

The natural forest gaps maintenance diversity of understory birds in Mae Sa-Kog Ma Biosphere Reserve, northern Thailand

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Abstract. Siri S, Ponpituk Y, Safoowong M, Marod D, Duengkae P. 2019. The natural forest gaps maintenance diversity of understory birds in Mae Sa-Kog Ma Biosphere Reserve, northern Thailand. *Biodiversitas* 20: 181-189. We compared the species composition and feeding guilds between under closed canopies and forest gaps in the low-elevation montane evergreen forest in Mae Sa-Kog Ma Biosphere Reserve. Monthly mist netting was used to capture birds from January 2015 to December 2017. In total, 958 individual birds belonging to 65 species were captured over 25,920 sampling hours. Of the total number of birds, 475 were from 51 species (Shannon-Wiener index: $H' 2.974$) under closed canopies and 483 were from 47 species ($H' 2.985$) in forest gaps. The number of bird species in gaps increased rapidly and constantly through 1 year following gap creation. Forest gap localities contained 48% of the understory birds in the area. Foliage-gleaning insectivores were the dominant bird feeding guild in both areas. Some species such as *Erythrura prasina* is a nomadic bird were found on first year of the forest gap only. Overall, we found that the forest gaps created by natural disturbances in the Mae Sa-Kog Ma Biosphere Reserve had no negative impact on the diversity of understory bird communities. The natural forest gap are created by intermediate disturbance promotes a relatively high biodiversity of birds in the ecosystem.

Keywords: Diversity, forest gap, mist netting, natural disturbance, nomadic bird

INTRODUCTION

A forest gap is a break in the tree canopy. Small gaps are created by the deaths of one or a few trees. Bigger gaps are created by large-scale disturbances, such as wildfires, typhoons, and insect outbreaks (Muscolo et al. 2014). In this study, we focused on forest gaps created by tree falls resulting from age-related tree deaths or wind storms. Whitmore (1975) recognized three sequential growth phases in the development of forest gaps: the gap phase (in which tree seedlings are present), the building phase, and the mature phase. Saplings occur when trees grow into the building phase. The gap phase may reoccur as the tree grows into the mature phase. Canopies reestablish in 5–40 years when gap diameters are in the range of 5–15 m²; canopy closure across gaps of 200–300 m² occurs in a period of ca. 30–60 years (Diaci et al. 2012). Tree falls and the consequent formation of canopy gaps are very important creators of environmental heterogeneity, which in turn strongly influences ecological structure and function (Kasenene 1987; Richards 1996). Intermediate levels of natural disturbance maintain the highest biological diversities; small-scale disturbance increases bird diversity and abundance (Collins & Glenn 1997; Restrepo & Gómez 1998; Chettri et al. 2005; Forsman et al. 2010).

The relationships between bird communities and their environments are important elements of community ecology. Specific community compositions vary by habitat

type and physical factors and are greatly influenced by habitat quality (Nakwa et al. 2008). The highly structured complexity of forests provides important resources for birds that are foraging or nesting; multilayered canopies also improve the chances of avoiding predators (Whelan 2001). Natural forest disturbances that create canopy gaps affect bird communities, but these effects are much smaller than those resulting from anthropogenic disturbance, particularly deforestation. Forest gaps function as keystone habitats for some birds (Levey 1990). Natural disturbance maintains populations of these avian species. Perkins and Wood (2014) suggested that conserving Cerulean Warblers will require creating small forest gaps (<100 m²). Thus, forest gaps provide important resources for many woodland bird species. Nevertheless, bird usage of forest gaps in mature stands has not been well documented in Thailand. Found only in the Mo-Singto plot, northeastern Thailand (Khamcha and Gale 2012). Previous studies suggest that understory birds are good indicators of natural disturbance in tropical forests (Barlow et al. 2002; Pearman 2002). Thus, the aim of our study was to examine changes in species composition and feeding guilds of understory birds following forest gaps areas compare with under closed canopies in the low-elevation montane evergreen forest in the Mae Sa-Kog Ma Biosphere Reserve in northern Thailand. Our findings improve understanding of the ways in which forest gaps help maintain bird species diversity.

MATERIALS AND METHODS

Study area

The study was conducted in a 16 ha permanent plot in the Mae Sa-Kog Ma Biosphere Reserve (18°48'45.7''N, 98°54'7.7''E), which is located in the Doi Suthep-Pui National Park in northern Thailand (Figure 1). Huai Kog Ma is north of the Bhubing Palace and ca. 20 km from Chiang Mai. This location has three seasons: a summer season extends from March through June, a rainy season from July through October, and a winter season from November through February. The average annual precipitation is 1736 mm/year. The most rainfall (335 mm/month) occurs in August during the rainy season (Glomvinya et al. 2016). Elevation at Huai Kog Ma ranges between 1,250–1,540 meters above mean sea level.

The natural vegetation is mature low-elevation montane evergreen forest; 189 plant species occur in the Huai Kog Ma Biosphere Reserve. The dominant species are *Castanopsis acuminatissima*, *C. armata*, *Styrax benzoides*, *Schima wallichii*, and *Vernonia volkamerioides* (Marod et al. 2014). Direct binocular observations have identified 86 bird species in eight orders and 26 families in the study area. The dominant birds are *Alcippe morrisonia*, *Garrulax strepitans*, *Alophoixus pallidus*, *Ixos mccllellandii*, *Culicicapa ceylonensis*, and *Pericrocotus flammeus* (Siri et al. 2013).

Data collection and analysis

We used mist-netting (18 m for each site) to capture understory birds in 9 sites located in under closed canopies (UCC) and forest gaps (FG) from January 2015 through December 2017. Forest gaps in this study refer to foliage-free areas in the forest canopy. Forest gap patches may

occur naturally; they can be created by the toppling of dead trees and by wind storms (Richards 1996; De Souza et al. 2001). The 9 gaps random selected for sampling were in the range of 200–600 m². We set 72 mist nets (each 2.5 × 9 m, 1 m high, with four shelves) per month in pairs in under closed canopy and forest gaps (Figure 2). The distance between under closed canopy and forest gap was approximately 10 m. The mist nets were set monthly. We collected data over 720 net sampling hours per month. The nets were open from dawn (0600) to dusk (1600) of bird sampling. Nets were checked every 30 min but more frequently during the morning and evening hours when birds were most active; the nets were closed during periods of rainfall (Bibby et al. 1998; Wunderle et al. 2005; Werema 2015). All birds were identified by species, then aged (juvenile or adult) and sexed. All mist-netted birds were ringed and then released at the capture points; activities complied with the protocols of the Department of National Park, Wildlife and Plant Conservation of Thailand, which granted permission issued no. DNP 0907.4/9819 for our research.

Species diversity was calculated using the Shannon-Wiener index (H' ; Magurran 1988); diversity measures for forest gaps and closed canopies were compared H' using Species Diversity and Richness program ver. 2.64 (Henderson and Seaby 1998). A similarity index was used to compare similarities in the bird faunas between different areas using either the presence/absence of species or species attributes (Krebs 1989). Pearson's correlation was performed in R ver. 3.1.1 (R Core Team 2014) to evaluate the correlation between UCC and FG. A principal components analysis (PCA) was performed to study relation habitat variables and birds distribution between UCC and FG in PCORD 6.

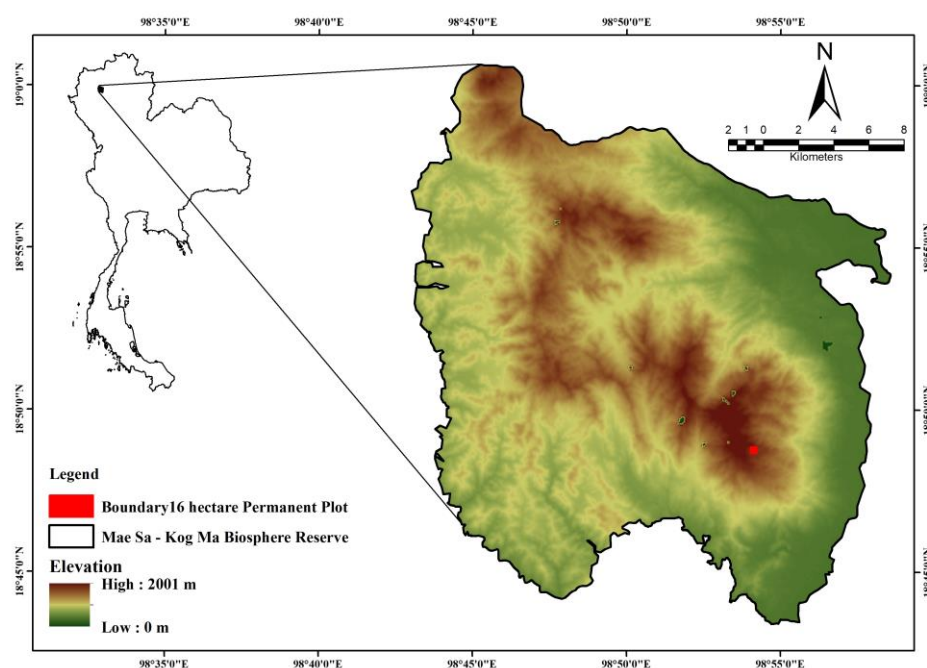


Figure 1. Location of a 16 ha permanent plot (red square) in the Mae Sa-Kog Ma Biosphere Reserve, Thailand



Figure 2. Crown cover tree forest in under closed canopy (left) and forest gap (right) in study area

RESULTS AND DISCUSSION

Bird species composition

Our mist nets captured 958 individual birds in five orders, 26 families, and 65 species over 25,920 netting hours in under closed canopy and forest gap locations. Of the total birds captured, 483 individual birds in 51 species were captured in closed canopy sites and 475 individuals in 47 species were caught in forest gap sites. Eighteen and 14 species were captured only in under closed canopy and forest gap sites, respectively; 32 species occurred in both sites (Table 1).

The following species were particularly common at both site types: *Alcippe fratercula*, *Cyornis banyumas*, *Stachyris nigriceps*, *Alophoixus pallidus*, and *Seicercus omeiensis*. *A. fratercula* was dominant species among understory birds in this area; we captured 81 under closed canopy and 126 individual birds in forest gaps.

Cumulative species curves for understory bird species in under closed canopy and forest gap site are presented in Figure 3. In both site types, the number of species increased rapidly and continually during the initiation of study period in 2015. In the same year on month 5 through month 12, species cumulative in the forest gaps higher than under closed canopies. After the first year, the slopes of the cumulative species curves for forest gaps became less steep, but the curves continue to rise over time, and were lower than those for under closed canopies.

The overall Shannon-Wiener index (H') for the study area was 3.11; values for under closed canopy and forest gaps sites were 2.97 and 2.98, respectively. H' values were not significantly different between closed canopy and forest gap sites ($P > 0.05$). Comparison of Similarity index (IS) between UCC and FG in each year, IS was highest on third year between UCC and FG (Table 2). Moreover, found that the IS in the first year and second year in the forest gap were highest when compared among forest gaps based on a different age.

The number of bird captures for the under closed canopy from 2015–2017 was 128, 181, 174 and 132, 140, 203 in the forest gaps. Pearson correlation coefficients of 6 habitat variables (UCC 1st in 2015, UCC 2nd in 2016, UCC 3rd in 2017, FG 1st in 2015, FG 2nd in 2016, FG 3rd in 2017) based on number of capture birds are presented in Figure 4. The overall trend of habitat, UCC 1st in 2015 was least positive related to FG 1st in 2015 ($r = 0.50$, $P < 0.05$). The correlation of UCC 2nd in 2016 and FG 3rd in 2017 has a very strong positive correlation ($r = 0.91$, $P < 0.05$).

The distribution of understory birds can be seen in Figure 5, Principal Component Analysis (PCA) showed a relationship among bird species and habitat variables. The first axis (eigenvalue=20.103) separated the under closed canopy from the forest gap habitats. The second axis (eigenvalue=13.820) separated the FG 2nd and FG 3rd from FG 1st. *Napothera epilepidota*, *Myiomela leucura*, *Urosphena squameiceps*, and *Niltava sundara* were strongly related with the dense forest (UCC 2nd and UCC 3rd). In the natural open area, *Pteruthius intermedius*, *Sitta frontalis*, and *Alcippe fratercula* were related to FG 2nd, *Macronus gularis*, *Phylloscopus claudiae* and *Erpornis zantholeuca* were the high captured in FG 3rd. *Chloropsis hardwickii*, *Dryonastes chinensis*, *Erythrura prasina* and *Phylloscopus inornatus* were present only in FG 1st.

Feeding guilds

The highest percentage of feeding guilds were founded in the foliage-gleaning insectivorous (UCC 51% and FG 57%), following by sallying insectivorous (UCC 20% and FG 13%). The arboreal frugivores and terrestrial frugivores were not found in under closed canopy. Similarly, nocturnal raptor was not found in the forest gaps (Table 4). In term of species number for feeding guilds, terrestrial insectivore was the most species in under closed canopy (12 species) than in the forest gaps (5 species). In general, we found terrestrial insectivore seek a dense forest to foraging on the ground.

Table 1. List of species and feeding guilds of understory bird in the under closed canopy and forest gap

Species	Code	Under closed canopy			Forest gap			Feeding guilds
		2015	2016	2017	2015	2016	2017	
<i>Abroscopus superciliaris</i>	ABSU	-	-	-	-	-	✓	FGI
<i>Aethopyga saturata</i>	AESA	✓	✓	✓	✓	-	✓	IN
<i>Alcippe fratercula</i>	ALFR	✓	✓	✓	✓	✓	✓	FGI
<i>Alophoixus pallidus</i>	ALPA	✓	✓	✓	✓	✓	✓	AIF
<i>Arachnothera longirostra</i>	ARLO	✓	-	-	✓	✓	-	IN
<i>Arachnothera magna</i>	ARMA	✓	✓	✓	✓	✓	✓	IN
<i>Chalcophaps indica</i>	CHIN	-	-	-	✓	✓	✓	TF
<i>Chloropsis hardwickii</i>	CHHA	-	-	-	✓	-	-	FGI
<i>Clamator coromandus</i>	CLCO	-	✓	-	-	-	-	FGI
<i>Culicicapa ceylonensis</i>	CUCE	-	-	✓	✓	✓	-	Sal
<i>Cyornis banyumas</i>	CYBA	✓	✓	✓	✓	✓	✓	Sal
<i>Dicaeum ignipectus</i>	DIIG	-	-	-	-	-	✓	AF
<i>Dicrurus aeneus</i>	DIAE	✓	-	-	-	-	-	Sal
<i>Dicrurus remifer</i>	DIRE	-	-	-	✓	✓	-	Sal
<i>Dryonastes chinensis</i>	DRCH	-	-	-	✓	-	-	TI
<i>Enicurus sinensis</i>	ENSI	✓	✓	-	-	-	✓	TI
<i>Erpornis zantholeuca</i>	ERZA	-	✓	-	✓	✓	✓	FGI
<i>Erythrura prasina</i>	ERPR	-	-	-	✓	-	-	AF
<i>Ficedula hyperythra</i>	FIHY	✓	-	✓	-	-	-	Sal
<i>Garrulax monileger</i>	GAMO	✓	-	✓	-	-	-	TI
<i>Garrulax strepitans</i>	GAST	✓	✓	✓	✓	✓	✓	TI
<i>Geokichla citrina</i>	GECI	✓	✓	✓	✓	✓	✓	TIF
<i>Glaucidium brodiei</i>	GLBR	-	✓	-	-	-	-	R
<i>Hemixos flavala</i>	HEFL	✓	-	-	-	-	✓	AIF
<i>Hypothymis azurea</i>	HYAZ	✓	✓	✓	✓	✓	✓	Sal
<i>Ixos mccllellandii</i>	IXMC	✓	✓	✓	✓	✓	✓	AIF
<i>Kittacincla malabarica</i>	KIMA	✓	-	✓	✓	-	-	TI
<i>Larvivora cyane</i>	LACY	-	✓	-	-	-	-	TI
<i>Macronus gularis</i>	MAGU	-	-	-	✓	✓	✓	FGI
<i>Monticola rufiventris</i>	MORU	✓	-	-	-	-	-	TI
<i>Muscicapa ferruginea</i>	MUFE	-	-	-	-	-	✓	Sal
<i>Myiomela leucura</i>	MYLE	✓	-	✓	-	-	-	TI
<i>Myophonus caeruleus</i>	MYCA	-	-	✓	-	-	-	TI
<i>Napothera epilepidota</i>	NAEP	-	✓	-	-	-	-	TI
<i>Niltava davidi</i>	NIDA	✓	-	-	-	-	-	Sal
<i>Niltava sundara</i>	NISU	✓	✓	✓	-	-	-	Sal
<i>Pellorneum ruficeps</i>	PERU	✓	✓	✓	✓	-	-	TI
<i>Pellorneum tickelli</i>	PETI	✓	✓	✓	-	-	✓	FGI
<i>Phylloscopus claudiae</i>	PHCL	✓	✓	✓	✓	✓	✓	FGI
<i>Phylloscopus davisoni</i>	PHDA	-	-	✓	-	✓	✓	FGI
<i>Phylloscopus inornatus</i>	PHIN	-	-	-	✓	-	-	FGI
<i>Phylloscopus ricketti</i>	PHRI	-	✓	✓	✓	✓	✓	FGI
<i>Phylloscopus tenellipes</i>	PHTE	-	-	✓	-	-	-	FGI
<i>Picumnus innominatus</i>	PIIN	✓	✓	✓	✓	✓	✓	BGI
<i>Picus guerini</i>	PIGU	-	-	-	-	-	✓	BGI
<i>Pitta cyanea</i>	PICY	-	-	✓	-	-	✓	TIV
<i>Pomatorhinus schisticeps</i>	POSC	-	✓	✓	-	-	-	TI
<i>Psilopogon asiaticus</i>	PSAS	-	-	-	✓	-	✓	AIF
<i>Pteruthius aeralatus</i>	PTAE	-	✓	-	-	-	-	FGI
<i>Pteruthius intermedius</i>	PTIN	-	-	✓	✓	✓	✓	FGI
<i>Pycnonotus flaviventris</i>	PYFL	✓	✓	✓	✓	-	✓	AIF
<i>Rhipidura albicollis</i>	RHAL	✓	✓	✓	✓	-	✓	Sal
<i>Sasia ochracea</i>	SAOC	✓	-	✓	✓	✓	-	BGI
<i>Seicercus omeiensis</i>	SEOM	✓	✓	✓	✓	✓	✓	FGI
<i>Seicercus valentini</i>	SEVA	✓	✓	✓	✓	✓	✓	FGI
<i>Serilophus lunatus</i>	SELU	✓	✓	✓	-	-	✓	FGI
<i>Sitta frontalis</i>	SIFR	-	-	✓	✓	✓	✓	BGI
<i>Stachyris nigriceps</i>	STNI	✓	✓	✓	✓	✓	✓	FGI
<i>Staphida castaniceps</i>	STCAI	-	-	-	✓	-	-	FGI
<i>Terpsiphone affinis</i>	TEAF	-	✓	-	-	✓	-	Sal
<i>Turdus dissimilis</i>	TUDI	-	✓	-	-	-	-	TIF
<i>Turdus obscurus</i>	TUOB	-	✓	-	-	-	-	TIF
<i>Urosphena squameiceps</i>	URSQ	✓	✓	✓	-	-	-	TI
<i>Zosterops erythropleurus</i>	ZOER	-	-	-	-	-	✓	AIF
<i>Zosterops palpebrosus</i>	ZOPA	-	✓	-	-	✓	-	AIF

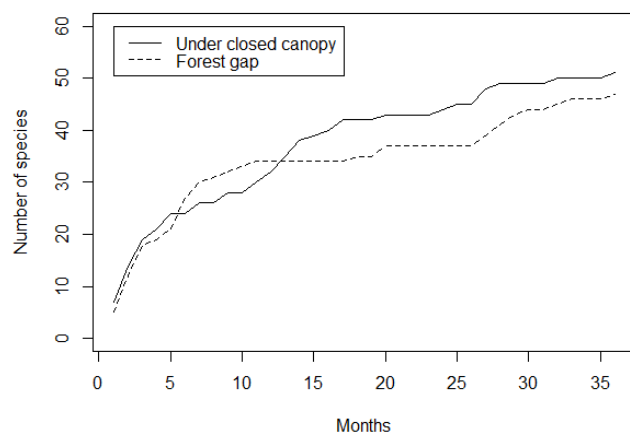
Note: Habitat type: under closed canopy (UCC) and forest gap (FG). Feeding guilds following Johns (1986): arboreal frugivore (AF), arboreal insectivore–frugivore (AIF), bark–gleaning insectivore (BGI), foliage–gleaning insectivore (FGI), insectivore–nectarivore (IN), nocturnal raptor (R), sallying insectivore (Sal), terrestrial frugivore (TF), terrestrial insectivore (TI), terrestrial insectivore–frugivore (TIF), terrestrial insectivore–faunivore (TIV)

Table 2. Species richness, Shannon-Wiener index (H') and Similarity index (IS) in under closed canopy and forest gap in each year.

Index	1 st yrs (2015)		2 nd yrs (2016)		3 rd yrs (2017)	
	UCC	FG	UCC	FG	UCC	FG
Sp. richness	32	34	35	27	35	34
H'	2.772	2.802	2.802	2.883	2.950	2.826
IS	57%		61%		66%	

Table 3. Species richness, Shannon-Wiener indices (H') and Similarity index (IS) within the forest gaps of the different ages.

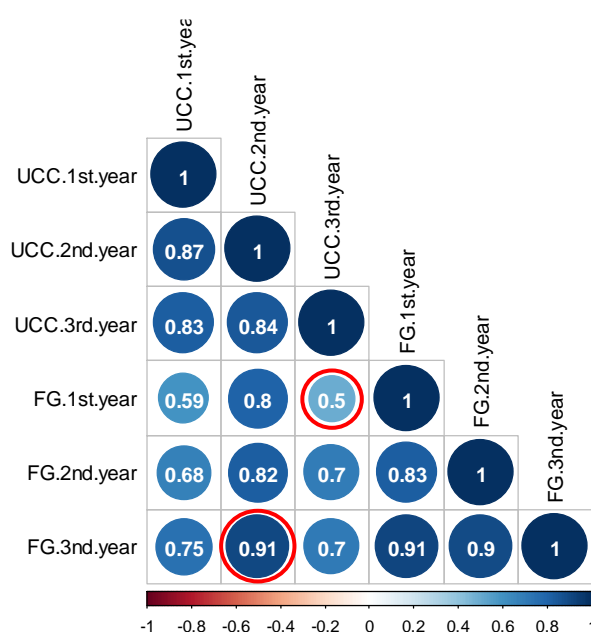
Index	Forest gap					
	1 st yrs	2 nd yrs	2 nd yrs	3 rd yrs	1 st yrs	3 rd yrs
Sp. richness	34	27	27	34	34	34
H'	2.802	2.883	2.883	2.826	2.802	2.826
IS	75%		72%		64%	

**Figure 3.** Cumulative species counts of understory birds in under closed canopy and forest gaps at Mae Sa-Kog Ma Biosphere Reserve, January 2015–December 2017

Discussion

Species composition

Species richness in Mae Sa-Kog Ma has increased since the binocular censuses compiled by Siri et al. (2013). Of the 65 species of understory birds we captured, 22 were new records in 16-hectare permanent plot; these included *Abroscopus superciliaris*, *Clamator coromandus*, *Ficedula hyperythra*, *Larvivora cyane*, *Phylloscopus ricketti*, *Pteruthius intermedius*, *Urosphena squameiceps*, *Turdus dissimilis* and *Erythrura prasina*. These species are mysterious understory birds. Mist net methodology is an effective means of capturing hard-to-observe, difficult-to-detect, quiet, and secretive species that live in the forest understory layer (Bibby et al. 1998; Lacher 2008).

**Figure 4.** Pearson's rank correlation matrix of habitat variable (UCC 1st: under closed canopy first year (2015), UCC 2nd: under closed canopy second year (2016), UCC 3rd: under closed canopy third year (2017); FG 1st: forest gap first year (2015); FG 2nd: forest gap second year (2016); FG 3rd: forest gap third year (2017)) and number of capture birds of understory birds in Mae Sa-Kog Ma Biosphere Reserve

We captured 65 species over our entire study area. Of these, 18 were captured exclusively under closed canopy, and 14 were found exclusively in forest gaps. The closed canopy-only and forest gap-only terminology does not specify that a species occurs exclusively in a single habitat (Marsden 1998). Closed canopy-only bird species such as *Myiomela leucura*, *Napothera epilepidota*, *Niltava sundara* and *Urosphena squameiceps* normally found in these under closed canopy locales. When dense forests are disturbed and open areas are created, those species living only in under closed canopy locations will disappear (Werema 2015). Continual anthropogenic creation of open areas in forests disturbs the ecological conditions that are required by forest-dependent understory birds (Karr and Freemark 1983). Species-specific impacts differ by habitat type and physical factors (Nakwa et al. 2008). Forest gap-only species such as *Muscicapa ferruginea*, *Macronus gularis*, *Abroscopus superciliaris*, *Chloropsis hardwickii*, and *Erythrura prasina*. Gap dynamics are closely related to niche partitioning. Some arboreal species in tropical forests visit the forest floor in the gaps (Greenberg 1981). Thus, *E. prasina* is a semi-nomadic bird (Round et al 2011), which is a forest gap-only species, feeds on diverse grass seeds that are available during the vegetation succession on the forest floor. Forest gaps are well illuminated by incoming solar radiation that promotes the development of grass swards (Esquivel et al. 2008), which provide seeds for foraging *E. prasina*. Natural disturbance increases the availability of food for birds (Woinarski and Recher 1997). Early successional gap creates the unique of vegetation for some species of birds (Gharehaghaji et al. 2012). Shrubs

replace the grasses during the succession process, and the *E. prasina* move elsewhere. Small birds respond most dramatically to altered environmental conditions (Liknes and Swanson 2011). The species composition of bird assemblages adapted to disturbance is regulated by habitat quality (Brawn et al. 2001).

The slopes of cumulative species curves for *Chalcophaps indica*, *Culicicapa ceylonensis*, *Sitta frontalis*, *Pteruthius intermedius*, *Macronus gularis*, and

Erythrura prasina in forest gaps were steep during the initial sampling period. Overall, we found that in the study period the diversity of birds (H') in forest gaps exceeded that in closed canopy locations. Natural disturbance maintains the greatest biological diversity; forest gaps are created by small-scale disturbances that increase bird diversity and abundance (Forsman et al. 2010; Forsman et al. 2013; Muscolo et al. 2014).

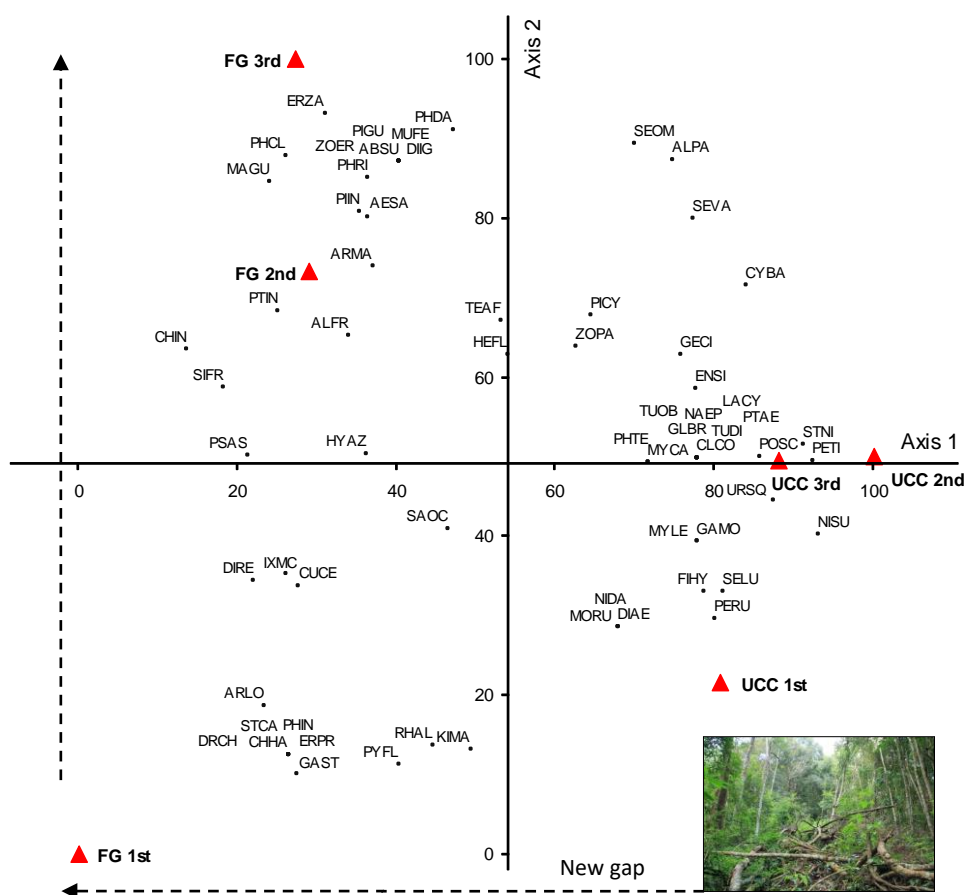


Figure 5. Principal component analysis (PCA) showing trends of species composition on the different age between under closed canopy and forest gap (by capture birds). UCC 1st: under closed canopy first year (2015), UCC 2nd: under closed canopy second year (2016), UCC 3rd: under closed canopy third year (2017); FG 1st: forest gap first year (2015); FG 2nd: forest gap second year (2016); FG 3rd: forest gap third year (2017).

Table 4. Proportion of captures birds in under closed canopy and forest gaps.

Feeding guilds	Under closed canopy		Forest gap	
	No. of captures (no. of species)	%	No. of captures (no. of species)	%
Arboreal frugivore	-	-	4 (2)	0.8
Arboreal insectivore–frugivore	47 (5)	9.7	60 (7)	12.6
Bark–gleaning insectivore	10 (3)	2.1	24 (4)	5.1
Foliage–gleaning insectivore	250 (14)	51.8	271 (16)	57.1
Insectivore–nectarivore	9 (3)	1.9	23 (3)	4.8
Nocturnal raptor	1 (1)	0.2	-	-
Sallying insectivore	99 (9)	20.5	62 (7)	13.1
Terrestrial frugivore	-	-	3 (1)	0.6
Terrestrial insectivore	45 (12)	9.3	16 (5)	3.4
Terrestrial insectivore–frugivore	20 (3)	4.1	11 (1)	2.3
Terrestrial insectivore–faunivore	2 (1)	0.4	1 (1)	0.2

In forest gap, the similarity index and captures bird of understory birds in the third years more similar to the under closed canopy than the two forest gap habitat. When the forest gap is succession continuously, bird composition in open habitat will similar to intact forest. For example, *Pellorneum tickelli* and *Serilophus lunatus* were common in all period in under closed canopy, which was also apparent in the third years of the forest gaps.

The result of the PCA analyses presented a difference in habitat variable and trend of bird distribution in this area. *Pycnonotus flaviventris*, *Rhipidura albicollis*, *Arachnothera longirostra* and *Chloropsis hardwickii* showed strongly related with FG 1st. The FG 2nd and FG 3rd were similar of bird composition, insectivore bird increased when compared to FG 1st. The composition dynamics of understory birds when large tree falling due to natural disturb in this study, it will changes in a clockwise direction (Figure 5). From the results of this study considered the same trend reported by Duengkae and Chimchome (2007) which study in the same forest type (about 1,000 meters above mean sea level) in western Thailand concluded that species diversity and abundance of birds were increased rapidly during successive parallel with vegetation recovery. Thus, ecological monitoring provides data that promote better understanding of the dynamics of bird species composition in natural ecosystems. Based on our results, we suggest that a heterogeneity of microhabitats promotes a relatively high biodiversity of birds in the ecosystem.

Feeding guilds

We classified the bird species into 11 feeding guilds (Table 1). The number of capture birds for the eleven other feeding guilds are depicted in Figure 4. The under closed canopy was dominated by foliage-gleaning insectivore (51%), following by sallying insectivore (20%) and arboreal insectivore-frugivore (10%). In forest gaps, foliage-gleaning insectivore (57%) was dominant followed by sallying insectivore (13%) and arboreal insectivore-frugivore (12%). The foliage-gleaning insectivore (FGI) in under closed canopy and the forest gap exceeded those of the other feeding guilds. The FGI were dominant included *Pellorneum tickelli*, *Stachyris nigriceps*, and *Serilophus lunatus* in under closed canopy, *Alcippe fratercula*, *Phylloscopus claudiae*, and *Phylloscopus ricketti* in the forest gaps. Most studies found that FGI and SaI as insectivorous birds are commonly the largest component of mixed species flocks of understory birds (Round et al. 2011; Shermila and Wikramasinghe 2013). The high levels of insect abundance and diversity in tropical forests attract a wide variety of insectivorous birds (Rinker and Lowman 2000). The difference of capture birds in each feeding guilds may vary by foraging substrate and vertical structure. Moreover, insectivores are able to control populations of insects; these birds are particularly sensitive to habitat disturbance (Yong et al. 2011; Mansor et al. 2012; Singh et al. 2014; Thivyanathan 2016). Based on our observations, we propose that successful conservation of

insectivorous birds will require efforts to maintain habitat heterogeneity, particularly in closed canopy and natural forest gaps.

The captured bird of insectivore-nectarivore birds in the forest gaps we studied exceeded the rate under closed canopy, which was also the case in *terra firme* forests of the Amazon lowlands (Wunderle et al. 2005). Members of the insectivore-nectarivore group in our study area included *Aethopyga saturata*, *Arachnothera magna*, and *A. longirostra*. These species have long bills. They feed on nectar and small invertebrates (Khobkhet 2011). *A. magna* and *A. longirostra* consume nectar from the inflorescences of wild banana plants in the forest gaps. Wild banana is a pioneer plant species that establishes in naturally disturbed areas (Takahashi et al. 1995). Many forest gaps support populations of *Phlogacanthus curviflorus* (Wall.) Nees (Figure 6), which is a source of nectar for these birds; the abundance of insectivore-nectarivore birds has been related to the flowering of this species (Bennett et al. 2014). *P. curviflorus* nectar in forest gaps is a key resource for members of this bird feeding guild. Canopy gaps maintain food resources for insectivore-nectarivore birds in tropical forests, particularly during the dry season (Marod et al. 2010). Several studies have shown that insectivore-nectarivore birds in tropical forests can be captured in areas with low canopy cover or in open habitats (Levey 1988; Pearman 2002; Chettri et al. 2005; Smith et al. 2015). Differences among bird groups are generally consistent with differences in the abundance of foraging substrata (George et al. 2005). Species composition and feeding guild clearly depend on the microhabitat and large-scale forest structure. A better understanding of species composition requires long-term monitoring because forest gap regeneration changes are evident over the first 5–6 years following gap creation (Brokaw 1985).



Figure 6. *Phlogacanthus curviflorus* (Wall.) Nees, a large shrub ca. 4–5 m tall with terminal inflorescences measuring 12–15 cm × 5–6 cm and bearing short-peduncled flowers that are present from January to March (Dutta et al. 2016). These flowers were a good source of nectar for nectarivorous birds in the natural forest gaps in Mae Sa-Kog Ma Biosphere Reserve, Thailand

We have shown that forest gaps created by natural disturbances are a common element in forest dynamics. Forest gaps promote high biodiversity and provide alternative sites for utilization by understory birds. We also found that bird diversity was significantly related to intermediate levels of disturbance in the forest canopy. Vegetation succession in forest gaps is correlated with forest bird biodiversity. The succession process increases bird diversity and the heterogeneity of the microhabitat in forests. Succession in gaps is important for the persistence of insectivore–nectarivore birds. The findings of our study on gap size in a natural forest can be extrapolated to tree plantations and protected areas in which the creation of gaps should become a component of bird diversity conservation.

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