas R. Rainwater [6]

[1–4] Wildlife Conservation Society–Myanmar Program, No. 12, Nanrattaw St., Kamayut Township, Yangon, Myanmar.
[5] Wildlife Conservation Society–Cambodia Program, #21 Street 21, Sangkat Tonle Bassac, Kam Chamkamon, P.O. Box 1620, Phnom Penh, Cambodia.
[6] Tom Yawkey Wildlife Center & Belle W. Baruch Institute of Coastal Ecology and Forest Science, Clemson University, P.O. Box 596, Georgetown, South Carolina 29442, USA.
[1] sgplatt@gmail.com, [2] mmwin@wcs.org, [3] nilzmw@gmail.com, [4] saung@wcs.org, [5] ajohn@wcs.org, [6] trrainwater@gmail.com (corresponding author)

Abstract: Rice *Oryza sativa* ecosystems provide foraging and nesting habitat for a variety of birds. Myanmar is a major rice-producing nation and yet bird use of rice ecosystems remains largely unstudied. We present the results of a case study of avian species richness in a traditional rice ecosystem at Limpha Village in upper Myanmar. The rice field at Limpha occupies 17.5 ha where a single crop is produced each year without chemical inputs (fertilizer and pesticides). Village lands are contiguous with the buffer zone of Htamanthi Wildlife Sanctuary. We conducted bird surveys of the rice field during dry and wet seasons (2013–20) and documented the occurrence of 85 species (exclusive of Buttonquail these included 58 resident species, 20 migratory species, six species with both resident and migratory populations in upper Myanmar), including 10 species of conservation concern. Species richness was greatest during the dry season when an influx of Palearctic migrants was present. We ranked 52 species as Common, 23 as Uncommon, and 10 as Rare. Most birds used the rice field as foraging rather than breeding habitat. Insectivore was the most common feeding guild (43 species), followed by Omnivore (22 species), Carnivore (12 species), Granivore (6 species), Frugivore (1 species), and Nectarivore (1 species) guilds. We observed eight species associated with domestic Water Buffalo *Bubalus bubalis* and 15 species foraging at active fires or in burned areas in the rice field. Piles of rice straw are important foraging sites for several species. Low intensity agricultural practices, habitat heterogeneity, and proximity to the nearby swamp, forest, & Chindwin River are probably responsible for the relatively high avian species richness at Limpha. Future agricultural intensification could negatively impact avian species richness in the Limpha rice field. Our findings suggest that traditional rice agriculture is compatible with conservation objectives in the buffer zone of Htamanthi Wildlife Sanctuary. Our study, however, requires replication before generalizations can be made concerning the value of traditional rice ecosystems to avian conservation in Myanmar.

Keywords: Bird conservation, bird diversity, buffer zone, Chindwin River, Htamanthi Wildlife Sanctuary, *Oryza sativa*, rice field, Sagaing Region, traditional agriculture, water buffalo.

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Competing interests: The authors declare no competing interests.

For **Author details, Author contributions** & **Myanmar abstract** see end of this article.

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INTRODUCTION

Land devoted to the production of food, fiber, plant oils, and other resources used by human society occupies a substantial and increasing proportion of terrestrial biomes around the world (Bennett et al. 2006). As the extent of anthropogenically-modified landscapes expands to meet the needs of a growing human population, the fate of global biodiversity will increasingly depend on the quality and characteristics of farming landscapes (Pimental et al. 1992; Pino et al. 2000; Perfecto et al. 2009; Friskhoff et al. 2014). Farmlands vary widely in their ability to support biodiversity with some species being lost from agricultural landscapes, while other species persist and can even proliferate (Friskhoff et al. 2014). Despite the species loss that accompanies the conversion of wildlands to farmland (Rutt et al. 2019), a growing body of literature suggests that agricultural landscapes can make substantial contributions to global biodiversity conservation (Pimental et al. 1992; Jackson & Jackson 2002; Perfecto et al. 2009; Van der Weijden 2010).

Rice *Oryza sativa* is one of the most important food crops in the world (Forĕs & Comín 1992; Bambaradeniya & Amarasinghe 2003). Rice is the primary source of nutrition for over half of the global human population and constitutes one-fifth of the world's grain supply (Elphick 2010). Rice is grown in at least 114 countries, rice ecosystems occupy >156 million ha of land (Elphick 2010), and more land is devoted to rice than any other agricultural crop (Forĕs & Comín 1992). Because most rice is grown under flooded conditions (Lawler 2001), rice ecosystems are in effect, agronomically-managed freshwater marshes supporting a single species of cultivated grass (Bambaradeniya & Amarasinghe 2003). As managed wetlands, rice ecosystems constitute important habitat for a diverse array of wetland plants, invertebrates, and vertebrates (Lawler 2001; Czech & Parsons 2002; Bambaradeniya & Amarasinghe 2003; Halwart 2006; Elphick 2010). Among vertebrates, rice ecosystems are notable for providing foraging and nesting habitat for a wide variety of birds (Remsen et al. 1991; Dhindsa & Saini 1994; Hohman et al. 1994; Czech & Parsons 2002; Elphick 2010), including locally rare and globally imperiled species (Van der Weijden 2010). Furthermore, in some areas, (particularly in Asia) waterbirds have come to rely on rice ecosystems owing to the widespread loss of natural wetlands (Fasola & Ruiz 1996; Czech & Parsons 2002; Elphick 2010). Indeed, rice fields are often the best remaining wetland habitat for birds in many regions of the world (Fasola & Ruiz 1996; Elphick 2010; Fujioka et al. 2010).

Despite the acknowledged importance of rice ecosystems to avian conservation (Round 2002; Amano 2009; Van der Weijden 2010), bird use of this habitat outside of North America and Europe remains under-studied (Czech & Parsons 2002; Elphick 2010). This is especially true in Asia where 90 % of the global rice crop is produced (Lawler 2001; Czech & Parsons 2002), and yet information on bird use of rice ecosystems remains surprisingly sparse (Duckworth 2007; Amano 2009; Fujioka et al. 2010; Sundar & Subramanya 2010). This situation is lamentable given the potentially high conservation value of rice ecosystems (Hohman et al. 1994; Amano 2009), coupled with the need to craft biologically-based management strategies that can maintain avian diversity without compromising agricultural production objectives (Van der Weijden 2010; Kumar & Sahu 2020). Furthermore, an enhanced understanding of avian ecology in rice ecosystems is critical for predicting the impacts of agricultural intensification likely to accompany the rapid economic development now occurring in much of southeastern Asia (e.g., Rao et al. 2013; Clements et al. 2014; Bhagwat et al. 2017).

Myanmar is one of the largest rice-producing nations in the world (GRiSP 2013), and rice production generates direct or indirect livelihoods for >75 % of the population (Naing et al. 2008). Rice is grown on 8 million ha of farmland with annual production amounting to >30 million tons (GRiSP 2013). Major rice-growing areas of Myanmar include the Ayeyarwady Delta, with significant production also occurring in the lowlands of Mandalay, Sagaing, and Magway Regions (Hla Myo Thwe et al. 2019). Rice was traditionally a monsoon crop until the 1970–80s when high-yielding varieties were introduced by the Myanmar government that allow double-cropping, i.e., cultivation of a crop during both the wet and dry seasons, with the dry season crop dependent on adequate irrigation (Naing et al. 2008; GRiSP 2013). Rice is typically grown on small farms (averaging 2.3 ha) by resource-poor farmers or landless agricultural laborers (Naing et al. 2008)

Despite the large amount of land devoted to rice production and the importance of this crop to the agricultural sector, other than passing mention of rice fields in scattered sources (Smythies 1953; Thet Zaw Naing et al. 2017) virtually nothing is known about bird use of rice ecosystems in Myanmar. We here present a case of study of avian species richness in a traditional rice ecosystem of upper Myanmar. In this study, we follow Bambaradeniya & Amarasinghe (2003) and define a traditional rice ecosystem as a sustainable agricultural system dedicated primarily to the production of rice (and occasionally other crops such as fish) that employs minimal mechanization and few if any chemical inputs. Traditional rice ecosystems are generally assumed to support higher levels of biodiversity than modern intensive systems of cultivation, although little empirical data exist (Wood et al. 2010). Our objective was to determine what species of birds are seasonally present in a traditional rice ecosystem in upper Myanmar and their respective habitat use. To our knowledge, this is the only study (but see also Suarez-Rubio et al. 2016) that highlights the importance of rice ecosystems to birds in Myanmar.

Study Area and Overview of Rice Cultivation

Our study was conducted at Limpha Village (25.805N & 95.528E; elevation= 132m) in Sagaing Region (formerly Division) of northwestern Myanmar. This region experiences a tropical monsoonal climate with a wet season extending from early June through mid-October (mean annual rainfall varies from 1,250 to 2,500 mm depending on elevation), followed by a dry season from late October through May (Terra 1944). High diurnal temperatures (to 43 °C maximum) are typical of the dry season with low nocturnal temperatures (to 4 °C minimum) occurring in the winter months (January and February) (Terra 1944). Limpha is located within the Western Ornithological Region of Myanmar as defined by King et al. (1975).

Limpha is situated on the east bank of the Chindwin River approximately 40 km downstream from the regional administrative center of Khamti (Image 1). Limpha is the site of the Wildlife Conservation Society/Turtle Survival Alliance River Turtle Conservation Project, hence our long-term (since 2008) institutional presence in the village (Platt & Platt 2019). The village consists of 34 occupied houses with an estimated population of 129 adults (≥18 years-old), most of whom are ethnic Shan. Subsistence agriculture supplemented by fishing and collection of non-timber forest products are the principal livelihoods, with many adult males employed as laborers in distant amber, jade, and gold mines. The origin of the rice ecosystem at Limpha is obscured by time; the rice field has been in existence for as long as the oldest residents (>80 years-old) of the community can remember. With the exception of the rice field (see below), the lands surrounding Limpha support dense tropical evergreen and semi-evergreen forest (Platt et al. 2013). Village lands are contiguous with the buffer zone that surrounds Htamanthi Wildlife Sanctuary (2,151 km^2).

The rice field is located adjacent to the village and occupies 17.5 ha of a terraced natural levee along the Chindwin River (Image 2a,b). The highest elevation in the rice field is along the natural levee (elevation ca. 134 m). The rice field slopes downwards, away from the river, and into a seasonally flooded swamp (elevation ca. 128 m) comprising about 5 ha that is filled by backwater flooding when river levels rise early in the wet season (July and August) and usually has dried completely by late March. Maximum water depth (ca. 2.0 m) in the swamp occurs in August and September. Soils under rice cultivation range from light silt-sand at the natural levee crest to heavy clay near the swamp. Much of the rice field is subdivided by low berms (20–30 cm high) into smaller square and rectangular-shaped paddies (mean ±1SD= 110.2 ± 46.2 m^2; range= 9.9 to 286 m^2) allotted to individual families for cultivation (Image 2b). Unlike more extensive rice ecosystems in central and southern Myanmar, the rice field at Limpha contains no irrigation ditches. A hedgerow (0.9 km) along the natural levee crest separates the rice field from the bed of the Chindwin River (Image 2c). The hedgerow is characterized by large clumps of bamboo, small to medium-stature trees, and thickets of the invasive perennial weed *Chromolaena odorata* (L.) King & H.E. Robbins, and serves as a source of construction materials (e.g., bamboo and timber) for the village.

Rice cultivation in Limpha is a subsistence activity to produce grain for domestic consumption, and little if any of the crop is sold. Rice is cultivated only during the wet season with a single crop being produced each year. Planting coincides with the onset of the wet season and generally begins in the last week of June or first two weeks of July, depending on rainfall. Tillage is accomplished with either wooden plows drawn by Water Buffalo *Bubalus bubalis* (Linnaeus, 1758) and Zebu Cattle *Bos taurus indicus* Linnaeus, 1758 or hand tractors; the latter came into use only in 2014 and four are now available in the village. Hand tractors are leased out by the hour with users responsible for the purchase of fuel. Rice seedlings are germinated in specially prepared beds in the village and then hand-planted into the field after the paddy substrate has been prepared by plowing (Image 3a). Planting is a communal activity with villagers reciprocally assisting one another as paddies are made ready to receive seedlings (Image 3b,c). Water for irrigation is supplied solely by rainfall and usually remains on the crop through the wet season. As defined by Khush (1984), the rice field at Limpha is a "rain-fed rice ecosystem"; i.e., lowland rice ecosystem dependent on rainfall, with water depth uncontrolled but usually

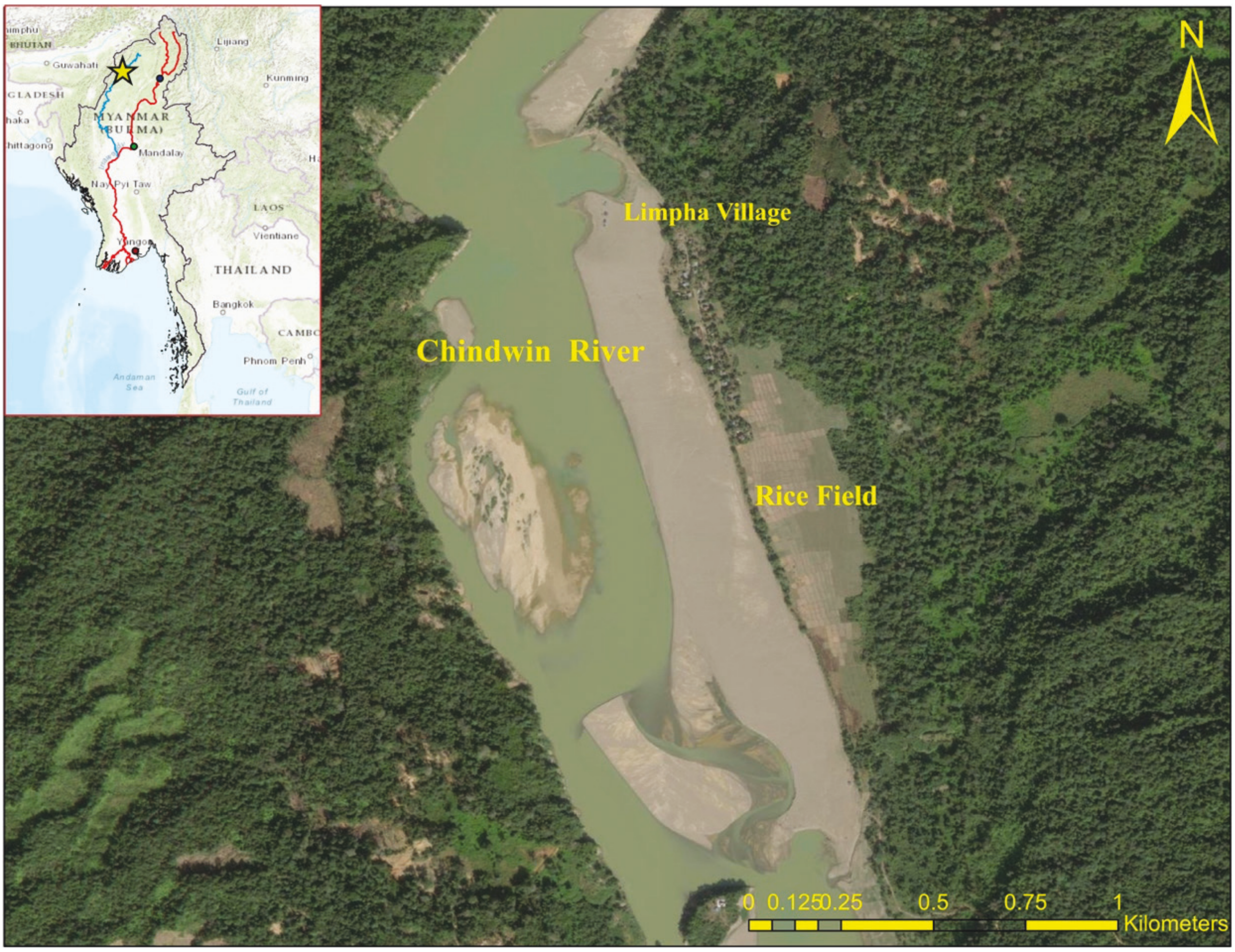

Image 1. Map of our study area showing Limpha Village, rice field, and Chindwin River. Inset shows the location of our study area (yellow star) within Myanmar. Ayeyarwady River= Red. Chindwin River= Blue.

shallow (1–50 cm).

Catastrophic crop failure is rare at Limpha but has occurred in the past when heavy rains in the headwaters caused prolonged overbank flooding of the Chindwin River. Herbicide and pesticide use is minimal to non-existent because villagers lack capital to purchase agrochemicals. Dung deposited by free-ranging domestic ungulates (Water Buffalo and Cattle) that graze the fallow rice field provides some fertilization. The rice crop is manually harvested during late October and early November. Hand threshing takes place at several locations scattered around the rice field. Like planting, harvesting is a reciprocal communal activity (Image 4). Although record keeping is minimal, villagers stated that annual rice yields can vary greatly, but average 900–1,000 kg/ha. Piles of rice straw are left at the threshing site and often (but not always) burned during the dry season. Rice straw is occasionally used as fodder for Water Buffalo. Rice stubble remains in the paddies to be plowed under during the next growing season.

Rice is cultivated in about 50 % of the paddies every year, with the remainder being left fallow for varying periods. Fallow paddies support grasses and sedges, various herbaceous weeds, scattered perennial shrubs, and thickets of *C. odorata*. Berms of active and fallow paddies support stands of high (2–3 m) grass. A herd of 20–25 Water Buffalo and two domestic cattle are kept by villagers; domestic ungulates serve as draft animals, provide fertilizer, and represent a capital investment that can be quickly converted to cash if the need arises. During the fallow season (October or early November through June) domestic ungulates graze in rice paddies, the adjacent swamp, and surrounding forest (Image 5a). At this time, ungulates are unrestrained and roam freely during the day, but are domiciled in the village at night to prevent the animals from straying into the forest and becoming feral. To protect the rice crop during the growing season, ungulates are tethered in areas of favorable grazing and returned to the village in the evening. Owners are financially responsible for any inadvertent damage wrought to the rice crop by their livestock.

Grazing and trampling by free-ranging domestic ungulates creates "lawns" (sensu Owen-Smith 1987) of closely cropped grass in fallow paddies and around the periphery of the rice field (Image 5b). Water Buffalo also create wallows in fallow paddies that are in effect, small ephemeral waterholes. Wallows generally contain water throughout the wet season but are dry by early December and remain so until the rains begin in June (Image 5c). The rice field is burned during the dry season to kill encroaching vegetation (particularly *C. odorata*) and stimulate the growth of new grass for grazing ungulates (Image 5d). Burning usually begins in March and continues through the dry season and seems to be a haphazard activity with fires being opportunistically ignited when weather conditions are favorable. The resulting conflagrations are low intensity ground fires that often burn for >24 hours and ultimately create a patchwork of burned and unburned vegetation. The system of rice cultivation and domestic ungulate husbandry that we describe here appears typical of other villages along the Chindwin River, including those within the buffer zone of Htamanthi Wildlife Sanctuary.

METHODS

We made preliminary observations of birds in the rice ecosystem at Limpha during our initial, brief, and sporadic visits to the village during February–March of 2013–15. Our preliminary observations were followed by more intensive surveys conducted during February–March 2016–20, October–November 2017, and July–September 2020 when the bulk of fieldwork was completed. On most days we searched for birds during the morning (0730–1100 h) and afternoon (1600–1800 h), although sampling during parts of the wet season was less frequent owing to heavy rainfall and occasional flooding. When searching for birds, we used footpaths that originate in the village and radiate throughout the rice field as sampling transects. These footpaths run atop paddy berms and alongside the hedgerow and forest edge (Image 2c). The complete study area was accessible during the dry season, although flooding occasionally precluded access to some areas during the wet season. We also recorded birds opportunistically encountered in the rice field during the course of other fieldwork (e.g., Platt et al. 2018; Platt & Duckworth 2019). We identified birds with the aid of binoculars (Zeiss® and Nikon® 8 × 42) and occasionally by vocalizations. Our observations were augmented by two motion-sensitive game cameras (Moultrie® Series A programmed to take three photographs at 1-minute intervals), each mounted on a wooden post (approximately 0.5 m above-ground) and positioned near piles of discarded straw at two threshing areas in the rice field. Both game cameras were continuously operational from 10 February through 31 March 2019 (98 camera-trap days).

We classified the different habitats where birds were observed in the rice field as (1) rice paddy (paddies under rice cultivation or where rice was cultivated within past 12 months), (2) grass (fallow rice paddies and field margins now supporting primarily grasses), and (3) hedgerow. We included birds that were observed aerially foraging above the study area (e.g., swifts, swallows, and martins), but not high-flying raptors; however, raptors perched in the hedgerow or in trees around the field periphery, and low-flying birds obviously searching for prey were considered to be using the rice field. We used a modification of methods outlined by Kumar & Sahu (2020) to rank each species according to relative abundance as Common (60–100 % of field visits), Uncommon (20–59 % of field visits), and Rare (<20 % of field visits). We followed Sundar & Subramanya (2010) and classified birds according to feeding guilds as Carnivore (consume mainly non-insect invertebrates and vertebrates), Frugivore (consume primarily fruits), Granivore (consume seeds), Herbivore (consume mainly plants and plant parts), Insectivore (consume mostly insects), Omnivore (consume animals and plant material), and Nectarivore (consume mainly nectar). We used information provided in Smythies (1953), Robson (2008), Ali & Ripley (1989), Sundar & Subramanya (2010), and Birds of the World (www.birdsoftheworld.org), supplemented by our personal observations to assign each species to a particular foraging guild. We determined whether a species was resident or migratory in the study area based on Smythies (1953), Robson (2008), Birds of the World (www.birdsoftheworld.org), and our personal observations. Geographic distribution records are based on comparisons with Smythies (1953), Robson (2008), and Thet Zaw Naing (2017). Rankings of conservation threat level are according to the IUCN Red List (2019) and Bird Conservation Society of Thailand (BCST 2020). Our taxonomic nomenclature (common and scientific names) follows Robson (2008) and scientific names for birds mentioned in the text are provided in Table 1.

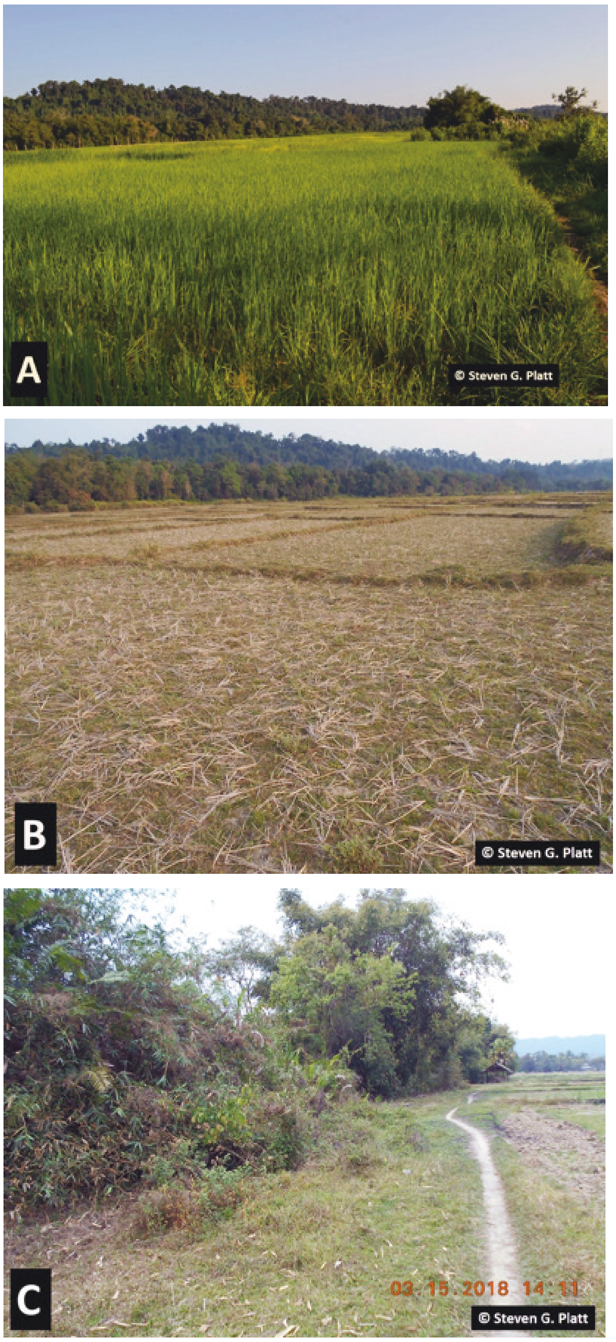

Image 2a–c. Rice field at Limpha in the late wet season just before harvest (2a) and during the dry season (2b); note low berms delineating individual rice paddies. A hedgerow separates village rice field from the Chindwin River (2c).

RESULTS

We recorded a total of 85 species of birds in the rice ecosystem at Limpha in 2013–20 (Table 1). Excluding Buttonquail (see below), we recorded 58 (69.0 %) resident species, 20 migratory species (23.8 %), and six (7.1 %) species with both resident and migrant populations in upper Myanmar (Table 1). Of the 85 species observed on our study site, 53 (62.3 %) and 14 (16.4 %) species were recorded only during the dry and wet seasons, respectively, while 18 (21.1 %) species were present during both seasons. Wading birds (except Cattle Egret), kingfishers, Pheasant-tailed Jacana, and waterfowl were recorded only during the wet season. Twelve (14.1 %) species were recorded only from the hedgerow, while 16 (18.8 %) used the hedgerow as well as rice paddy and/or grass habitats of our study area. Trees in the hedgerow appeared to provide important observation sites for smaller raptors (Collared Falconet, Amur Falcon). Six (7.0 %) species were only recorded while aerially foraging over the study area. We confirmed nesting by four species (4.7 %) of birds within the rice field, while four other species (4.7 %) nested in the adjacent swamp, forest, hedgerow, and village (Table 1). We ranked 52 (61.1 %) species as Common, 23 (27.0 %) as Uncommon, and 10 (11.7 %) as Rare (Table 2); three of the latter were recorded only once during our study (Indian Thick-knee, Amur Falcon, and Glossy Ibis). Indian Thick-knee and Glossy Ibis (Image 6a) have not previously been reported from the Western Ornithological Region of Myanmar. Buttonquail was encountered only in 2014 but observed on multiple occasions. We were unable to confidently identify the Buttonquail to species; three species of Buttonquail potentially occur in the area, one (Yellow-legged Buttonquail) of which is migratory (Table 1). Spotted Dove was the most abundant species in the study area with individual flocks often consisting of >50 birds (Image 6b,c). The Insectivore guild (43 species; 50.5 %) was the best represented feeding guild in our study area, followed by Omnivore (22 species; 25.8 %), Carnivore (12 species; 14.1 %), and Granivore (6 species; 7.0 %) guilds; Frugivore and Nectarivore guilds were each represented by a single species (1.1 %) that was only recorded in the hedgerow (Table 2; Figure 1). We recorded 8 (9.4 %) species of birds in association with domestic ungulates (primarily Water Buffalo), including members of the Omnivore (6 species), Carnivore (1 species), and Insectivore (1 species) feeding guilds (Table 1). We recorded 15 (17.6 %) species of birds foraging at active fires or within recently burned areas, including members of four feeding guilds (Insectivores= 7; Granivore= 4; Carnivore= 2; Omnivore= 2). Our automated game cameras detected three species (Red Junglefowl, White-breasted Waterhen, and Spotted Dove) foraging in piles of discarded rice straw (Images 6d,e), and we directly observed three additional species (Baya Weaver, Scaly-breasted Munia, and White-rumped

Table 1. Annotated checklist of birds observed in a traditional rice ecosystem at Limpha Village, Sagaing Region, Myanmar (2013–20). Season: D= Dry; W= Wet. Asterisk denotes species observed foraging in burned areas. Status: R= Resident; M= Migratory; R/M= Resident and Migratory populations present in Upper Myanmar. Our taxonomic nomenclature (common and scientific names) follows Robson (2008).

		Habitat			
Species	**Season**	**Rice Paddy**	**Grass**	**Hedgerow**	**Status; notes and observations**
Buttonquail (*Turnix* sp.)	D	X	X	–	Observed on multiple occasions in 2014; encountered among weeds around periphery of field and in fallow paddies. Three species of Buttonquail known to occur in this area, including Barred Buttonquail (*T. suscitator*), Yellow-legged Buttonquail (*T. tanki*), and Small Buttonquail (*T. sylvaticus*).
Red Junglefowl (*Gallus gallus*)	D,W	X	X	–	R; Occasionally feeding with domestic ungulates; foraging in piles of discarded rice straw; nesting in forest adjacent to rice field.
White-winged Duck (*Asarcornis scutulata*)	W	–	X	–	R; Observed in flooded rice field during late wet season; occurs in adjacent swamp throughout much of the year.
Lesser Whistling Duck (*Dendrocygna javanica*)	W	X	X	–	R; Nesting in flooded rice and grass
Lineated Barbet (*Megalaima lineata*)	D	–	–	X	R; Fruiting trees in hedgerow are important food resource.
Common Hoopoe (*Upupa epops*)*	D,W	X	X	–	R/M
Indian Roller (*Coracias benghalensis*)	D	X	–	–	R
Plaintive Cuckoo (*Cacomantis merulinus*)	D	–	X	–	R
Asian Koel (*Eudynamys scolopaceus*)	D	–	–	X	R
Greater Coucal (*Centropus sinensis*)	D,W	X	X	–	R; Usually encountered where ungulate “lawns” are interspersed with high grass and scrub.
White-throated Kingfisher (*Halcyon smyrnensis*)	W	X	–	–	R; Occasional in flooded rice paddies.
Common Kingfisher (*Alcedo atthis*)	W	X	X	–	R/M; In flooded rice paddies and around field margins.
Chestnut-headed Bee-eater (*Merops leschenaulti*)*	D	X	X	X	R; Nest burrows constructed in fallow paddies, paddy berms, and ungulate “lawns”; large communal roost in trees at village monastery until nesting begins.
Little Green Bee-eater (*Merops orientalis*)	D	X	X	–	R; Sally from small trees on edge of field and fenceposts.
Blue-tailed Bee-eater (*Merops philippinus*)	W	X	X	–	R
Himalayan Swiftlet (*Aerodramus brevirostris*)	D	–	–	–	M; Aerial foraging
Asian Palm-swift (*Cypsiurus balasiensis*)	D	–	–	–	R; Aerial foraging
Mountain Scops Owl (*Otus spilocephalus*)	D	–	–	X	R
Spotted Dove (*Streptopelia chinensis*)*	D,W	X	X	X	R; Large flocks (>50) feed on spilled rice in threshing areas; nesting and large communal roosts in hedgerow.
Oriental Turtle-dove (*Streptopelia orientalis*)	D	X	X	–	R/M
Common Crane (*Grus grus*)	D	X	X	–	M; Brief (< 24 hrs) migratory stopover in 2019 and 2020.
White-breasted Waterhen (*Amaurornis phoenicurus*)	D,W	X	–	X	R; Feeding in straw piles and on insects flushed by grazing ungulates; common in swamp adjacent to rice field.
Gray-headed Swamphen (*Poryphyrio poliocephalus*)	W	X	X	–	R
Common Moorhen (*Gallinula chloropus*)	W	X	X	–	R; Common throughout year in swamp adjacent to rice field.
Pheasant-tailed Jacana (*Hydrophasianus chirugus*)	W	X	X	–	R
Indian Thick-knee (*Burhinus indicus*)	D	–	X	–	R; Single observation (March 2013).
Small Pratincole (*Glareola lactea*)	D	–	–	–	R; Aerial foraging, often in late afternoon; nesting on nearby island in Chindwin River.
River Lapwing (*Vanellus duvaucelii*)	D,W	X	X	–	R; Nesting on nearby island in Chindwin River.
Grey-headed Lapwing (*Vanellus cinereus*)	D,W	X	X	–	M
Red-wattled Lapwing (*Vanellus indicus*)	D,W	X	X	–	R; Nesting in ungulate “lawn”

		Habitat			
Species	**Season**	**Rice Paddy**	**Grass**	**Hedgerow**	**Status; notes and observations**
Pacific Golden Plover (*Pluvialis fulva*)	W	X	X	–	M
Little Ringed Plover (*Charadrius dubius*)	D	X	X	–	M
Pied Harrier (*Circus melanoleucos*)*	D	X	X	–	M
Collared Falconet (*Microhierax caerulescens*)	W	X	X	X	R
Common Kestrel (*Falco tinnunculus*)*	D	X	X	–	R/M
Amur Falcon (*Falco amurensis*)	W	X	–	X	M; Single record (November 2018).
Black-shouldered Kite (*Elanus caeruleus*)	D	X	X	–	R
Eastern Cattle Egret (*Bubulcus coromandus*)	D,W	X	X	–	R; Feeding on insects flushed by grazing ungulates.
Chinese Pond Heron (*Ardeola bacchus*)	W	X	X	–	R
Black-crowned Night Heron (*Nycticorax nycticorax*)	W	X	X	–	R
Glossy Ibis (*Plegadis falcinellus*)	W	X	–	–	R; Single record (October 2018); foraging in water-filled buffalo wallows.
Long-tailed Broadbill (*Psarisomus dalhousiae*)	D	–	–	X	R; fruiting trees in hedgerow are important food resource; common in adjacent forest.
Golden-fronted Leafbird (*Chloropsis aurifrons*)	D	–	–	X	R
Grey-backed Shrike (*Lanius tephronotus*)*	D	X	X	X	M
Long-tailed Shrike (*Lanius schach*)	D	X	X	–	R
Eastern Jungle Crow (*Corvus levaillanti*)	D	X	–	–	R; Occasionally with domestic ungulates; gleaning ectoparasites?
Black-hooded Oriole (*Oriolus xanthornus*)	D	–	–	X	R; three observations of birds consuming large caterpillars.
Hair-crested Drongo (*Dicrurus hottentottus*)	D	–	–	X	R/M
Black Drongo (*Dicrurus macrocercus*)	D	X	X	–	R/M
Ashy Woodswallow (*Artamus fuscus*)	D	X	X	X	R; Aerial foraging; roost and nest in village.
White-throated Fantail (*Rhipidura albicollis*)	D	–	–	X	R
Bluethroat (*Luscinia svecica*)	D	–	X	–	M
Siberian Rubythroat (*Luscinia calliope*)	D	–	X	–	M
Oriental Magpie-robin (*Copsychus saularis*)	D,W	X	X	–	R
White-tailed Stonechat (*Saxicola leucura*)	D,W	X	X	–	R
Eastern Stonechat (*Saxicola maurus*)	D	X	X	–	M
Pied Bushchat (*Saxicola caprata*)*	D	X	X	–	R; Nesting in rice paddy berm.
Daurian Redstart (*Phoenicurus auroreus*)	D	X	X	–	M
Black Redstart (*Phoenicurus ochruros*)	D	X	X	–	M
Chestnut-tailed Starling (*Sturnus malabaricus*)*	D	–	X	X	R
Common Myna (*Acridotheres tristis*)	D	X	X	X	R
White-vented Myna (*Acridotheres grandis*)	D,W	X	X	–	R; Feeding on insects flushed by grazing ungulates; glean ectoparasites from ungulates.
Collared Myna (*Acridotheres albocinctus*)	D	X	X	–	R; Feeding no insects flushed by grazing ungulates.
Asian Pied Starling (*Gracupica contra*)*	D	X	X	–	R; Feeding on insects flushed by grazing ungulates.
Grey-throated Sand Martin (*Riparia chinensis*)	D	–	–	–	R; Aerial foraging; scattered nesting colonies on banks of Chindwin River.
Red-rumped Swallow (*Cecropis daurica*)	D	–	–	–	M; Aerial foraging.
Red-whiskered Bulbul (*Pycnonotus jocosus*)	D,W	–	X	X	R; Large communal roost in secondary forest adjacent to rice field.

		Habitat			
Species	**Season**	**Rice Paddy**	**Grass**	**Hedgerow**	**Status; notes and observations**
Red-vented Bulbul (*Pycnonotus cafer*)	D,W	–	X	X	R
Striated Grassbird (*Megalurus palustris*)	D	X	X	–	R; Feeding on insects flushed by grazing ungulates.
Yellow-bellied Prinia (*Prinia flaventris*)	D	–	X	–	R; In high grass of fallow rice paddies; vocalizing males; nesting?
Indian Reed-warbler (*Acrocephalus brunnescens*)	D	–	X	–	M; Present in dense thickets of *Chromolaena odorata.*
Common Tailorbird (*Orthotomus sutorius*)*	D,W	–	X	X	R
Dusky Warbler (*Phylloscopus fuscatus*)	D	–	–	X	M
Chestnut-crowned Warbler (*Seicercus castaniceps*)	D	–	–	X	R
Pin-striped Tit-babbler (*Macronous gularis*)	D	–	–	X	R; Often encountered in bamboo clumps of hedgerow.
Purple Sunbird (*Cinnyris asiaticus*)	D	–	–	X	R
Citrine Wagtail (*Motacilla citreola*)	D	X	X	–	M; Frequently in mixed flocks with White Wagtail and occasionally Red Junglefowl; present on closely cropped lawns and in fallow rice paddies.
White Wagtail (*Motacilla alba*)	D,W	X	X	–	M; See comments for Citrine Wagtail.
Olive-backed Pipit (*Anthus hodgsoni*)*	D	X	X	–	M; Present on closely cropped lawns and fallow rice paddies; avoid areas with thick grass.
Paddyfield Pipit (*Anthus rufulus*)*	D	X	X	–	R; See comments for Olive-backed Pipit.
Rosy Pipit (*Anthus roseatus*)	D	X	X	–	M; See comments for Olive-backed Pipit.
Baya Weaver (*Ploceus phillippinus*)*	D,W	X	X	X	R; Feeding on waste rice in piles of discarded straw; nesting in coconut palms in village.
Scaly-breasted Munia (*Lonchura punctulata*)*	D	X	X	X	R; Feeding on waste rice in piles of discarded straw.
White-rumped Munia (*Lonchura striata*)	D	X	X	X	R; Feeding on waste rice in piles of discarded straw.
Black-faced Bunting (*Emberiza spodocephala*)*	D	X	X	X	M; Commonly encountered among weeds and high grass in fallow rice paddies and in thickets on field margin.

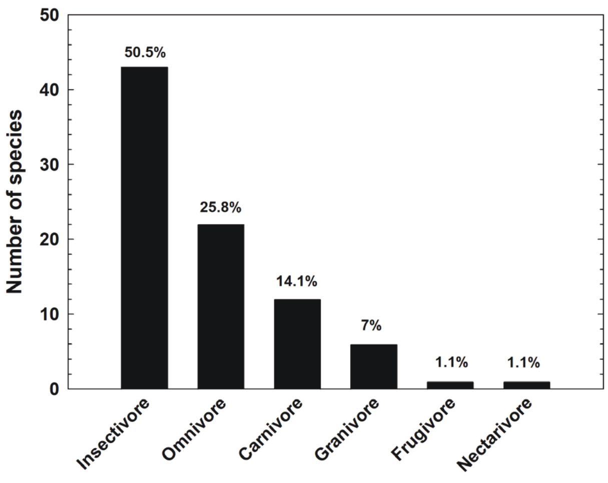

Figure 1. Feeding guilds of birds recorded in a traditional rice field at Limpha, Sagaing Region, Myanmar (2013–20). Percent of total species above columns.

Munia) foraging in piles of rice straw. We recorded 10 species considered to be of conservation concern by the IUCN and BCST in the rice ecosystem at Limpha (Table 3).

White-winged Duck was the only Critically Endangered (BCST) or Endangered (IUCN) species that we recorded in the Limpha rice ecosystem (Image 6f). We observed White-winged Duck foraging in shallow water only when the rice field was flooded during the late wet season; however, they were present in the adjacent swamp throughout much of the year so long as water was available.

DISCUSSION

Our study documented significant avian species richness in a traditional rice ecosystem along the Chindwin River in upper Myanmar. In the only similar study available for Myanmar, Suarez-Rubio et al. (2016) recorded 33 species in rice fields along an urban-rural gradient near Mandalay. A comparison with rice ecosystems elsewhere in Asia is challenging because most published studies are region-wide in scope rather than focused on a single site (e.g., Fujioka et al. 2010; Sundar & Subramanya 2010; Wood et al. 2010). A limited

Table 2. Feeding guild and relative abundance of birds observed in a traditional rice ecosystem at Limpha Village, Sagaing Region, Myanmar (2013–20). Feeding guild: C= Carnivore; F= Frugivore; G= Granivore; H= Herbivore; I= Insectivore; O= Omnivore; N= Nectarivore. Relative abundance: C= Common; U= Uncommon; R= Rare.

	Common name	Scientific name	Feeding guild	Relative abundance
1	Buttonquail	*Turnix* sp.	O	U
2	Red Junglefowl	*Gallus gallus*	O	C
3	White-winged Duck	*Asarcornis scutulata*	O	R
4	Lesser Whistling Duck	*Dendrocygna javanica*	O	U
5	Lineated Barbet	*Megalaima lineata*	F	C
6	Common Hoopoe	*Upupa epops*	I	C
7	Indian Roller	*Coracias benghalensis*	I	U
8	Plaintive Cuckoo	*Cacomantis merulinus*	I	U
9	Asian Koel	*Eudynamys scolopaceus*	O	C
10	Greater Coucal	*Centropus sinensis*	O	C
11	White-throated Kingfisher	*Halcyon smyrnensis*	C	C
12	Common Kingfisher	*Alcedo atthis*	C	U
13	Chestnut-headed Bee-eater	*Merops leschenaulti*	I	C
14	Little Green Bee-eater	*Merops orientalis*	I	U
15	Blue-tailed Bee-eater	*Merops philippinus*	I	U
16	Himalayan Swiftlet	*Aerodramus brevirostris*	I	C
17	Asian Palm-swift	*Cypsiurus balasiensis*	I	C
18	Mountain Scops Owl	*Otus spilocephalus*	C	C
19	Spotted Dove	*Streptopelia chinensis*	G	C
20	Oriental Turtle-dove	*Streptopelia orientalis*	G	R
21	Common Crane	*Grus grus*	O	R
22	White-breasted Waterhen	*Amaurornis phoenicurus*	O	C
23	Gray-headed Swamphen	*Poryphyrio poliocephalus*	O	U
24	Common Moorhen	*Gallinula chloropus*	O	C
25	Pheasant-tailed Jacana	*Hydrophasianus chirugus*	C	U
26	Indian Thick-knee	*Burhinus indicus*	O	R
27	Small Pratincole	*Glareola lactea*	I	C
28	River Lapwing	*Vanellus duvaucelii*	I	U
29	Grey-headed Lapwing	*Vanellus cinereus*	I	C
30	Red-wattled Lapwing	*Vanellus indicus*	I	C
31	Pacific Golden Plover	*Pluvialis fulva*	O	U
32	Little Ringed Plover	*Charadrius dubius*	O	U
33	Pied Harrier	*Circus melanoleucos*	C	U
34	Collared Falconet	*Microhierax caerulescens*	C	U
35	Common Kestrel	*Falco tinnunculus*	C	C
36	Amur Falcon	*Falco amurensis*	C	R
37	Black-shouldered Kite	*Elanus caeruleus*	C	U
38	Eastern Cattle Egret	*Bubulcus coromandus*	C	C
39	Chinese Pond Heron	*Ardeola bacchusx*	C	C
40	Black-crowned Night Heron	*Nycticorax nycticorax*	C	U
41	Glossy Ibis	*Plegadis falcinellus*	I	R
42	Long-tailed Broadbill	*Psarisomus dalhousiae*	I	C
43	Golden-fronted Leafbird	*Chloropsis aurifrons*	I	C

	Common name	Scientific name	Feeding guild	Relative abundance
44	Grey-backed Shrike	*Lanius tephronotus*	I	C
45	Long-tailed Shrike	*Lanius schach*	I	C
46	Eastern Jungle Crow	*Corvus levaillanti*	O	C
47	Black-hooded Oriole	*Oriolus xanthornus*	O	C
48	Hair-crested Drongo	*Dicrurus hottentottus*	I	C
49	Black Drongo	*Dicrurus macrocercus*	I	R
50	Ashy Woodswallow	*Artamus fuscus*	I	C
51	White-throated Fantail	*Rhipidura albicollis*	I	U
52	Bluethroat	*Luscinia svecica*	I	U
53	Siberian Rubythroat	*Luscinia calliope*	I	U
54	Oriental Magpie-robin	*Copsychus saularis*	I	C
55	White-tailed Stonechat	*Saxicola leucura*	I	C
56	Eastern Stonechat	*Saxicola maurus*	I	C
57	Pied Bushchat	*Saxicola caprata*	I	C
58	Daurian Redstart	*Phoenicurus auroreus*	I	R
59	Black Redstart	*Phoenicurus ochruros*	I	R
60	Chestnut-tailed Starling	*Sturnus malabaricus*	O	C
61	Common Myna	*Acridotheres tristis*	O	C
62	White-vented Myna	*Acridotheres grandis*	O	C
63	Collared Myna	*Acridotheres albocinctus*	O	U
64	Asian Pied Starling	*Gracucpica contra*	O	C
65	Grey-throated Sand Martin	*Riparia chinensis*	I	C
66	Red-rumped Swallow	*Cecropis daurica*	I	C
67	Red-whiskered Bulbul	*Pycnonotus jocosus*	O	C
68	Red-vented Bulbul	*Pycnonotus cafer*	O	C
69	Striated Grassbird	*Megalurus palustris*	I	R
70	Yellow-bellied Prinia	*Prinia flaventris*	I	C
71	Indian Reed-warbler	*Acrocephalus brunnescens*	I	U
72	Common Tailorbird	*Orthotomus sutorius*	I	C
73	Dusky Warbler	*Phylloscopus fuscatus*	I	C
74	Chestnut-crowned Warbler	*Seicercus castaniceps*	I	U
75	Pin-striped Tit-babbler	*Macronous gularis*	I	C
76	Purple Sunbird	*Cinnyris asiaticus*	N	C
77	Citrine Wagtail	*Motacilla citreola*	I	C
78	White Wagtail	*Motacilla alba*	I	C
79	Olive-backed Pipit	*Anthus hodgsoni*	I	C
80	Paddyfield Pipit	*Anthus rufulus*	I	C
81	Rosy Pipit	*Anthus roseatus*	I	U
82	Baya Weaver	*Ploceus phillippinus*	G	C
83	Scaly-breasted Munia	*Lonchura punctulata*	G	C
84	White-rumped Munia	*Lonchura striata*	G	C
85	Black-faced Bunting	*Emberiza spodocephala*	G	C

Image 3a–c. Rice seedlings (3a) are germinated in specially prepared beds, transported to the field (3b), and then hand-planted in paddies by villagers (3c).

Image 4. Harvesting and threshing the rice is a communal activity at Limpha.

Table 3. Species of conservation concern recorded in a rice agroecosystem at Limpha Village, Sagaing Region, Myanmar (2013-2020). Rankings of threat level from International Union for Conservation of Nature and Natural Resources (IUCN) and Bird Conservation Society of Thailand (BCST). Threat level: CR= Critically Endangered; E= Endangered; VU= Vulnerable; NT= Near Threatened; LC= Least Concern.

	Common name	Scientific name	IUCN	BCST
1	White-winged Duck	*Asarcornis scutulata*	EN	CR
2	Small Pratincole	*Glareola lactea*	LC	NT
3	River Lapwing	*Vanellus duvaucelii*	NT	VU
4	Pied Harrier	*Circus melanoleucos*	LC	NT
5	Collared Falconent	*Microhierax caerulescens*	LC	NT
6	Black-shouldered Kite	*Elanus caeruleus*	LC	NT
7	Long-tailed Shrike	*Lanius schach*	LC	VU
8	Grey-throated Sand Martin	*Riparia chinensis*	LC	VU
9	Red-whiskered Bulbul	*Pycnonotus jocosus*	LC	VU
10	Black-faced Bunting	*Emberiza spodocephala*	LC	NT

number of site-based studies are available, however, from rice ecosystems in India and Sri Lanka; these found 34–65 species of birds (Nathan & Rajendran 1982; Srinivasulu et al. 1997; Borad et al. 2000; Bambaradeniya et al. 2004) suggesting that avian species richness at our study site is comparatively quite high, even after removing those species (N= 12) recorded only in the hedgerow and other species more typical of forested habitats (Red Junglefowl, White-winged Duck). That said, among-site comparisons must be undertaken with caution given differences in sampling methodologies, geographic location, farming intensity, position within migratory flyways, and differing systems of cultivation (Hohman et al. 1994; Valente et al. 2012; Cunningham et al. 2013). Most of the species we recorded at Limpha are birds of open-country, grassland, and early successional vegetation, which is typical of species inhabiting not just rice ecosystems (Sundar & Subramanya 2010), but agricultural habitats in general (Friskhoff et al. 2014; Kumar & Sahu 2020). In common with most studies of birds in rice ecosystems (Fasola & Ruiz 1996; Townsend et al. 2006; Fujioka et al. 2010; Pierluissi 2010; Sundar & Subramanya 2010), the rice field at Limpha appears to be used by birds primarily as foraging rather than breeding habitat.

We attribute the relatively high levels of bird species richness at Limpha to the low intensity (i.e., non-mechanized, absence of agrochemicals) farming practices used by villagers to produce a single crop of rice each year. Farming intensity is known to determine the abundance and diversity of birds within agricultural landscapes (Cunningham et al. 2013), with intensification usually leading to declines in avian biodiversity (Maeda 2001; Ibáñez et al. 2010; Friskhoff 2014). At Limpha, farming practices create a heterogeneous mosaic of different habitats within the rice monoculture that includes rice paddies under cultivation, fallow rice paddies in various successional stages, closely grazed "lawns" maintained by domestic ungulates, tangles of weeds and high grass, and a hedgerow with vertical woody structure. Previous studies at varying spatial scales have consistently found that landscape heterogeneity is the single most important factor in determining species richness of birds (Böhning-Gaese 1997; Pino et al. 2000; Söderström et al. 2003; Tews et al. 2004). Moreover, the dearth of agrochemical inputs at our study site probably favors the development of speciose communities of arthropods and weeds (Fasola & Ruiz 1996; Bambaradeniya & Amarasinghe 2003; Ibáñez et al. 2010), many of which are important food resources for birds (Stafford et al. 2010). Finally, the close proximity of forest, swamp, and the Chindwin River provides cover and additional food resources for birds using the rice field at Limpha and probably serves as a source for some species (e.g., White-winged Duck, River Lapwing, Small Pratincole, Grey-throated Sand Martin) that would otherwise be unlikely to occur in more expansive and homogenous rice landscapes (e.g., Pierluissi 2010; Kumar & Sahu 2020).

We recorded considerably more species of birds during the dry season in comparison to the wet season, and attribute this disparity to the influx of Palearctic migrants that occurs during the dry season in upper Myanmar; i.e., almost 25 % of the species we recorded at Limpha were migrants. We recorded wading birds and waterfowl at Limpha only during the wet season, most likely because moist-soil and flooded habitat was unavailable in the rice field during the dry season. Irrigation reservoirs and water-filled ditches are absent from the rice ecosystem at Limpha, and these habitats can serve as critical dry season refugia for wetland birds when flooded fields are unavailable (Herzon & Helenius 2008; Valente et al. 2012). Although not included as part of our study, the swamp adjacent to the rice field appears to function in this capacity, harboring wetland birds (e.g., White-winged Duck, Common Moorhen, and White-breasted Waterhen) throughout most of the dry season.

Rice seed is perhaps the most important food resource available to birds in rice agroecosystems (Borad et al. 2000; Stafford et al. 2010). Rice seed is a concentrated energy source made available to birds when spilled during harvest, i.e., "waste rice" (Stafford et al. 2006), but birds also forage on recently planted rice seeds, rice seedlings, and grains in maturing seed heads before harvest (Stafford et al. 2010). Waste rice is most abundant immediately after harvest and resists decomposition (Stafford et al. 2006), and in North America and Japan, the dry mass of rice seed remaining in fields after mechanized harvest ranged from 56–627 kg/ha (Stafford et al. 2010). Because hand threshing is more efficient than mechanical threshing, lesser but nonetheless significant amounts of rice seeds are lost to wastage in traditional rice ecosystems (Borad et al. 2000). For example, in India Borad et al. (2000) found the dry mass of rice seed remaining in fields after hand threshing ranged from 60-199 kg/ha. Our observations suggest that waste rice is an abundant and important food resource for several species of birds at Limpha, most notably small seed-eaters, Spotted Dove, and Red Junglefowl. Additionally, piles of rice straw left in fields after harvesting contain abundant waste rice and arthropods (Bird et al. 2000; Lawler & Dritz 2005) and as such are important avian foraging sites in the Limpha rice ecosystem.

Our observations suggest that free-ranging ungulates, primarily Water Buffalo, provide a number of benefits for birds in the Limpha rice ecosystem. As reported for wild ungulates and birds (Heatwole 1965; Dean & MacDonald 1981; Isenhart & DeSante 1985), we observed two common interactions between domestic ungulates and birds: 1) grazing ungulates acted as "beaters" to flush insects towards waiting birds, and 2) cleaning symbiosis, whereby birds gleaned nutritionally rich ectoparasites directly from ungulates. Water Buffalo also appear to function as "ecosystem engineers" (sensu Jones et al. 1994) in the Limpha rice ecosystem by maintaining closely grazed "lawns" favored by some birds (e.g., Red Junglefowl, wagtails, pipits, lapwings), and creating wallows that harbor invertebrates, small fish, and amphibians and serve as foraging sites for wading birds during the wet season. Furthermore, Water Buffalo disperse seeds, especially those of small-seeded herbs and grasses inadvertently consumed while grazing (Corlett 2017), and possibly aid in the passive dispersal of aquatic invertebrates in the same manner described for large wallowing mammals in Africa (Vanschoenwinkel et al. 2011). Wild Water Buffalo once played a critical role in maintaining the ecological integrity of wetlands in southeastern Asia (Wharton 1968), and Grey et al. (2019) recommend using domestic

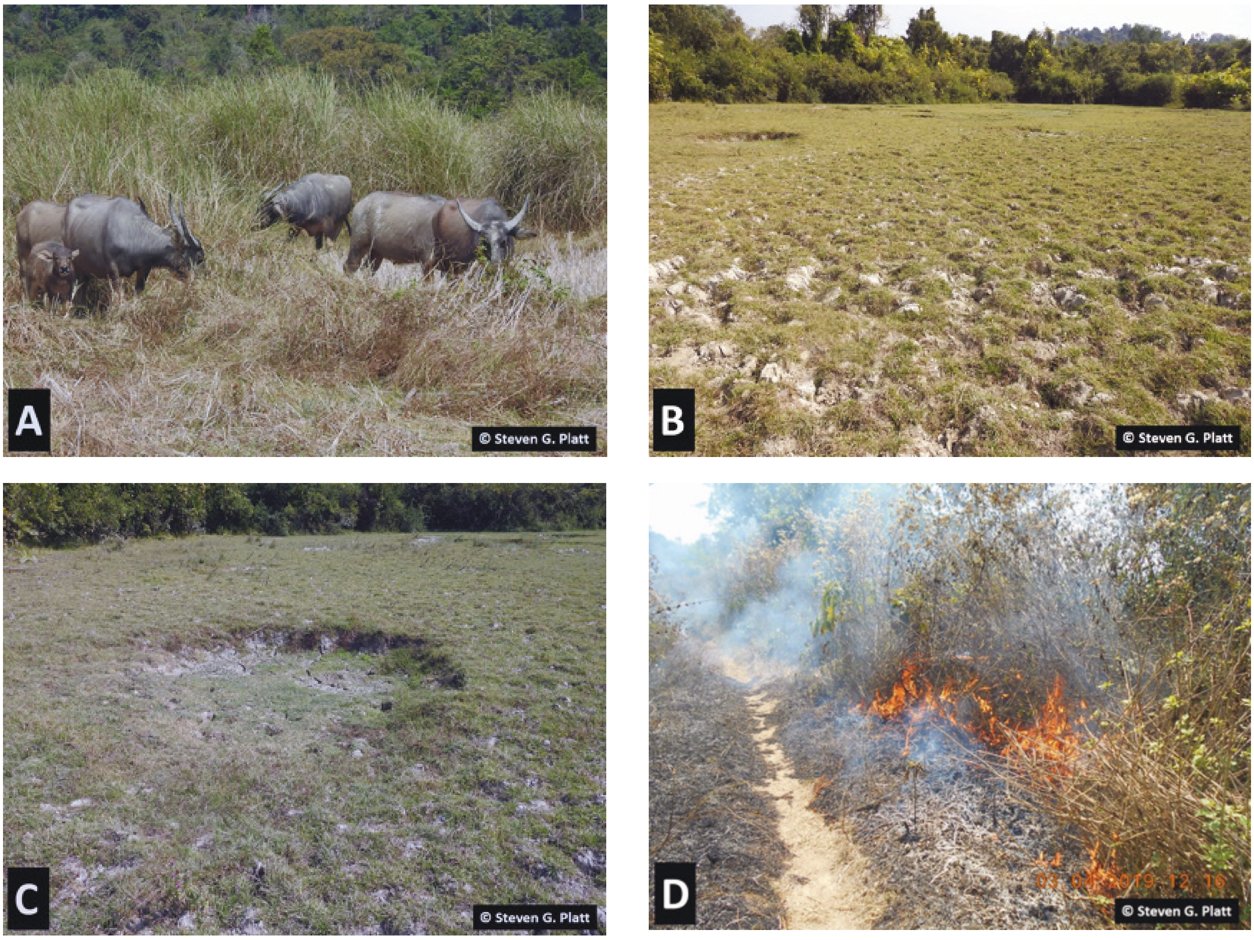

Image 5a–d. Village Water Buffalo grazing in fallow rice paddies with typical vegetation of grasses, herbaceous weeds, and scattered perennial shrubs (5a). Grazing water buffalo maintain "lawns" of closely cropped grass around the periphery of the rice field (5b). Water Buffalo wallow during the dry season (5c). These wallows contain water throughout much of the year. Low-intensity ground fire ignited to prevent encroachment of weeds and other vegetation into rice field (5d).

Water Buffalo as ecological surrogates for extinct (or nearly so) megafauna to replicate historic patterns of grazing and wallowing in rewilding projects.

The effects of anthropogenic burning on wildlife in southeastern Asia remain largely unstudied (Rabinowitz 1990). Dry season burning at Limpha is no doubt at least partly responsible for the heterogeneous mosaic of early successional vegetation in the rice ecosystem (e.g., Peterson & Reich 2001). Additionally, we frequently observed birds in association with fires and in recently burned-over areas, suggesting burning is important in ways other than maintaining early successional habitats. Fires can remove concealing vegetative cover and flush insects and small vertebrates, providing foraging opportunities for insectivorous and carnivorous birds as reported by others (Komarek 1969; Woinarski & Recher 1997; Bonta et al. 2017), and by incinerating ground litter, fires expose seeds that would otherwise remain hidden and unavailable to birds (Komarek 1969; Woinarski & Recher 1997). Furthermore, arthropod abundance is generally high in post-fire regrowth, creating foraging opportunities favorable for insectivorous birds (Woinarski & Recher 1997). At Limpha, fires ignited to remove piles of rice straw leftover from the harvest expose waste rice, which is resistant to burning (Havens et al. 2009), and in turn attracts flocks of foraging Spotted Dove and small seed-eaters. Anthropogenic dry season burning as practiced at Limpha would seem to pose little threat to nesting birds because most species reproduce during the wet season when moist fuel conditions preclude ignition.

Similar to our observations at Limpha, Sundar & Subramanya (2010) found the guild structure of birds using rice fields in the Indian Subcontinent was dominated by insectivorous and omnivorous species. Although the most abundant species at Limpha (Spotted Dove) is largely granivorous (Fujioka et al. 2010), we otherwise recorded few granivorous birds, which is

Image 6a–e. Birds of the Limpha rice field. Two Glossy Ibis (previously unrecorded in this region of Myanmar) foraging on the flooded margins of the rice field near the end of the wet season (6a). Spotted Doves were the most abundant species of bird recorded in the rice field. Large flocks gathered in late afternoon to roost in the hedgerow (6b). Spotted Doves often foraged on bare soil exposed by dry season burns (6c). Camera trap images of White-breasted Waterhen (6d) and Red Junglefowl (6e) foraging in piles of discarded rice straw remaining after the harvest. White-winged Duck was the only Critically Endangered or Endangered Species recorded in the Limpha rice field (6f).

somewhat surprising given the abundance of waste rice and weed seeds typically present in rice ecosystems (Stafford et al. 2010). Our results stand in contrast to previous mist-netting studies that yielded primarily seed-eating birds from rice fields in Malaysia (reviewed by Bambaradeniya & Amarasinghe 2003).

The preponderance of insectivorous species in rice ecosystems suggests this avifauna could be at particular risk from pesticide exposure (Czech & Parsons 2002; Ibáñez et al. 2010). Pesticides can result in direct mortality as well as sublethal effects that include reproductive and behavioral impairment (Fry 1995; Smith et al. 2010; Parsons et al. 2010). Pesticides can also negatively impact local avian abundance by reducing or eliminating insect prey (Ibáñez et al. 2010; Parsons et al. 2010; Nocera et al. 2012), and widespread use of herbicides can eliminate important food plants (Czech & Parsons 2002; Stafford et al. 2010). Pearlstine et al. (2004) suggest that some agricultural lands could function as population sinks by attracting birds to use habitat that is potentially hazardous to their survival owing to the likelihood of pesticide exposure. Pesticide and herbicide use is currently of little concern at Limpha because capital is unavailable to purchase agrochemicals, although this situation could change as villagers become increasingly enmeshed in the global economy.

The importance of rice ecosystems as foraging and in some cases, breeding habitat for threatened and endangered birds is well-documented (e.g., Pearlstine et al. 2004; Yu et al. 2006; Acosta et al. 2010; Elphick 2010; Van der Weijden 2010; Pickens & King 2011). Although the threat status for most of the species we recorded at Limpha is listed as 'Least Concern' by the IUCN (IUCN 2019) and BCST (2020), complacency is unwarranted because even common species can undergo rapid and catastrophic declines if land-use changes or agriculture intensifies (Newton 2004; Friskhoff et al. 2014; Amano et al. 2010). This is certainly the case in Europe where some of the most threatened birds were once considered common farmland species (Fuller et al. 1995; Sotherton 1998; Van der Weijden 2010). Similarly, a trend towards "clean farming" practices (e.g., removal of hedgerows, chemical elimination of weeds and brush, etc.) in agricultural landscapes of the Southeastern United States is in part responsible for declines among Northern Bobwhite *Colinus virginanus* (Linnaeus, 1758) populations (Brennan 1991; Hernández et al. 2013). In rice ecosystems, intensification usually involves a transition to mechanized, capital-intensive production systems, the planting of rapidly maturing, high-yielding rice varieties that require high inputs of agrochemicals, and substantial increases in water consumption (Bambaradeniya & Amarasinghe 2003). In Japan, several species of once common rice field birds are now declining, largely as the result of agricultural intensification (Amano et al. 2010; Kasahara & Koyama 2010). Intensification of rice agriculture probably represents the single greatest threat to avian biodiversity in traditional rice ecosystems in Myanmar and elsewhere (Bambaradeniya & Amarasinghe 2003).

In conclusion, our case study at Limpha demonstrates that a relatively small traditional rice ecosystem in Myanmar can host a rich assemblage of birds, including species of conservation concern and others that are likely to be so in the near future. In accordance with species-area relationships (Bennett et al. 2006), we predict that even higher levels of avian richness will be found in larger rice ecosystems elsewhere in Myanmar. Anecdotally, this indeed seems to be the case in an extensive (151 ha) rice ecosystem surrounding Htamanthi Village (ca. 65 km downstream from Limpha) where our recreational bird-watching has documented a number of species of shorebirds, wading birds, waterfowl, passerines, and raptors not recorded at Limpha. Given these apparent high levels of observed avian biodiversity, traditional rice agriculture seems compatible with conservation objectives in the ecologically-sensitive buffer zone surrounding Htamanthi Wildlife Sanctuary. According to Bambaradeniya & Amarasinghe (2003), traditional rice ecosystems that have been cultivated over long periods can be considered stable, climax communities that meet the criteria of sustainability; i.e., maintain or enhance the quality of the environment and conserve natural resources. Finally, we close with a cautionary caveat and emphasize that our study constitutes but a single datum that requires replication before generalizations can be made concerning the value of traditional rice ecosystems to avian conservation in Myanmar. To this end, additional studies of rice field biodiversity should be undertaken, especially in central Myanmar and the Ayeyarwady Delta, where the bulk of the national rice crop is produced (Hla Myo Thwe et al. 2019).

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အကျဉ်းချုပ်: ဆန်စပါးစိုက်ပျိုးရေး ဂေဟစနစ်များသည် ငှက်မျိုးစိတ်များ၏ အစားအသောက် နှင့် အသိုက် ဆောက်လုပ် မျိုးပွားခြင်းများအတွက် များစွာအထောက်အကူပြုပါသည်။ မြန်မာနိုင်ငံသည် ဆန်စပါးကို အဓိကစိုက်ပျိုးထုတ်လုပ်သော နိုင်ငံဖြစ်ပြီး ငှက်မျိုးစိတ်များ၏ စိုက်ပျိုးရေး ဂေဟစနစ်များအပေါ် ဆက်စပ်၊ မှီခိုနေမှုများအား သိရှိနိုင်ဖို့ လေ့လာသုတေသနပြုရန် အများကြီးလိုအပ်လျက်ရှိပါသည်။ မြန်မာနိုင်ငံအထက်ပိုင်း လင်းဖါးကျေးရွာရှိ မိရိုးဖလာ ဆန်စပါးစိုက်ကွင်းများ၏ ငှက်မျိုးစိတ်ကြွယ်ဝမှုများ၏ လေ့လာမှု စစ်တမ်းတစ်ခု၏ ရလဒ်များကို တင်ပြချင်ပါသည်။ လင်းဖါးကျေးရွာရှိ ဆန်စပါးစိုက်ခင်းသည် ၁၇.၅ ဟတ်တာ ကျယ်ဝန်းပြီး ဓာတုဆေးဝါးများ (ဓါတ်မြေသြဇာနှင့်ပိုးသတ်ဆေး) အသုံးပြုခြင်းမပြုဘဲ နှစ်စဉ် သီးနှံတစ်မျိုး သာ စိုက်ပျိုးလျက်ရှိပါသည်။ ကျေးရွာပိုင်မြေများသည် ထမံသီတောရိုင်းတိရစ္ဆာန် ဘေးမဲ့တော ၏ ကြားခံနယ်နိမိတ်နှင့်ဆက်စက်လျက်ရှိပါသည်။ ငှက်သုတေသန ကွင်းဆင်းလုပ်ငန်းများကို ၂၀၁၃ ခုနှစ်မှ ၂၀၂၀ ခုနှစ်အထိ မိုးရာသီ နှင့် ပွင့်လင်းရာသီအချိန်များတွင် ဆောင်ရွက်ခဲ့ပါသည်။ ဆောင်းခိုငှက်မျိုးစိတ် ၂၁ မျိုး၊ ဌာနေငှက်မျိုးစိတ် ၅၈ မျိုး၊ မြန်မာပြည်မြောက်ပိုင်း၏ ဌာနေငှက် နှင့် ဆောင်းခိုငှက်မျိုးစိတ် ၆ မျိုးအပါအဝင် စုစုပေါင်း ငှက်မျိုးစိတ် ၈၅ မျိုးကို မှတ်တမ်း တင်နိုင်ခဲ့ပြီး ထိန်းသိမ်းရေးအတွက် အရေးပါသော ငှက်မျိုးစိတ် ၁၀ မျိုး ပါဝင်ပါသည်။ ဆောင်းခိုငှက်များ ရောက်ရှိကျက်စားချိန်ဖြစ်သော ပွင့်လင်းရာသီသည် ငှက်မျိုးစိတ်များ ပေါကြွယ်ဝဆုံးသော အချိန်ဖြစ်ပါသည်။ စစ်တမ်းကောက်ယူမှုအတွင်း သဘာဝတွင်ပေါများစွာ ရှိသော ငှက်မျိုးစိတ် ၅၂ မျိုး၊ ပေါများစွာတွေ့ရလေ့မရှိသော မျိုးစိတ် ၂၃ မျိုး နှင့် ရှားပါးမျိုးစိတ် ၁၀ မျိုးကို မှတ်တမ်းတင်နိုင်ခဲ့ပါသည်။ ငှက်မျိုးစိတ်အများစုမှာ လယ်ကွင်းများတွင် မျိုးပွား၊ အသိုက်ဆောက်လုပ်ခြင်းထက် အစားအစာ စားသုံးရာနေရာအဖြစ် အသုံးပြုမှု ပိုမိုများပါး ပါသည်။ အများဆုံးငှက်မျိုးစိတ်များမှာ အင်းဆက်စားသုံးသောငှက်မျိုးစိတ်များ (၄၃ မျိုး) ဖြစ်ပြီး၊ ဒုတိယအများဆုံး မျိုးစိတ်မှာ အစာမျိုးစုံစားသုံးသောမျိုးစိတ်များ(၂၂ မျိုး) ဖြစ်ပြီး၊ အသားစားမျိုးစိတ်(၁၂ မျိုး)၊ စပါးကဲ့သို့သီးနှံများစားသော မျိုးစိတ်များ (၆ မျိုး)၊ အသီးစားမျိုးစိတ် (၁ မျိုး) နှင့် ဝတ်ရည်စုတ်မျိုးစိတ် (၁ မျိုး) စသည်တို့ကို လေ့လာတွေ့ရှိရပါသည်။ လူတို့မွေးမြူထားသော ကျွဲနှင့်ဆက်စပ်သော ငှက်မျိုးစိတ် (၈) မျိုး၊ လယ်ကွင်းများအတွင်း မီးလောက်နေသောနေရာများ၊ မီးလောင်ထားသော နေရာများတွင် အစာစားသောငှက်မျိုးစိတ် (၁၅) မျိုးတို့ကိုလဲ တွေ့ရှိခဲ့ပါသည်။ ကောက်ရိုးပုံများသည် ငှက်မျိုးစိတ်များ၏ အရေးကြီးသော အစားအစာနေရာများ ဖြစ်ပါသည်။ ဆန်စပါး အလွန် အကျုံစိုက်ပျိုးထုတ်လုပ်မှုမရှိမှု၊ မတူကွဲပြားသော နေရင်းဒေသများတည်ရှိမှု နှင့် ချင်းတွင်းမြစ်၊ သဘာဝသစ်တော၊ စိမ့်စမ်းရေးများနှင့် နီးကပ်စွာ တည်ရှိမှု စသည်တို့သည် မတူကွဲပြားသော ငှက်မျိုးစိတ် ပေါကြွယ်ဝမှုများကို ထောက်ပံ့ပေးလျက်ရှိပါသည်။ ရေရှည်တွင် ဆန်စပါး စိုက်ပျိုး ထုတ်လုပ်မှုများ ကို အလွန်အကျွံ တိုးချဲ့လာလျှင် လင်းဖါးကျေးရွာရှိ လယ်ကွင်းများ အတွင်း ငှက်မျိုးစိတ် ပေါကြွယ်ဝစွာကျက်စားနေမှုများကို ထိခိုက်လာနိုင်ပါသည်။ ကျွန်တော် တို့၏ သုတေသနပြု လေ့လာမှုအရ လင်းဖါးကျေးရွာရှိ မိရိုးဖလာ ဆန်စပါး စိုက်ပျိုး ထုတ်လုပ်မှုများသည် ထမံသီဘေးမဲ့တော၏ ကြားခံနယ်မြေ ထိန်းသိမ်းရေး ရည်မှန်းချက် များနှင့် သဟဇာတဖြစ်လျက်ရှိပါသည်။ သို့သော် မိရိုးဖလာ ဆန်စပါး စိုက်ပျိုးရေး ဂေဟစနစ် တန်ဖိုးသည် မြန်မာငှက်မျိုးစိတ်များ ထိန်းသိမ်းရေးလုပ်ငန်းများအတွက် အရေးပါ ဆက်စပ်ပတ်သက်နေမှုကို ပြသနိုင်ရန် ကျွန်တော်တို့သည် သုတေသနလုပ်ငန်းများ ကို ပိုမို ဆက်လက် လုပ်ကိုင်ရန်လိုအပ်ပါသည်။

Author details: Steven G. Platt is the Associate Conservation Herpetologist for Wildlife Conservation Society in Southeast Asia. He is responsible for herpetological conservation projects in Myanmar, Lao, PDR, and Cambodia. Conservation of endemic tortoises and freshwater turtles in Myanmar is a major focus of his work. Myo Min Win is the Manager of the Burmese Roofed Turtle Restoration Project for Wildlife Conservation Society-Myanmar Program. He oversees all aspects of the field project on the upper Chindwin River, including egg collection and incubation, head-starting, assurance colonies, and community-based conservation efforts. Naing Lin is the Wildlife Conservation Society-Myanmar Program Landscape Coordinator for the Ayeyarwady River Landscape Conservation Project. He is responsible for a basin-wide conservation initiative that focuses on the regions unique biodiversity. He is currently pursuing a graduate degree in Conservation Project Management at the University of Kent, UK. Swann Htet Naing Aung is a Field Research Officer with the Wildlife Conservation Society—Myanmar Program responsible for reintroduction of the critically endangered Burmese Star Tortoise at Shwe Settaw Wildlife Sanctuary. Swann is also involved in various other turtle conservation efforts, including the Burmese Roofed Turtle on the Chindwin River. Ashish John is a Community Conservation Management Advisor with the Wildlife Conservation Society - Cambodia Program. In this capacity he assists rural communities with developing and implementing conservation schemes linked to community-based natural resource management and ecotourism. He works primarily in Cambodia and Myanmar. Thomas R. Rainwater is a Research Scientist with the Tom Yawkey Wildlife Center and Baruch Institute of Coastal Ecology and Forest Science of Clemson University in Georgetown, South Carolina, USA. His current research focuses on the ecology, ecotoxicology, and conservation of wild reptiles, birds, and mammals.

Author contributions: Steven G. Platt—Conceived and designed the study, conducted fieldwork, analyzed data, wrote the manuscript, and secured funding. Myo Min Win—Conducted fieldwork, and assisted with manuscript preparation. Naing Lin—Conducted fieldwork, assisted with manuscript preparation, and prepared the abstract translation. Swann Htet Naing Aung—Conducted fieldwork, prepared maps and figures, and assisted with manuscript preparation. Ashish John—Conducted fieldwork and assisted with manuscript preparation. Thomas R. Rainwater—Conceived and designed the study, analyzed data, prepared figures, and assisted with manuscript preparation. All authors reviewed and approved the final draft.

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