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RESEARCH ARTICLE

Shifting agriculture supports more tropical forest birds than oil palm or teak plantations in Mizoram, northeast India

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ABSTRACT

Conversion of tropical forests and diverse multicrop agricultural land to commercial monocultures is a conservation concern worldwide. In northeast India, landscapes under shifting agriculture (or jhum) practiced by tribal communities are increasingly being replaced by monoculture plantations (e.g., teak, oil palm). We compared oil palm and teak plantations, shifting agricultural fields, and forest fallows (0–8 yr regeneration) with tropical rainforest edge and interior sites in Dampa Tiger Reserve, Mizoram, India. Twenty replicate transects were surveyed in each of the 5 study strata for vegetation structure, bird species richness and density, bird abundance, and species composition. Tree density and canopy and vertical structure were lowest in oil palm plantations, intermediate in teak plantations and jhum, and highest in rainforest sites. Tree density in jhum (4.3 stems per 100 m^2) was much higher than in oil palm plantations (0.5 stems per 100 m^2), but lower than in rainforest (6.8–8.2 stems per 100 m^2), with bamboo absent in oil palm plantations and most abundant in regenerating jhum (25 culms per 50 m^2). We recorded 107 bird species (94 forest species, 13 open-country species). Oil palm plantations had the lowest forest bird species richness (10 species), followed by teak plantations (38), while jhum (50) had only slightly lower species richness than the rainforest edge (58) and interior (70). Forest bird abundance in the jhum landscape was similar to that in rainforest, on average 304% higher than in oil palm plantations, and 87% higher than in teak plantations. Jhum sites were more similar in bird community composition to rainforest than were monocultures. Rapid recovery of dense and diverse secondary bamboo forests during fallow periods makes the shifting agricultural landscape mosaic a better form of land use for bird conservation than monocultures. Land use policy and conservation plans should provide greater support for shifting agriculture, while mandating better land use practices such as retention of forest remnants, native trees, and riparian vegetation in monoculture plantations.

Keywords: bird communities, rainforest, slash-and-burn agriculture, jhum, *Tectona grandis*, *Elaeis guineensis*, biodiversity hotspot, land use change

Mizoram, India hmarchhakah oil palm leh teak hmun aiin tlangram lo neih hi ramhnuai sava te tan a hnemhnanawm zawk

THU TLANGPUI

Ramngaw leh thlai chi hrang hrang chinna thlawhhma te thlai mal chin bingna atana chán zel hi khawvel pum a humhalhtu te ngaimawh a ni ta. India hmarchhakah pawh, tlang mi te thlawhhma chu, thlai mal (teak, oil palm)-in a lan chho mek bawk. Oil palm leh teak hmun te, chulram (kum 0 – 8 léng) leh lo (ringthar) te leh Dampa ngawpui, Mizoram, India-a mi te kan khaikhin a. Zirbing tura thlan chi nga te hi hmun sawmhnih-ah theuh thendarh a ni a, chumi chhunga thingkung awm te, sava chi hrang awm te, an bit dan leh an tam dan te zirchian a ni. Oil palm hmunah thingkung a tlem ber a, teak hmunin a dawt a, lo leh ngawah te a tam ber thung. Loa thingkung bit zawng (4.3/100m^2) hi oil palm hmun (0.5) aiin a sang a, ngawchhung (6.8 – 8.2) a sang fal hle, oil palm hmunah mau a awm lo a, chulah erawh mau a tam thung (25/50m^2). Sava chi 107 (ramhnuai-sava 94, dai-sava 13) chhinchiahah oil palm hmunah a tlem ber a (10), teak hmunin a dawt (38); Ngaw hmawr (58) leh chhungril (70) te chu ringthar (50) aiin a sang zawk. Loah leh ngawa ramhnuai sava tam dan a thuhmun a, oil palm hmun aiin 304%-in a sang a, teak hmun aiin 87%-in a sang bawk. Thlai mal chin-bingna aiin lo leh ngawah sava chi thuhmun a tam zawk. Chulramah thing leh mau a than chak avang te, mau hmunin ngai a awh leh hma avangin lo neih hi sava humhalh nan a tha zawk. Lo neih tihmasawn tur zawnga leilung enkawl dan duan chhuah hi a tul takzet a, vahchap sawngbawl dan tha zawk te, tualto thlai uar tur te leh thlaimal chin-bingna hmun hnaia luikam thing chi dang te humhalh tura inkaihhruai a tul hle.

Tawngkam hman bik: sava chi ho, ngawpui, thlawhhma, lo, *Tectona grandis*, *Elaeis guineensis*, thilnung tinreng tamna, leilung hmandan tihdanglam

INTRODUCTION

In tropical forest regions, changes in the nature and intensity of land use practices influence the conservation prospects of wild species within the landscape. Studies of tropical forest bird communities, which have included a diversity of species that respond to resulting habitat alteration, have helped to assess the relative conservation values of different land uses for sustaining biological diversity in the landscape (Daily et al. 2001, Schulze et al. 2004, Burivalova et al. 2015). The conversion of mature tropical forest to timber plantations such as teak, pine, and eucalyptus, or to commercial crops such as tea, coffee, rubber, and oil palm, has led to habitat loss, fragmentation, and reductions in diversity or abundance of forest-dependent species (Clay 2004, Zurita et al. 2006, Koh and Gardner 2010, Goodale et al. 2014). Negative effects may arise when plantations are intensive monocultures that form highly altered habitats avoided by forest species or when plantations cause habitat fragmentation and degradation (Wilcove et al. 2013, Bregman et al. 2014, Newbold et al. 2014). Land use may also be relatively benign, or even have a positive influence, when it includes habitats such as agroforestry, with native shade trees or regenerating secondary and selectively logged forests (Tscharntke et al. 2008, Srinivasan et al. 2015, Wolfe et al. 2015). Such habitats may act as buffers that allow the persistence of forest-dependent species, may help to sustain larger populations in the landscape, or may enhance connectivity between natural forest fragments (Koh 2008, Edwards et al. 2010, Jambari et al. 2012).

The establishment and expansion of commercial monoculture plantations may also occur at the expense of traditional multicrop agricultural practices, such as shifting cultivation. Tropical forest conversion for shifting agriculture may have negative effects on some forest-dependent birds, while enhancing bird diversity through increased landscape heterogeneity that allows entry of open-habitat species (Anderson 2001, Raman 2001). In shifting agricultural fields and fallows, open-country bird species may occur alongside forest birds that persist in the heterogeneous habitat mosaic, particularly when mature forests are retained in the landscape (Bowman et al. 1990, Waltert et al. 2005). For protected areas in tropical forest regions, surrounding land uses that sustain more forest cover and forest bird species can be considered more favorable habitats for bird conservation. While tropical forests and wildlife species are affected by both shifting agriculture and monoculture plantations, the relative ecological and social impacts of these contrasting land uses has been debated in scientific papers, the mainstream media, and public policy forums (Harvey et al. 2008, Chazdon et al. 2009, Sengupta 2013, Goswami et al. 2014, Raman 2014). Besides their relative impacts on biological diversity, aspects debated include whether shifting agriculture causes forest loss or helps to sustain more forest cover than do commercial monocultures, whether monocultures enhance farmer livelihoods or compromise food security and cultural values provided by shifting agriculture, and whether shifting agriculture cultivation practices need to be refined or replaced by settled agriculture (Grogan et al. 2012, Raman 2014, Teegalapalli and Datta in press).

In India's northeast region, parts of which fall within 2 global biodiversity hotspots (Himalaya and Indo-Burma), tropical forest conversion to other land uses is a major conservation concern (Mittermeier et al. 2004). Historically, the dominant form of land use in these hill tracts has been the farming system of shifting agriculture, locally known as jhum cultivation, the primary means of subsistence for indigenous tribal communities in the region (Ramakrishnan 1992). Jhum, a rotational system of organic farming that involves clearing of forests (typically secondary forests) for cultivation, results in a patchwork mosaic of open fields, fallows, and regenerating and mature forests in the landscape (Raman et al. 1998). Over the last 200 yr, large forest tracts in northeast India have also been converted to commercial plantations for tea and timber (especially teak), and, increasingly, monocultures of rubber and oil palms supported by development programs (Saikia 2011, Dasgupta 2014). Conversion of jhum landscapes that contain extensive secondary forests to areas under permanent monoculture could have serious negative effects on biological diversity in biodiversity hotspots in northeast India (Pawar et al. 2004, Srinivasan 2014). Research on the nature and the magnitude of the impacts of differing land uses on the conservation of wild species can help to inform wildlife management within protected areas and identify ecologically sustainable land use policies for surrounding landscapes.

This study was carried out in the core and buffer zones of Dampa Tiger Reserve (DTR), Mizoram, India, an area that was the focus of studies in 1994–1995 on the recovery of tropical forest, birds, and arboreal mammals following shifting agriculture (Raman et al. 1998, Raman 2001). Since then, the landscape around the reserve has seen an increase in the area of teak and oil palm plantations established on what was formerly shifting agriculture lands. While teak plantations have been mostly established under State Forest Department programs, oil palm plantations have been established since 2007 under government horticulture promotion schemes and the state's New Land Use Policy, the stated goal of which is the eradication of so-called "wasteful" shifting agriculture in Mizoram (Singh 2009). An earlier study (Raman 2001)

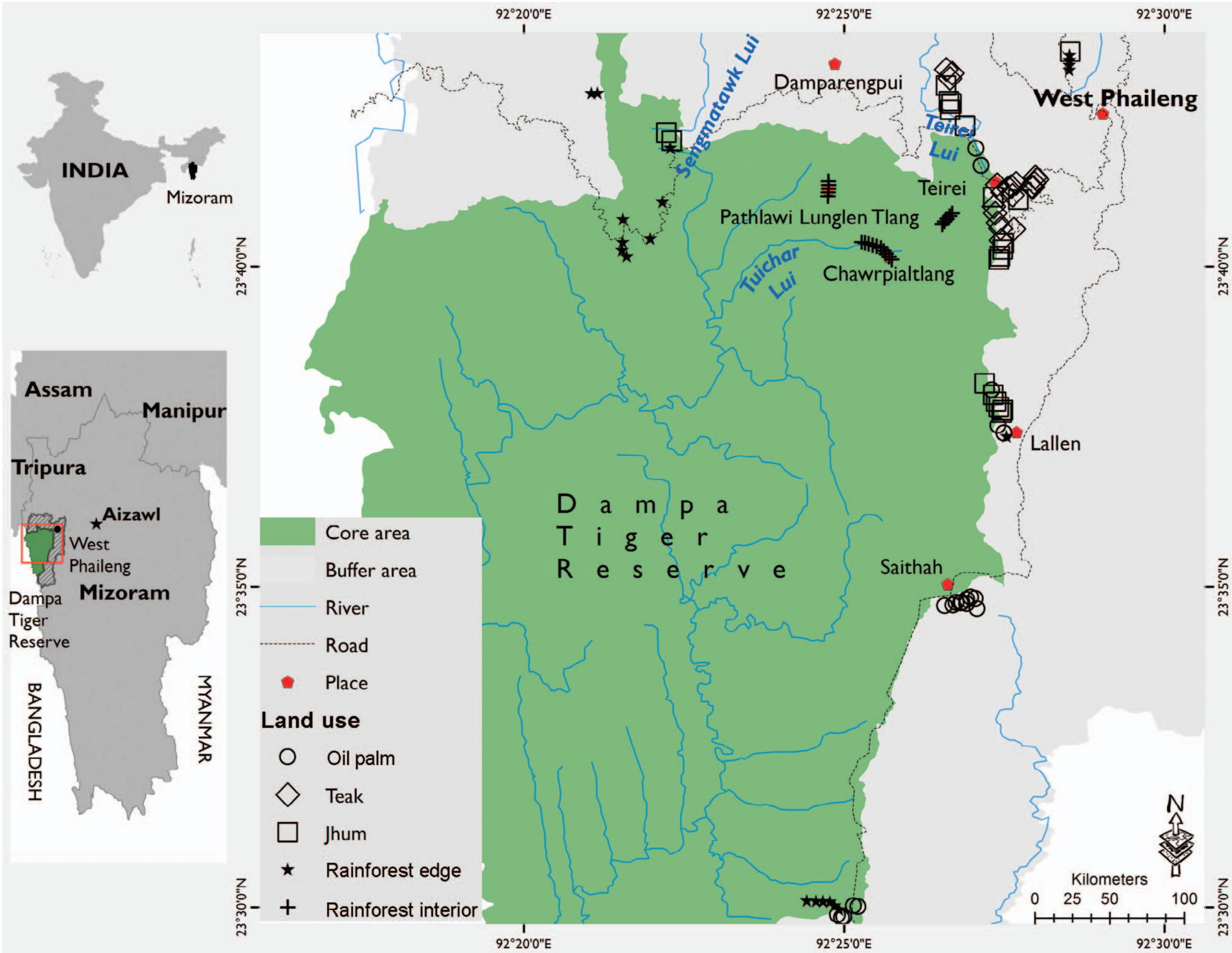

FIGURE 1. Sampling sites for bird species and habitat assessment in the Dampa Tiger Reserve in western Mizoram, India, in 2014.

suggested that long-rotation (>10 yr) shifting cultivation in the buffer zone, coupled with protection of mature forests in the core area of DTR, could be better for conservation than monocultures. The study also noted the need to assess whether "... monoculture plantations ... are superior in conservation value to successional habitats arising after jhum, especially bamboo and secondary forests, which harbor many forest bird species" (Raman 2001:695).

Here, returning to the Dampa Tiger Reserve landscape after 19 yr, we assess forest bird use of oil palm and teak plantations and jhum in relation to mature forest use. As land use changes differentially affect open-country and forest birds, we expected habitats that retained structural attributes more similar to mature forests to contain a greater number and proportion of forest bird species. We hypothesized that, when compared with mature forests, monocultures would contain fewer forest bird species and more altered bird communities than the landscape mosaic of jhum shifting agriculture.

METHODS

Study Area

Dampa Tiger Reserve (DTR) is located in the Lushai hills of the Indian state of Mizoram, with its western boundary along the border with Bangladesh (Figure 1). The reserve has a core area of ~500 km^2 (23°20′55″N–23°47′50″N and 92°16′08″E–92°31′39″E) and a buffer zone of ~488 km^2 (~23°47′62″N–23°20′72″N and 92°19′37″E–92°31′44″E), making it Mizoram's largest wildlife protected area. Nine villages within DTR were relocated to the periphery in 1989–1990, and 1 village (Andermanik) was relocated in 2011, making the core area presently free of human settlements. These villages are located in the buffer zone of DTR, which includes 4,748 households (24,578 persons) in 17 villages in Mamit District (Zathang and Sharma 2014). The population is predominantly tribal, with people of Lushai, Riang (Bru), and Chakma communities (Census of India 2011, http://www.censusindia.gov.

in/2011census/population_enumeration.html). In this paper, DTR refers mainly to the core area, while the core area and surrounding buffer zone together are referred to as the Dampa landscape.

The terrain in the Dampa landscape comprises steep, rugged ranges running in an approximately north–south direction, with an altitudinal range from ~100 m to the highest point of 1,095 m at Chawrpialtlang within DTR. The temperature ranges from a low of 4°C in winter (January) to 36°C in summer (May–June). The average annual rainfall is 2,200 mm, a large part of which falls during the southwest monsoon (June to September), followed by a long dry season that ends with premonsoon thundershowers in April–May.

The natural vegetation is mainly tropical wet evergreen and semi-evergreen forest from the valleys up the gentler eastern and northern aspects to the ridgelines. At lower elevations, the forest canopy height is 30–35 m, with evergreen and some deciduous trees interspersed with tall (~40 m) emergent trees such as *Dipterocarpus turbinatus*, *Tetrameles nudiflora*, *Michelia champaca*, and *Artocarpus chaplasha*. Above 700 m, the forest forms a canopy at 25–35 m and is characterized by trees such as *Schima wallichii*, *Castanopsis indica*, and *Mesua ferrea*. On the steeper slopes and below cliffs on the western aspect, there are tropical mixed deciduous forests with *Dendrocalamus longispathus* (in Mizo vernacular: Rawnal) bamboo. A large part of DTR, in areas where shifting agriculture was practiced earlier, contains secondary successional forests with extensive *Melocanna baccifera* (in Mizo vernacular: Mautak) bamboo.

Shifting agriculture, or jhum (locally known as 'Lo' in Mizo and 'Hu' in Riang), is still extensively practiced in the buffer zone landscape of DTR (Raman et al. 1998). Cultivated fields and recently rested fallows occur alongside successional forest vegetation dominated by *Melocanna* spp. bamboos. In most areas, farmers return to clear the secondary vegetation for another round of cultivation (rotation period or jhum cycle) between 5 and 10 yr (average 7.2 yr; Singh 1996). Mature forest with tree cover is retained in the jhum landscape mosaic as strips along ridges, ravines, and rivers, in village reserves, and along field boundaries.

In recent years, village community lands that were under shifting agriculture have been increasingly converted to monoculture plantations under State control or private ownership. While the State Forest Department has established timber plantations, Mizoram State's New Land Use Policy (http://nlup.mizoram.gov.in) has focused on eradicating shifting agriculture by promoting other land uses, including horticulture and plantations. As a result, large parts of DTR's buffer zone have been converted to Forest Department plantations of teak (*Tectona grandis*), established since the 1980s or earlier, and oil palm (mainly *Elaeis guineensis*) monocultures, established from 2006–2007 onward (Raman 2014).

Study Sites

For bird surveys and habitat assessment, we surveyed 20 sites (100-m long-line transects) in each of the following 5 strata, giving a total of 100 transects that were each surveyed once:

Oil palm. Plantations established near 4 villages (Phuldungsei, Saithah, Lallen, and Teirei) in the buffer zone and abutting DTR were surveyed. The plantations were mostly established during 2007–2008 onward on shifting agricultural lands, mostly on slopes, but occasionally in valley bottoms (Saithah), and abutted or were less than 250 m from mature forest sites.

Teak. As teak is less extensive around other villages in DTR, 15–25-yr-old plantations established near Teirei and Salem Boarding were surveyed. Most sites had *Melocanna* spp. bamboos in the understory (indicative of earlier jhum in these sites), except for a few where the understory had been burnt in the fires that often occur in dry teak understory during February–March.

Jhum. We sampled a range of sites representing jhum in the landscape: recently burned fields, 1-yr-old rested fallows, and up to 7–8-yr-old successional forests regenerating after jhum. These sites, near the villages of West Phaileng, Lallen, Teirei, Salem Boarding, and Tuilut, represent the typical habitats in the jhum landscape mosaic around Dampa (although conservatively excluding mature forest remnants and strips that are also part of the jhum landscape).

Mature forest edge. Mature forests (dominated by evergreen trees and woody vegetation in the understory) were surveyed close to 6 buffer zone villages. While 5 sites were entirely in the buffer zone, the remainder were at the edge of the DTR core zone but abutting villages. Human presence and movement were noticeably higher along the trails in this area.

Mature forest interior. These were mature rainforest sites well inside the core zone of DTR (>2 km from villages) containing relatively undisturbed primary rainforest vegetation that had never been cleared for cultivation. Bird surveys were carried out along four 500-m-long transects established for a parallel study of forest recovery and bird communities (Raman et al. 1998). For each of these 4 transects, we extracted data from 2 segments (100–200 m and 300–400 m) from 1 survey occasion and data from the 3 remaining nonoverlapping segments from a subsequent day, thereby ensuring 100-m spacing between each day's transects in all cases, and independence of observations as far as possible. Each of the twenty 100-m transect segments was surveyed once, providing 20 replicates for the purposes of this study.

Bird Surveys and Habitat Assessment

Bird surveys were carried out between March 14 and April 14, 2014, a period during which both resident and long-distance migrant birds are present in the Dampa landscape and summer migrants arrive (Ali and Ripley 1983, Raman et al. 1998). Bird surveys along transects were carried out on foot during early morning hours (05:30–08:30), when bird activity was highest, mostly on clear or partly cloudy days. Two observers (most often T. R. S. Raman as primary observer, followed by J. Mandal) walked slowly to complete each 100-m transect in 10 min, noting all birds seen, heard, or flying under the canopy (or $<$5 m above the canopy). All birds detected within 30 m on either side of the transect line were recorded, while birds detected at greater distances were noted separately and not included in the data for each transect. We restricted our analyses to birds detected within 30 m on either side of the transect line to minimize variation in bird detectability across habitats and to exclude birds that may have been using other habitats at the edge of the transect. Using a narrow strip width provides a simple estimate of bird abundance without fitting complex detection functions (Raman 2001). Bird species were categorized as forest birds and open-country species based on natural history information (Ali and Ripley 1983) and our earlier work in the study area (Raman 2001). In oil palm plantations, we also noted whether the birds seen were using oil palm trees, the ground layer, other natural vegetation (native trees, secondary growth), or remnant crop plants found alongside (banana plants). Replicate transects surveyed in the same stratum on the same day were spaced a minimum of 100 m apart from each other, and each transect was surveyed only once. Birds were identified using standard field guides (Rasmussen and Anderton 2005, Grimmett et al. 2011).

Habitat assessment was carried out simultaneously by the second observer (following methods detailed in Raman et al. [1998] and Raman [2001]), who measured the following vegetation variables: tree density, bamboo density, canopy overlap index, canopy cover, and vertical stratification. Tree density was estimated from counts of trees (woody stems greater than 20 cm girth at breast height of 1.3 m) in a 100 m^2 circular plot located at the center of the transect. Bamboo density (chiefly *Melocanna baccifera*) was enumerated by counting culms (taller than 1 m and at least 1 cm in diameter) in a 50 m^2 circular plot within the same centrally located plot used for estimating tree density. The canopy overlap index was ranked as follows: 0 = no canopy overhead; 1 = foliage present overhead, but branches not overlapping; 2 = canopy overlapping above, but sky visible through overhead leaves; and 3 = canopy closed due to overlapping branches and culms, and sky not visible overhead. Canopy cover was measured at the center of the transect using a spherical densiometer, noting whether or not overhead foliage covered each of the 25 points marked on the reflective mirror, repeated 4 times (readings in 4 perpendicular directions) to obtain 100 readings. Vertical stratification was measured at the transect center by noting the presence or absence of green foliage in the following vertical distance bands (in meters): 0–1, 1–2, 2–4, 4–8, 8–16, 16–24, 24–32, and $>$32 m. We also recorded general notes on the site, presence of other crops, and occurrence of natural vegetation remnants in plantations.

Data Analysis

Bird taxonomy (including common and scientific names) in this paper follows the 2014 eBird/Clements checklist (http://www.birds.cornell.edu/clementschecklist/) as implemented in eBird (http://ebird.org; Sullivan et al. 2014). All transect counts and supplementary bird observations were uploaded to eBird.

Analyses were carried out using the R statistical and programming environment (version 3.1.2; R Core Team 2014). We compared treatments using Fisher exact tests applied to the contingency table of frequency of species in the forest and open-country categories across the 5 land-use strata. Mean and SE of vegetation parameters were calculated across replicate sites in a stratum, with vertical stratification indexed by the number of vertical layers (bands) with foliage present. Stem densities were estimated separately for planted crop (oil palm and teak) and other trees (native tree density) across strata.

The number of bird species, bird abundance (total individual birds detected by sight or call), and habitat parameters were summarized per replicate transect in the 5 study strata. As these were all count variables, we analyzed variation across strata using generalized linear models (GLM) with a quasi-Poisson family and log link function (Crawley 2007), which accounted for overdispersion in the data. To subsequently assess the significance of pairwise differences in means between strata, Tukey HSD multiple comparisons tests were carried out on the GLM output using the multcomp package in R (Hothorn et al. 2008).

Rarefaction, species richness estimation, and bird community composition analyses were carried out using the vegan package in R (Oksanen et al. 2013). Rarefaction analyses were performed on bird species richness against a standardized sample of individual birds detected to compare strata. While the rarefaction curves that we obtained appeared to be leveling off, we also estimated forest bird species richness in each strata using the data from the replicate transect surveys. Using the specpool function in package vegan, we calculated the nonparametric first-order jackknife (Jack1) estimator and confidence interval (Jack1 $\pm$ 2 SE), appropriate for incidence data

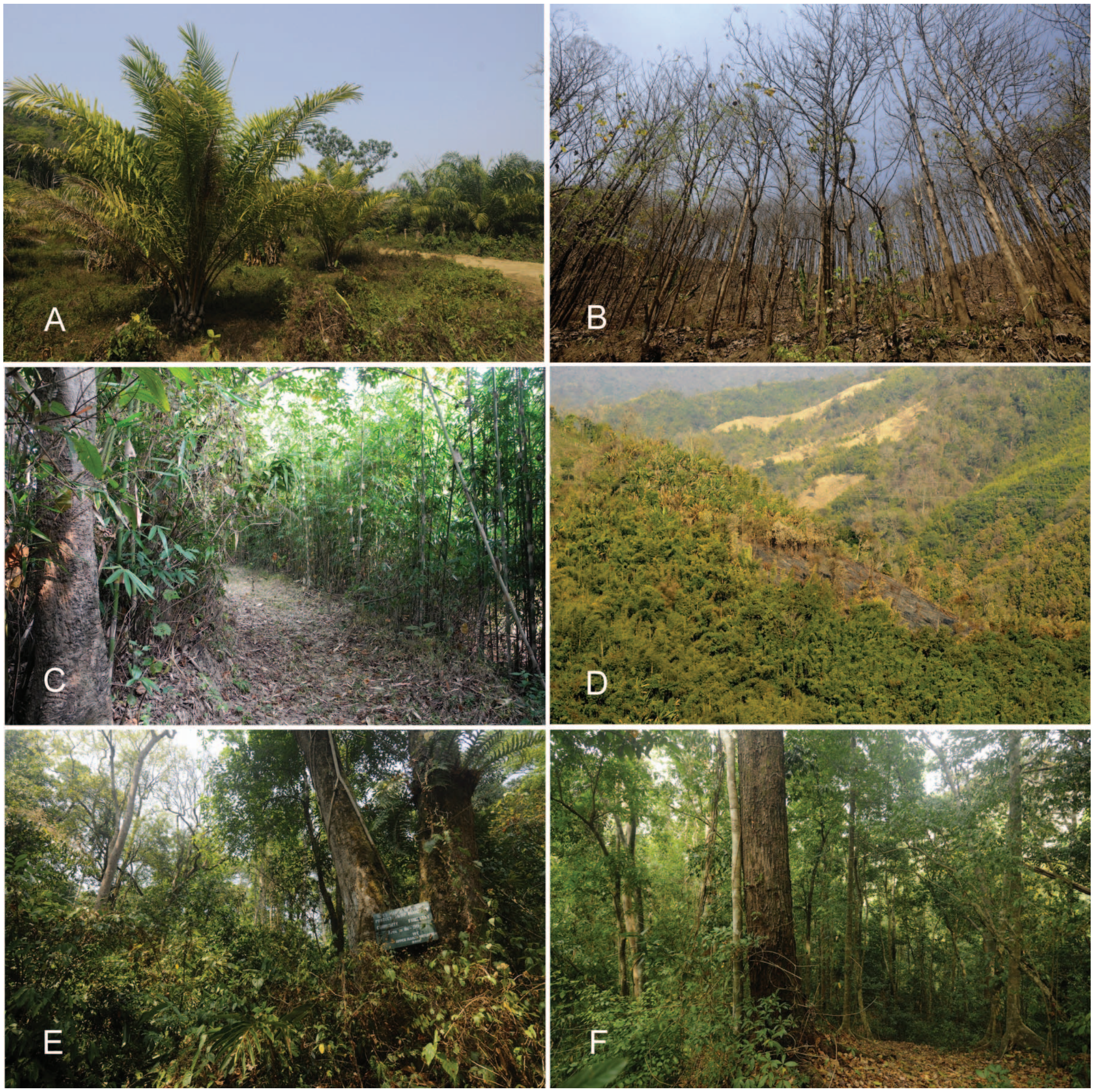

FIGURE 2. Photographs of the main study strata selected for bird surveys in the Dampa Tiger Reserve, Mizoram, India, in 2014, showing structural differences in habitat: (**A**) oil palm plantation, (**B**) teak plantation, (**C**) jhum (shifting agriculture), (**D**) landscape view of jhum mosaic of fields, fallows, and secondary forests, (**E**) mature forest edge, and (**F**) mature forest interior.

across replicate transects (Brose et al. 2003, Gotelli and Colwell 2011).

Bird abundance data were pooled by replicates within strata to compute the dissimilarity matrix in community composition using the Bray-Curtis index. Nonmetric multidimensional scaling (NMDS) was carried out using the dissimilarity matrix to visually display the variation in community composition across strata in an ordination plot. We also used bird abundance within replicate transects to perform an analysis of similarities (ANOSIM), excluding transects along which fewer than 5 individual birds were counted (10 transects in oil palm plantations, 3 in teak plantations, and 1 in rainforest edge).

RESULTS

Habitat Variation across Land Use Strata

The study strata, which ranged from oil palm plantations to mature rainforest interior, formed a structural and floristic gradient from an intensively managed monoculture to relatively undisturbed and diverse closed-canopy forest (Figure 2). The density of native trees showed a clear, statistically significant pattern of being lowest in oil palm plantations (0.50 $\pm$ 0.17 SE stems per 100 m^2), second-lowest in teak plantations (1.50 $\pm$ 0.37 SE stems per 100 m^2), intermediate in jhum landscapes (4.30 $\pm$ 0.66 SE

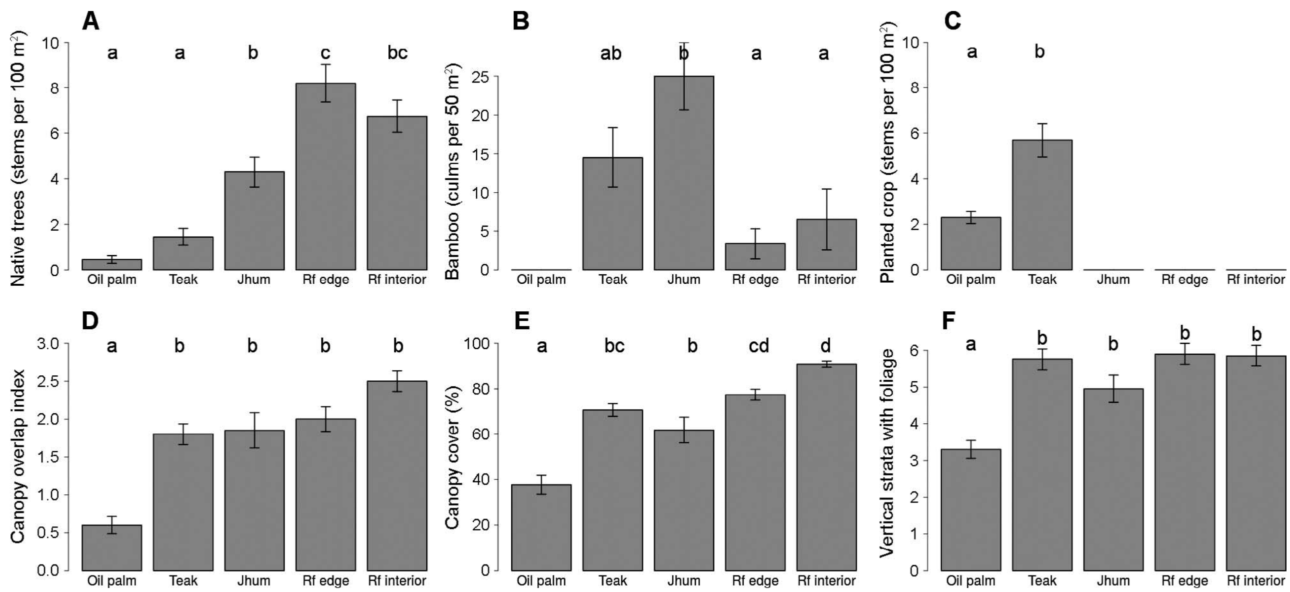

FIGURE 3. Differences in vegetation structure attributes across the 5 major study strata (Rf = rainforest; jhum = shifting agriculture) selected for bird surveys in the Dampa landscape, Mizoram, India (bars represent means, and error bars show SE): (**A**) native tree density, (**B**) bamboo density, (**C**) plantation crop density, (**D**) canopy overlap index, (**E**) canopy cover, and (**F**) vertical stratification. In each panel, bars marked with different lowercase letters differ significantly from each other ($P < 0.05$) in Tukey HSD multiple comparisons tests.

stems per 100 m^2), and highest in rainforest edge (8.20 ± 0.83 SE stems per 100 m^2) and interior (6.80 ± 0.71 SE stems per 100 m^2) strata (GLM: $F_{4,95} = 36.3$, $P < 0.001$; Tukey HSD multiple comparisons tests between strata: $P < 0.05$; Figure 3A). Bamboo was absent in oil palm plantations, of intermediate density in teak plantations and rainforest strata, and highest (averaging 25 ± 4 SE stems per 50 m^2) in the jhum landscape (GLM: $F_{3,76} = 5.79$, $P =$ 0.001; Figure 3B). Plantation trees were found only in oil palm and teak plantations, with the latter planted at a higher stem density (GLM: $F_{1,38} = 23.8$, $P < 0.001$; Figure 3C). Substantial alteration of habitat structure was evident in oil palm plantations, which had a significantly lower canopy overlap index, canopy cover, and vertical stratification, compared with the other strata (GLM: $F_{4,95} > 14.6$, $P < 0.001$ in all 3 cases; Figures 3D–3F). In contrast, teak plantations and the jhum landscape were intermediate or similar in canopy and vertical structure parameters relative to the rainforest edge and interior (Tukey HSD multiple comparisons tests between strata: $P < 0.05$; Figures 3D–3F).

Bird Species Richness across Land Use Strata

During our study, we recorded a total of 1,151 bird detections, comprising a minimum of 1,369 individual birds and 112 species. Within the belt of 30 m on either side of the transect line, we recorded 107 bird species (957 detections; minimum of 1,152 individual birds) across strata (Appendix Table 1). Most (94/107, or ~88% of species) were forest bird species, such as the Gray-throated Babbler (*Stachyris nigriceps*), Pale-chinned Blue-Flycatcher (*Cyornis poliogenys*), Ashy Bulbul (*Hemixos flavala*), and Red-headed Trogon (*Harpactes erythrocephalus*), which occur mainly in secondary successional and mature rainforests. A smaller proportion of the total (13/107, or ~12%) were open-country bird species, such as the Olive-backed Pipit (*Anthus hodgsoni*), Common Tailorbird (*Orthotomus sutorius*), Red-vented Bulbul (*Pycnonotus cafer*), and Oriental Turtle-Dove (*Streptopelia orientalis*), which typically occur in areas that are open or sparsely vegetated.

Oil palm plantations had substantially fewer bird species, especially forest bird species, compared with teak, jhum, and rainforest strata. The number of forest bird species in oil palm plantations (10) was just one-fifth of the number of forest species recorded in jhum landscapes (50), and one-seventh of that found in the rainforest interior (70; Figure 4A). The jhum stratum occupied an intermediate position between teak plantations (38) and the rainforest interior (70) in the number of forest bird species. Although the total number of bird species was higher in the jhum landscape than in the rainforest edge, this was partly due to the higher number (12 vs. 3) of open-country bird species seen in the former. The percentage of forest bird species was lowest in oil palm plantations (50%), intermediate in teak plantations (~84%) and jhum (~81%), and highest in the rainforest edge (~95%) and interior (100%; Figure 4A). The number of forest bird species vs.

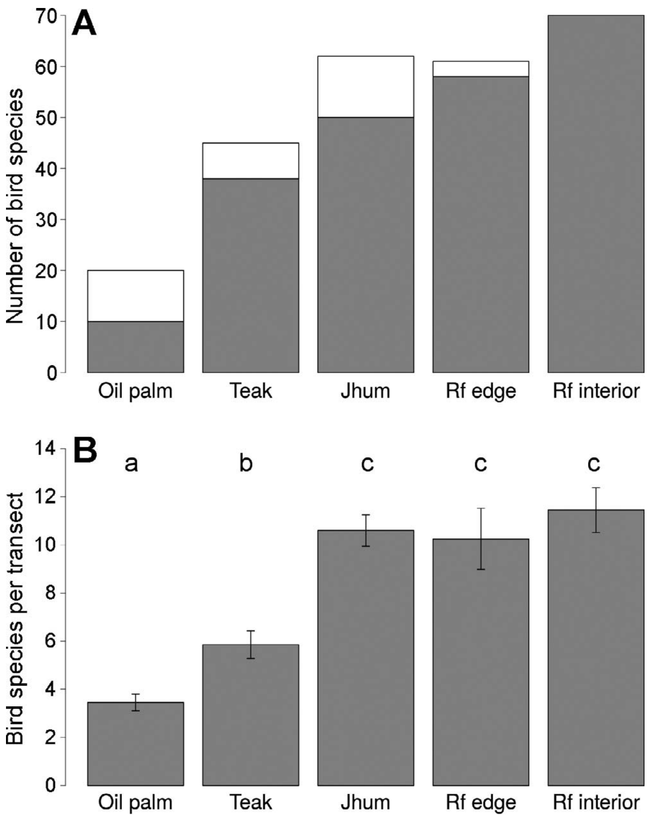

FIGURE 4. (**A**) Cumulative number of open-country (white bars) and forest bird species (gray bars), and (**B**) mean number of bird species per transect (error bars = SE) across the 5 study strata (Rf = rainforest; jhum = shifting agriculture) in the Dampa landscape, Mizoram, India, in 2014. Bars marked with different lowercase letters differ significantly from each other ($P < 0.05$) in Tukey HSD multiple comparisons tests.

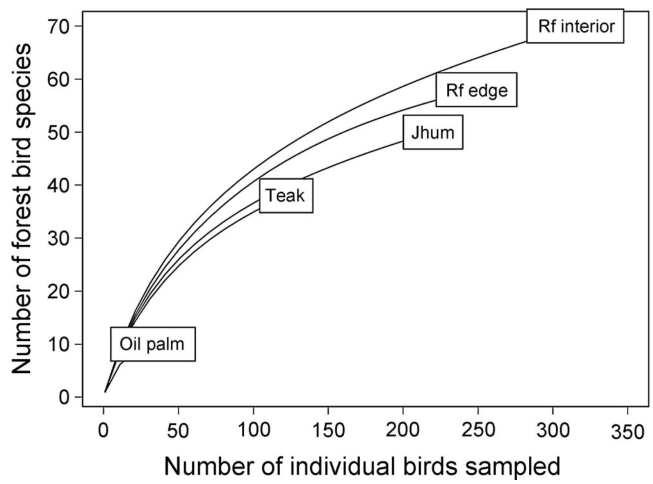

FIGURE 5. Rarefaction curves of bird species richness across the 5 study strata (Rf = rainforest; jhum = shifting agriculture) in the Dampa landscape, Mizoram, India, in 2014.

open-country species differed significantly across the 5 study strata (Fisher exact test: $P < 0.001$). Similar results were obtained when the analysis was repeated considering only species detected at least thrice within each strata (Fisher exact test: $P < 0.001$).

The number of bird species per transect was also lowest in oil palm plantations (3.5 ± 0.3 SE), intermediate in teak plantations (5.9 ± 0.6 SE), and highest in jhum (10.6 ± 0.7 SE), rainforest edge (10.3 ± 1.3 SE), and rainforest interior (11.5 ± 0.9 SE) strata (Figure 4B). The number of bird species per transect varied significantly across land use strata (GLM: $F_{4,95} = 22.5$, $P < 0.001$), with jhum and the 2 rainforest strata not differing significantly (Tukey HSD multiple comparisons tests between strata: $P < 0.05$; Figure 4B). As jhum sites also had some open-country species (Figure 4A), when forest birds alone were considered, the number of forest bird species per transect was slightly lower in jhum than in the rainforest edge and interior (data not presented here). This is clearly illustrated in the rarefaction analysis (species accumulation curves), which indicates that, even when standardized by the number of individuals sampled, the jhum landscape supports far more forest bird species than oil palm plantations, slightly more than teak plantations, and fewer species than the rainforest edge or interior (Figure 5). A similar pattern was noted when comparisons were based on the first-order jackknife estimate of forest bird species richness (Jack1 mean and confidence intervals: oilpalm = 14 [9–18] species; teak = 56 [42–71] species; jhum = 70 [59–81] species; rainforest edge = 77 [62–92] species; and rainforest interior = 97 [82–112] species). Oil palm plantations had significantly lower forest bird species richness than the other strata, including jhum. While there was some overlap in the confidence intervals of teak, jhum, and rainforest edge strata, forest bird species richness in the rainforest interior was higher than in the 3 non-rainforest strata.

Bird Abundance and Composition across Land Use Strata

As equal amounts of area were surveyed in each of the 5 strata, comparing along the x-axis of Figure 5 indicates that the abundance of forest birds (number of individuals detected) was lowest in oil palm plantations (33), followed by abundance in teak plantations (122). The abundance of forest birds in the jhum landscape (220 individuals) was 667% higher than that in oil palm plantations, ~12% lower than that in the rainforest edge (249), and 30% lower than that in the rainforest interior. Total bird abundance (including forest and open-country species) per transect was lowest in oil palm plantations (5.1 ± 0.6 SE individuals per transect), followed by abundance in teak plantations (8.3 ± 0.8 SE individuals per transect), and highest and similar across jhum (15.5 ± 1.4 SE individuals per transect), rainforest edge (13.0 ± 1.6 SE individuals per

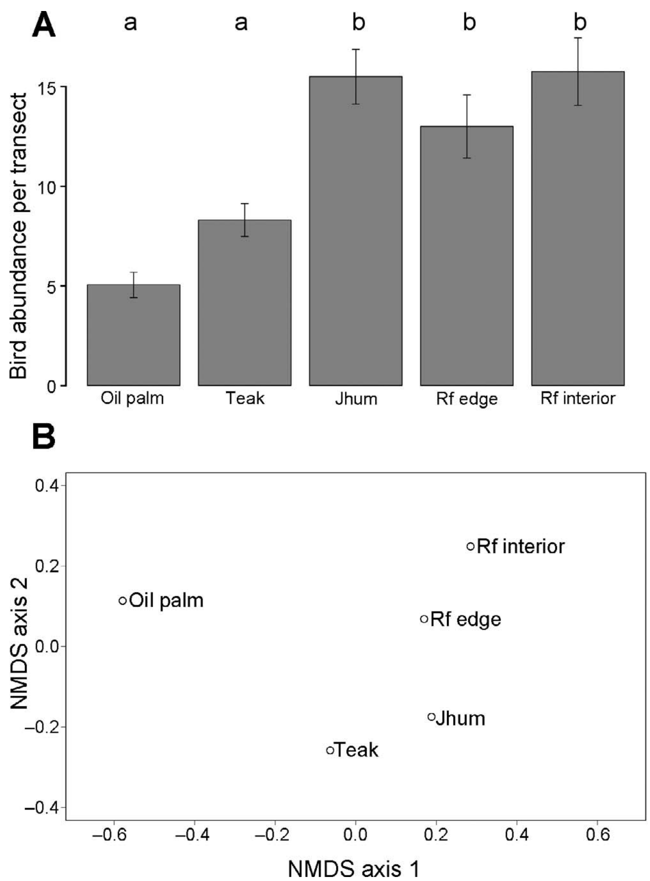

FIGURE 6. (**A**) Bird abundance per transect (bars = means, error bars = SE); bars marked with different lowercase letters differ significantly from each other ($P < 0.05$) in Tukey HSD multiple comparisons tests, and (**B**) nonmetric multidimensional scaling (NMDS) ordination of variation in bird community composition across the 5 study strata (Rf = rainforest; jhum = shifting agriculture) in the Dampa landscape, Mizoram, India, in 2014.

transect), and rainforest interior (15.8 ± 1.7 SE individuals per transect) strata (GLM: $F_{4,95} = 16.0$, $P < 0.001$; Tukey HSD multiple comparisons tests between strata: $P < 0.05$; Figure 6A). Jhum also occupied an intermediate position in bird abundance per transect when only forest birds were considered (data not presented here). Overall, for forest bird species richness and abundance, our results clearly indicate that jhum occupies an intermediate position between the depauperate monoculture plantations and the richer and denser rainforest strata.

Bird community composition varied substantially across the 5 strata (Appendix Table 1). Oil palm plantations had mainly 5 common and widespread open-country bird species: Red-vented Bulbul, Olive-backed Pipit, Common Tailorbird, Spotted Dove (*Streptopelia chinensis*), and Oriental Turtle-Dove. Teak plantations had a mix of open-country and forest bird species, most of which were also found in the jhum landscape. The jhum stratum (from recently burned fallows to secondary successional bamboo forests) held most of the open-country birds and a substantial fraction of the forest bird species, from terrestrial and understory babblers and flycatchers to canopy minivets, pigeons, drongos, and woodpeckers. A few forest bird species occurred almost exclusively in the jhum landscape (and in teak plantation that retained bamboo in the understory): Yellow-bellied Warbler (*Abroscopus superciliaris*), Brown-cheeked Fulvetta (*Alcippe poioicephala*), White-browed Piculet (*Sasia ochracea*), Pale-headed Woodpecker (*Gecinulus grantia*), Yellow-vented Flowerpecker (*Dicaeum chrysorrheum*), and White-browed Scimitar-Babbler (*Pomatorhinus schisticeps*). The rainforest strata either had few (edge) or no (interior) open-country birds, and a wide array of forest birds. Twenty-five forest bird species were restricted to the rainforest edge or interior strata in the sample, including species such as the Gray Peacock-Pheasant (*Polyplectron bicalcaratum*), Red-headed Trogon, Blue Pitta (*Hydrornis cyaneus*), Mountain Imperial-Pigeon (*Ducula badia*), Long-tailed Broadbill (*Psarisomus dalhousiae*), Gray-headed Canary-Flycatcher (*Culicicapa ceylonensis*), and Wreathed Hornbill (*Rhyticeros undulatus*; Appendix Table 1).

The analysis of similarities showed that the variation in bird community composition across strata relative to within each strata was statistically significant (ANOSIM: $R = 0.349$, $P < 0.001$). Oil palm plantations were the most dissimilar to other sites, particularly the rainforest interior, as indicated by the nonmetric multidimensional scaling (NMDS) ordination (Figure 6B). Relative to monoculture oil palm and teak plantations, the bird community composition in the jhum landscape was clearly more similar to that in the rainforest strata, as indicated by the jhum position closer to rainforest strata in the ordination diagram (Figure 6B) and the significant number of forest bird species that persisted in the jhum landscape (Appendix Table 1).

DISCUSSION

This study showed that, in the hills of northeast India, monoculture plantations of oil palm and teak provided poorer habitat for tropical forest birds than the traditional shifting agriculture (jhum) landscape mosaic of fields, fallows, and forests. Plantations, particularly of oil palm, involve the near-total removal of native trees and bamboo, contributing to lower canopy cover and less-developed habitat structural attributes. The diversity and density of forest birds was similarly lower in plantations than in the jhum landscape. Jhum was thus intermediate between plantations and mature rainforests in habitat structure, bird community composition, and conservation value.

Shifting agriculture and monoculture plantations represent contrasting land uses that differ in the spatial and temporal features of the resultant landscape. Jhum includes small open cultivated fields (typically <2–3 ha; occasionally larger blocks when multiple farmers clear contiguous areas), which form a mosaic with recent fallows, secondary forests in various stages of regeneration, and mature forest remnants (retained along ravines and ridges, and in reserves). Although the clearing, burning, and farming of fields involve major habitat alteration, the resultant opening up of forest is only temporary as there is immediate and rapid recovery of forest vegetation when the fields are rested (Singh 1996, Raman et al. 1998, Dunn 2004). In contrast, commercial teak and oil palm plantations typically convert larger areas (tens to hundreds of hectares), usually permanently replacing forest with low-diversity monocultures (Aratrakorn et al. 2006, Saikia 2011, Jambari et al. 2012). Selective comparisons of sites such as mature plantations or rainforests with recently burned or cultivated jhum fields provide an inadequate picture of the relative habitat and conservation values of these differing land uses (Andrade and Rubio-Torgler 2002). A better approach is to compare these land uses at the spatial extent of the landscape and on a temporal scale corresponding to plantation establishment and at least one full jhum cycle. We attempted to do this in our study by comparing multiple established plantations with the landscape mosaic of fields, fallows, and forest sites (from recently burned to 7–8-yr-old regeneration) that comprise the typical jhum landscape around Dampa Tiger Reserve (DTR).

The results were unequivocal: jhum landscapes fared better than plantations in retaining habitat structure and in the density of native trees, bamboo, and forest birds. The narrow strip width used in bird surveys minimized detectability biases, but as jhum sites contained denser habitat than the more open monocultures, incorporation of detectability estimates may only strengthen this observed pattern. While poorer than mature rainforests, the jhum landscape also supported an impressive diversity of forest bird species. Although this was noted in earlier studies, it was not explicit because earlier comparisons were restricted to comparing individual fallow sites that had regenerated for a fixed number of years (1 yr, 5 yr, etc.) with mature rainforest sites (Raman et al. 1998, Raman 2001), rather than comparing the jhum landscape with a forested landscape as in the present study. It is also worth noting that had mature forest remnants that are part of the jhum landscape been included, additional forest bird species may have been recorded, thereby further increasing the conservation value of the jhum landscape around DTR. Studies from other tropical forest regions have shown that the habitat alteration that accompanies increasing intensification of land use affects the persistence and diversity of forest-dependent bird species (Waltert et al. 2005, Moura et al. 2013). As evidenced in these studies, habitats such as secondary forest and agroforestry occupy an intermediate position between intact or mature forests and more highly altered habitats such as commercial plantations, pastures, and permanent agriculture with annual cropping.

In Mizoram, oil palm plantations were poorest in bird density and diversity, which can be attributed to the extreme habitat alteration represented by this commercial monocrop. Oil palm plantations were substantially poorer in bird density and diversity compared with both mature forest edge sites along the DTR boundary and interior sites well within the core zone. As some mature forest edge sites abutted some oil palm sites along the DTR boundary, the difference between these 2 strata in bird density and diversity can be attributed to habitat differences rather than proximity or location in the reserve. With the removal of trees, bamboo, and understory vegetation, and their sparse, open canopy, oil palm plantations around DTR mostly supported open-country bird species, such as the Common Tailorbird, Red-vented Bulbul, and Olive-backed Pipit. Similarly, a study in Peninsular Malaysia found that open-habitat birds such as the Oriental Magpie-Robin (*Copsychus saularis*), Common Tailorbird, and Red Junglefowl (*Gallus gallus*) were more frequently detected in oil palm than in forest habitat (Azhar et al. 2011, 2013). Although a few common forest bird species such as the Blue-throated Barbet (*Psilopogon asiaticus*) and Little Spiderhunter (*Arachnothera longirostra*) did occur in oil palm plantations, they were mostly seen in the few standing trees, scattered banana plants, and shrubs that had not been cleared or that remained near the plantation edge. Azhar et al. (2013) noted that other bird species, such as woodpeckers, may occur in older, more mature (>16 yr old) plantations if resources such as dead trees are available, but conversion to oil palm plantations may still account for the loss of 48–60% of forest bird species. A review of oil palm impacts on biodiversity noted that these plantations supported fewer than half of the vertebrate species found in primary forests, and, across taxa, a mean of only ~15% of forest species was found in oil palm plantations (Fitzherbert et al. 2008). These results suggest that, although oil palm plantations in the Dampa landscape are relatively young (<7 yr old), their negative impacts on forest birds are likely to remain high.

Similarly to the results of this study, commercial tree plantations (of alien *Pinus* spp. and native *Araucaria angustifolia*) were found to have lower canopy closure, bamboo cover, native tree diversity, and concomitant lower bird diversity compared with native forest plots in Atlantic forests of Argentina (Zurita et al. 2006). Studies from the Brazilian Amazon (Moura et al. 2013), Papua New Guinea (Bell 1979), and South Asia (Kumar et al. 2011, Goodale et al. 2014) have noted that timber plantations such as teak are poorer habitat than mature and secondary forests, and therefore support fewer rainforest bird species. Oil palm and teak plantations could potentially reduce their drastic impact through improvements in land use practices, such as by protecting forest patches in the landscape, and retaining epiphytes, leguminous plants, and ground vegetation within the plantations (Koh 2008, Moura et al. 2013, Azhar et al. 2014, 2015).

Bamboo recovery and density appear to have a significant influence on habitat structure and bird community changes in teak plantations and jhum landscapes. As noted in earlier research (Raman et al. 1998, Raman 2001), bamboo has a negative effect on open-country bird species. The rapid recovery of *Melocanna baccifera* bamboos (along with other plants such as banana plants and pioneer trees) creates a dense understory habitat for many forest bird species such as Brown-cheeked Fulvettas, flycatchers, spiderhunters, and tit-babblers, as well as for birds that prefer or specialize on bamboo such as Yellow-bellied Warblers, White-browed Piculets, and Pale-headed Woodpeckers. As some teak plantations that we examined had been established on erstwhile jhum lands in the Dampa landscape, they contained regenerating bamboo in the understory, which contributed to the foliage structure and forest bird diversity in teak. If bamboos are absent (as they are in many teak plantations in Mizoram), teak plantations have a sparser understory and likely support fewer forest birds.

Conservation Implications

The expansion of monoculture plantations, such as those of oil palm and rubber, at the expense of forests and multicrop agriculture is affecting the conservation of biological diversity over large parts of the world's tropics (Fitzherbert et al. 2008, Harvey et al. 2008, Warren-Thomas et al. 2015). Our study in northeast India adds to a growing body of work indicating that traditional shifting agricultural landscapes, with tropical secondary forests, are superior to teak and oil palm monocultures for forest and bird conservation. Regionally, the results of this study are relevant in the context of Mizoram State Government's New Land Use Policy (now being replicated in other states in northeast India), which is aimed at eradicating jhum, promoting alternative livelihoods and land uses, and rainforest conservation. Specifically, the establishment of monoculture plantations such as oil palm at the expense of jhum is counterproductive to the goals of conserving forest cover and biological diversity. Shifting agriculture, or jhum, is a better form of land use than monoculture plantations, and the denser and more diverse forest mosaic that it creates also helps to retain a significant fraction of forest birds in the landscape. As a form of land use, jhum therefore deserves to be supported as a better option for the buffer zone around Dampa Tiger Reserve, as noted in the reserve's management plan (Zathang and Sharma 2014). At a wider level, the State government could enhance support for jhum cultivation and jhum farmers by working to refine rather than replace this system of cultivation (Grogan et al. 2012). To minimize the impact of monoculture plantations and enhance their conservation value, regulations and international best-practice guidelines need to be adopted in the region. This could include strictures to retain forest patches along ravines, riparian buffers, and ridgelines, integrate native shade trees and natural vegetation such as hedges between rows or fields of oil palm, and prohibit the establishment of plantations in areas of high conservation value, especially around conservation reserves.

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APPENDIX TABLE 1. Abundance of bird species across 5 study strata in the Dampa landscape, Mizoram, India, in 2014. Values are numbers of individuals detected. Data are sorted in descending order of habitat affinity (open-country and forest birds). Open-country birds are arranged in descending order of their abundance in oil palm plantations, while forest birds are arranged in descending order of abundance in rainforest (Rf) interior, edge, and jhum (shifting agriculture) strata.

Species	Scientific name	Oil palm	Teak	Jhum	Rf edge	Rf interior
Open-country birds						
Red-vented Bulbul	*Pycnonotus cafer*	23	18	11	4	
Olive-backed Pipit	*Anthus hodgsoni*	15		6		
Common Tailorbird	*Orthotomus sutorius*	12	10	25	6	
Spotted Dove	*Streptopelia chinensis*	8	4	3		
Oriental Turtle-Dove	*Streptopelia orientalis*	5	2	19		
Red-whiskered Bulbul	*Pycnonotus jocosus*	1	8	11		
Greater Coucal	*Centropus sinensis*	1	1	1		
Taiga Flycatcher	*Ficedula albicilla*	1	1	1		
Chestnut-tailed Starling	*Sturnia malabarica*	1		3		
Gray-backed Shrike	*Lanius tephronotus*	1		1		
White-rumped Munia	*Lonchura striata*			8		
Gray Bushchat	*Saxicola ferreus*			1		
Blyth's Reed-Warbler	*Acrocephalus dumetorum*				1	
Forest birds						
Black-crested Bulbul	*Pycnonotus flaviventris*		3	11	25	23
White-throated Bulbul	*Alophoixus flaveolus*			4	13	21
Western Crowned Leaf Warbler	*Phylloscopus occipitalis*					20
Ashy Bulbul	*Hemixos flavala*		2	5	7	17
Blue-throated Barbet	*Psilopogon asiaticus*	6	12	4	22	15
Black-naped Monarch	*Hypothymis azurea*	2	4	5	7	15
Pin-striped Tit-Babbler	*Mixornis gularis*		5	11	13	14
Greenish Warbler	*Phylloscopus trochiloides*			3	3	11
Plain Flowerpecker	*Dicaeum minullum*		9	15	14	9
Yellow-browed Warbler	*Phylloscopus inornatus*	3	1	8	13	8
Scarlet Minivet	*Pericrocotus speciosus*	2	1	1	5	8
Gray-headed Canary-Flycatcher	*Culicicapa ceylonensis*				2	8
Large Woodshrike	*Tephrodornis virgatus*		5	1	1	8
Little Spiderhunter	*Arachnothera longirostra*	10	18	30	15	7
Greater Racket-tailed Drongo	*Dicrurus paradiseus*		3	2	2	7
White-rumped Shama	*Copsychus malabaricus*		2	7	5	6
White-bellied Erpornis	*Erpornis zantholeuca*		1	1	3	6
Lesser Racket-tailed Drongo	*Dicrurus remifer*		2	2	2	6
Pale-chinned Blue-Flycatcher	*Cyornis poliogenys*		3	8	3	5
Blue-winged Leafbird	*Chloropsis cochinchinensis*		2	1	1	5
Hair-crested Drongo	*Dicrurus hottentottus*					5
Streaked Spiderhunter	*Arachnothera magna*		3		3	4
Bar-winged Flycatcher-shrike	*Hemipus picatus*		1	1	2	4
Speckled Piculet	*Picumnus innominatus*				2	4
Golden-fronted Leafbird	*Chloropsis aurifrons*	1	8	5	1	4
Red-headed Trogon	*Harpactes erythrocephalus*				1	4
Bronzed Drongo	*Dicrurus aeneus*		8	4	5	3
Necklaced Laughingthrushes	*Ianthocincla pectoralis*, *Garrulax monileger*			3	4	3
Dark-necked Tailorbird	*Orthotomus atrogularis*				4	3
Buff-chested Babbler	*Cyanoderma ambiguum*		2	8	3	3
Puff-throated Babbler	*Pellorneum ruficeps*		1	5	2	3
Great Barbet	*Psilopogon virens*				2	3
Vernal Hanging-Parrot	*Loriculus vernalis*		3	1	1	3
Gray Peacock-Pheasant	*Polyplectron bicalcaratum*				1	3
Blue-eared Barbet	*Psilopogon duvaucelii*			1		3
Blue-bearded Bee-eater	*Nyctyornis athertoni*					3
Gray-throated Babbler	*Stachyris nigriceps*		1	6	7	2
Orange-bellied Leafbird	*Chloropsis hardwickii*			1	4	2
Bay Woodpecker	*Blythipicus pyrrhotis*			1	3	2
Oriental White-eye	*Zosterops palpebrosus*		1	3	1	2
Asian Fairy-bluebird	*Irena puella*					2

APPENDIX Continued.

Species	Scientific name	Oil palm	Teak	Jhum	Rf edge	Rf interior
Blue-naped Pitta	*Hydrornis nipalensis*					2
Sultan Tit	*Melanochlora sultanea*					2
Mountain Imperial-Pigeon	*Ducula badia*				4	1
Nepal Fulvetta	*Alcippe nipalensis*				4	1
Blue Whistling-Thrush	*Myophonus caeruleus*				2	1
Greater Yellownape	*Picus flavinucha*				2	1
Long-tailed Broadbill	*Psarisomus dalhousiae*				2	1
Yellow-vented Flowerpecker	*Dicaeum chrysorrheum*			7	1	1
Emerald Dove	*Chalcophaps indica*			1	1	1
Gray-headed Woodpecker	*Picus canus*			1	1	1
Square-tailed or Fork-tailed Drongo-Cuckoo	*Surniculus lugubris* or *S. dicruroides*		1		1	1
Chestnut-bellied Nuthatch	*Sitta cinnamoventris*	1			1	1
Maroon Oriole	*Oriolus traillii*				1	1
Yellow-bellied Warbler	*Abroscopus superciliaris*		3	16		1
Brown-cheeked Fulvetta	*Alcippe poioicephala*		3	10		1
Gray-bellied Tesia	*Tesia cyaniventer*			1		1
Pale-headed Woodpecker	*Gecinulus grantia*			1		1
Black-backed Forktail	*Enicurus immaculatus*		1			1
Asian Barred Owlet	*Glaucidium cuculoides*					1
Black-throated Sunbird	*Aethopyga saturata*					1
Blue Pitta	*Hydrornis cyaneus*					1
Gray Treepie	*Dendrocitta formosae*					1
Great Slaty Woodpecker	*Mulleripicus pulverulentus*					1
Jungle Owlet	*Glaucidium radiatum*					1
Large Hawk-Cuckoo	*Hierococcyx sparverioides*					1
Little Pied Flycatcher	*Ficedula westermanni*					1
Oriental Honey-buzzard	*Pernis ptilorhynchus*					1
White-cheeked Partridge	*Arborophila atrogularis*					1
White-tailed Flycatcher	*Cyornis concretus*					1
Common Iora	*Aegithina tiphia*	5		3	5	
Wreathed Hornbill	*Rhyticeros undulatus*				4	
Green-billed Malkoha	*Phaenicophaeus tristis*		3		3	
Ashy-headed Green-Pigeon	*Treron phayrei*				3	
Common Hill Myna	*Gracula religiosa*				3	
Thick-billed Pigeon	*Treron curvirostra*				3	
Black-winged Cuckooshrike	*Lalage melaschistos*			1	2	
White-browed Scimitar-Babbler	*Pomatorhinus schisticeps*			5	1	
Ashy Drongo	*Dicrurus leucophaeus*	2	3	2	1	
Blue-throated Flycatcher	*Cyornis rubeculoides*		1		1	
Gray-cheeked Warbler	*Seicercus poliogenys*				1	
Red Junglefowl	*Gallus gallus*		1	2		
White-browed Piculet	*Sasia ochracea*		1	2		
White-throated Kingfisher	*Halcyon smyrnensis*		1	2		
Black-hooded Oriole	*Oriolus xanthornus*			2		
Dollarbird	*Eurystomus orientalis*			2		
Black-naped Oriole	*Oriolus chinensis*			1		
Gray-capped Woodpecker	*Dendrocopos canicapillus*			1		
Wedge-tailed Pigeon	*Treron sphenurus*			1		
Yellow-bellied Prinia	*Prinia flaviventris*			1		
Indian Paradise-Flycatcher	*Terpsiphone paradisi*		1			
Crimson Sunbird	*Aethopyga siparaja*		1			
Large-billed Crow	*Corvus macrorhynchos*		1			
Rufous Woodpecker	*Micropternus brachyurus*	1				