Composition and Structure of Mixed Species Bird Flocks and Their Seasonal Changes in Montane Forest Habitats of Horton Plains National Park, Sri Lanka

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Abstract
Mixed-species flocks are the frequent phenomenon in many habitats worldwide. The composition, structure and seasonal changes of mixed species bird flocks were observed in the tropical montane cloud forest habitats of Horton Plains National Park from December 2017 to October 2018. Line transects of 1000m length and 20m width were surveyed in three selected study sites of this park. A total of 2,140 individual birds belonging to 16 species were recorded in MSBFs during the study. Annual average flock size and species richness values were 25.8 ± 8.3 and 6.9 ± 1.6 respectively. The canopy height utilization significantly differed among these 16 species observed. There were nine species who acted as leading species in the MSBFs. Sri Lanka Orange-billed Babbler *Turdoides rufescens* was the most specific leading species. The average number of flocks was relatively higher in the Southwest monsoon season and lower in 1st inter monsoon season when compared to other seasons. A significantly higher flock size and a species richness were recorded in 2nd inter monsoon season and significantly lower values were recorded in the 1st inter monsoon season. There were no significant differences on average flock number in each study site and between the seasons. The findings indicate an even distribution of MSBFs in the HPNP without any seasonal barrier. The 2nd Inter monsoon season (October–November) can be identified as the most suitable period for observations of MSBFs. Conservation measures should be integrated in ecotourism activities especially during the holidays.

1. Introduction

Mixed-species flocking behavior is a common phenomenon in tropical and temperate habitats worldwide (Shermila & Wikramasinghe 2013; Pagani-Núñez *et al.* 2018). Mixed-species flocks are defined as "an association of two or more species that move consistently irrespective of the location of specific food resources in contrast to aggregations (Greenberg 2001; Goodale *et al.* 2009). This behavior is a significant feature of birds (Goodale *et al.* 2009).

Flock participants can be categorized according to the regularity of participation and the role of maintaining flock cohesion as nuclear species and attendant or adherent species (Eguchi *et al.* 1993; Goodale & Kotagama 2005). A "Nuclear species" is described under the obligate participants that exhibited several behavioral and morphological features as; rarely foraging alone (high flocking propensity), joined and followed by other species, high vocalization, intraspecifically gregarious, numerous in flocks, most common in flocks, conspicuous calls and active behavior (Harrison & Whitehouse 2011; Hutto 1994). "Attendant species" is defined as a species that joins and follows flocks (Greenberg 2001).

Participant species of mixed species bird flocks (MSBFs) can be categorized by considering both occurrence and the flocking propensity factors (Munoz 2016). The occurrence of a species can be used to suggest how common a particular species in flocks (high frequency in flocks). Flocking propensity shows whether a species forage alone or as MSBFs. The abundance of flocking species is also important to determine the nuclear species. Conspicuous calls and active behavior of nuclear species are

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useful factors when identifying MSBFs in the field.

When a bird flock moves, canopy species are considered as "leaders" and the others as "followers" (Partridge & Ashcroft 1976). "Leader species" means a species that combines the flock or is followed by other species (Greenberg 2001). The "followers" use the calls of front members to locate the rest of the flock.

There is a niche partitioning among the members of a mixed species flock. The participants obtain benefits from their association with other species. Birds in mixed species flocks may benefit directly or indirectly from this association, through increased foraging and reduced predation risk without increasing intraspecific competition as selective principle advantages (Bohórquez 2003; Goodale *et al.* 2009).

MSBFs have been always observed within the cloud forest habitats in the tropical country of Sri Lanka (Pethiyagoda 2012). Horton Plains National Park (HPNP) is the home for 78 species of birds including 66 resident species (with 13 endemic species) and 12 migratory species (Chandrasiri *et al.* 2018). It is one of the sites where the phenomenon of mixed species flocks was studied initially (Pethiyagoda 2012). However, a study was conducted many years ago by Partridge & Ashcroft (1976). Therefore, our objective was to provide updated and further information regarding mixed species bird flocks in the sensitive montane cloud forest habitats of HPNP and to investigate any changes from the previous observations. Seasonal changes of MSBFs were also investigated in the present study.

2. Materials and Methods

2.1. Study area

HPNP is located between the western and central ridges of the central highlands massif in the latitudes 6°47'–60°50'N and longitudes 80°46'–80°50'E (Green 1990). The elevation is ranging from 1,800 to 2,389 m above sea level. Horton Plains spreads across over 3,169 hectares of the highest land area of the island (Gunatilleke & Gunatilleke 1986; Chandrajith *et al.* 2009; Jayalal *et al*. 2017). Tropical montane cloud forests and wet Patana grasslands make up the vegetation in a mosaic pattern with a narrow ecotone belt in between (Premathilake 2012). The census was conducted in cloud forest habitats associated with North Western flank, North Eastern flank and plateau within the HPNP, and they were named as Site 1 (S1), Site 2 (S2) and Site 3 (S3) respectively (Fig. 1). The altitude range between 2,100 and 2,150 m was considered as the plateau of the HPNP. The study site where path to Dayagama was considered as North Western flank and Ohiya region was observed as North Eastern flank.

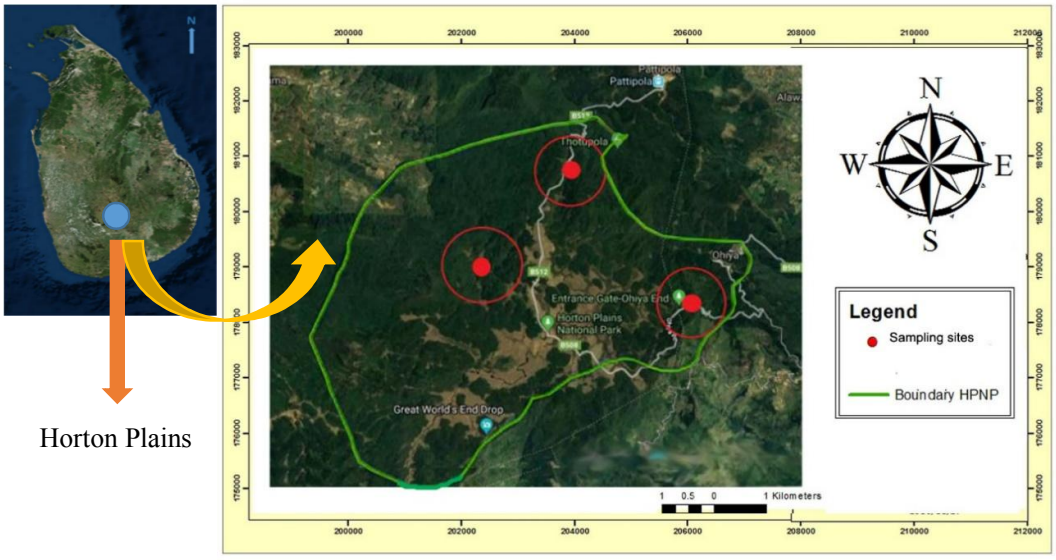

Fig. 1. Location of the study sites within Horton Plains National Park (Modified after http://www.arcgis.com/home/webmap/viewer.html)

2.2. Data collection

The study was carried out from December 2017 to October 2018 in HPNP. Line transect method was used and three transects were randomly laid in each sampling site. Each transect was 1 km in length and about 20 m in width to each side (Hostetler & Main 2001). The distance between any two transects varied 400–1,000 m (Naithani & Bhatt 2012) and a distance of 200 m was maintained between two flocks during the counting to avoid the repeated counts (Shermila & Wikramasinghe 2013). Birds were recorded using 10×50 binoculars (Nikon) while walking in slow pace over these line transects. Transects were surveyed in diurnal time period (06.00–18.00 h). No counts were made during rainy and misty conditions (Srinivasan *et al.* 2012). Bird species were identified using the Field Guide to the Birds of Sri Lanka (Harrison 2011).

2.2.1. Identification of vertical distribution of birds in MSBFs

As soon as a MSBF was met, the vegetation was scanned thoroughly from the canopy layer down to the forest understory to identify all flock participants (Rodewald & Paul 2003). The height of each participant occupied was visually estimated. The height of perching and foraging substrates was grouped into classes to minimize the errors in estimating the height (O'Donnell & Dilks 1988; Somasundaram & Vijayan 2008).

a) Ground (< 1 m)
b) Shrub (1–3 m)
c) Sub-canopy (3.1–6 m)
d) Canopy (6.1–9 m)
e) Top canopy (> 9 m)

2.2.2. Identification of horizontal distribution of birds in MSBFs

This was determined by standing at a fixed point, and recording the order in which each species appeared and disappeared as the flock went past the observation point (Partridge & Ashcroft 1976).

2.2.3. Determination of the environmental variables

Environmental variables were obtained at five randomly selected points within each transects. These monthly data were converted into seasonal mean values for four climate seasons [First inter monsoon season (March–April), Southwest monsoon season (May–September), Second inter monsoon season (October–November) and Northeast monsoon season (December–February)] (Chandrapala 1996).

2.2.4. Measuring physical environmental factors

Temperature (°C), relative humidity (%) and wind speed (kmh^{-1}) were recorded using weather meter (Kestrel 4000 weather meter, USA) within each point. Data on monthly total rainfall of HPNP recorded at the Nuwara Eliya weather station (Station ID: 43473) were obtained from the Department of Meteorology, Colombo, Sri Lanka.

2.2.5. Obtaining vegetation data

Canopy cover was measured using Spherical Densiometer. Litter depth on the forest floor was measured using a 15cm (6 inch) Stainless Steel Double-sided metal ruler (Gonçalves *et al.* 2017). The percentage cover of trees, shrubs, grasses, ground vegetation and coarse woody debris/ logs were recorded in an area of 5m radial distance of above randomly selected plots (Gonçalves *et al.* 2017).

2.3. Data analysis

Sample data sets were checked for normal distribution before using parametric or nonparametric test. The average number of flocks between four seasons was compared using One-way ANOVA. Turkey's test was used to obtain the significant difference between mean values. Data were tested for the normality. Kruskal-Wallis Test was used to examine the variation of non-parametric data for species richness between four seasons. One-way ANOVA was used for comparison of the flock size between four seasons. Turkey's test was used to obtain the significant difference between mean values. Pearson correlation was used to identify the correlation between the flock size and species richness (Shermila & Wikramasinghe 2013). Kruskal-Wallis Test and One-way ANOVA were used to compare the environmental parameters in different seasons as well as three sites (S1, S2 and S3). These calculations were done by using Minitab (Version 17, Minitab Inc., USA) statistical

software. The level of significance was set at 0.05.

Propensities and occurrences or the frequency of flock participant species were calculated for each species (Kotagama & Goodale 2004). Propensity was calculated for each species by using the following equation to find out the frequency in which a species uses the flocking behavior (Munoz 2016).

$$\text{Flocking propensity of "species A"} = \frac{\text{Total number of birds of "species A" in flocks}}{\text{Total sightings of the "species A" birds in and out of flocks}} \times 100$$

Occurrence was calculated as follows to calculate the number of flocks in which species was present (Munoz 2016).

$$\text{Occurrence of "species A"} = \frac{\text{Total number of detections of "species A" in flocks}}{\text{Total number of flocks of that type}}$$

Flocking Index was calculated by using both flocking propensities and occurrences for a particular species as below (Munoz 2016).

Flocking Index = Occurrence × Flocking propensity

There were four categories according to Flocking Index; (a. Obligate flocking species – Flocking Index > 0.6, b. Regular flocking species – Flocking Index 0.30–0.59, c. Occasional flocking species – Flocking Index 0.05–0.29, d. Accidental flocking species – Flocking Index <0.049).

The horizontal distribution was determined by calculating the Crossing score as follows (Kotagama & Goodale 2004).

$$\text{Crossing score} = \frac{\text{Position of the bird in the crossing}}{\text{Total number of birds that crossed}}$$

3. Results

3.1. Composition of MSBFs

A total of 2,140 individual birds belonging to 15 families and 16 species including 8 endemic species were recorded during the study period (Appendix 1). One vulnerable (VU) species, four near threatened (NT) species were reported and the rest of them were least concern (LC) species. Among them, 355 were Sri Lanka White-eye *Zosterops ceylonensis* and 281 were Sri Lanka Yellow-eared Bulbul *Pycnonotus penicillatus* and they had higher average number of individuals than other species (4.3±2.6 and 3.4±2.4 respectively). Sri Lanka Blue Magpie *Urocissa ornata* and Greater Sri Lanka Flameback *Chrysocolaptes stricklandi* had lower average number of individuals having only six and five recordings in MSBFs (0.1 ± 0.4 and 0.1 ± 0.3). There was not any common species which participated all the flocks observed. The highest number of individuals recorded in a single flock was for Sri Lanka Orange-billed Babbler (21 individuals per flock). The Velvet-fronted Nuthatch *Sitta frontalis* and Grey-headed Canary Flycatcher *Culicicapa ceylonensis* also had a higher range of individuals (0–12 individuals). The Sri Lanka Blue Magpie was only recorded in S2 and the Greater Sri Lanka Flameback was only observed in S1.

The highest number of flocks consisted of eight species (23 flocks). Most flocks were in the range of 5 to 9 species. The number of flocks consisted of 3, 4, 10 and 11 species were relatively low. Most number of flocks had a flock size range of 11–20 (31 flocks) and the range of flock size was 21–30 in 29 flocks. The number of flocks with <10 flock size and 41–50 flock size were very low (2 and 4 flocks respectively). An average flock size of 25.8 ± 8.3 and a species richness of 6.9 ± 1.6 were

calculated based on 83 flocks recorded during the study period. There was no significant difference between species richness and flock size within the three sites. There was a positive significant relationship between the flock size and species richness of MSBFs (r=0.765, P<0.05, Fig. 2).

When the species occurrence was considered, Sri Lanka White-eye had the highest frequency in MSBFs. Considering the flocking index, Sri Lanka White-eye, Great Tit *Parus major* and Sri Lanka Scimitar Babbler *Pomatorhinu melanurus* had values greater than 0.6 and they were Obligate flocking species (Core species) in MSBFs. The Grey-headed Canary Flycatcher, Sri Lanka Yellow-eared Bulbul, Pale-billed Flowerpecker *Dicaeum erythrorhynchos*, Dark-fronted Babbler *Rhopocichla atriceps* and Velvet-fronted Nuthatch had flocking index values between 0.30–0.59 and they can be considered as Regular flocking species. Sri Lanka Blue Magpie and Greater Sri Lanka Flameback had flocking index values less than 0.049 and they were Accidental flocking species. Other species had flocking index value between 0.05–0.29 that were occasional flocking species (Table 1). Most of them follow the flocks as attendant species, except Sri Lanka Orange-billed Babbler.

Table 1. Occurrence, flocking propensity and flocking index of bird species in MSBFs

Species	Occurrence	Flocking Propensity %	Flocking Index (FI)
Greater Sri Lanka Flameback *Chrysocolaptes stricklandi*	0.05	44.19	0.02
Bar-winged Flycatcher shrike *Hemipus picatus*	0.18	87.93	0.16
Scarlet Minivet *Pericrocotus flammeus*	0.18	76.45	0.14
Sri Lanka Blue Magpie *Urocissa ornata*	0.04	100.00	0.04
Grey-headed Canary Flycatcher *Culicicapa ceylonensis*	0.57	95.51	0.54
Great Tit *Parus major*	0.81	89.61	0.72
Sri Lanka Yellow-eared Bulbul *Pycnonotus penicillatus*	0.83	63.89	0.53
Common Tailorbird *Orthotomus sutorius*	0.17	62.81	0.11
Sri Lanka Warbler *Elaphrornis palliseri*	0.29	61.04	0.18
Sri Lanka White-eye *Zosterops ceylonensis*	0.89	72.33	0.64
Dark-fronted Babbler *Rhopocichla atriceps*	0.67	71.27	0.48
Sri Lanka Scimitar Babbler *Pomatorhinus melanurus*	0.72	84.11	0.61
Sri Lanka Orange-billed Babbler *Turdoides rufescens*	0.13	67.46	0.09
Velvet-fronted Nuthatch *Sitta frontalis*	0.43	96.42	0.42
Sri Lanka Dull-blue Flycatcher *Eumyias sordidus*	0.25	50.33	0.13
Pale-billed Flowerpecker *Dicaeum erythrorhynchos*	0.66	77.70	0.51

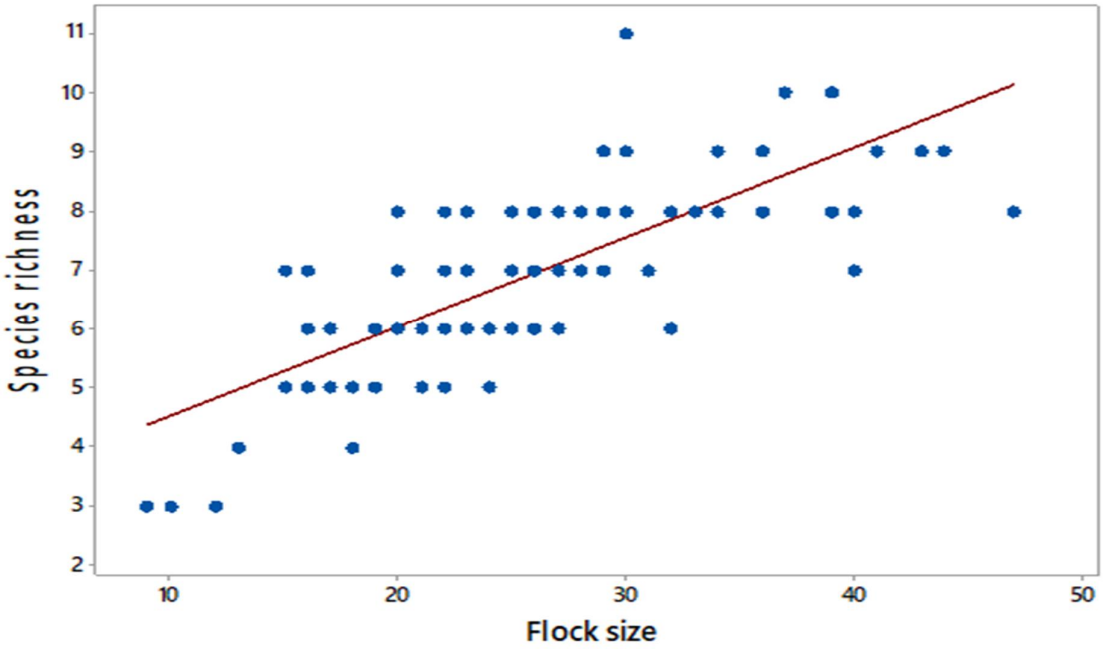

Fig. 2. Relationship between flock size and species richness in MSBFs.

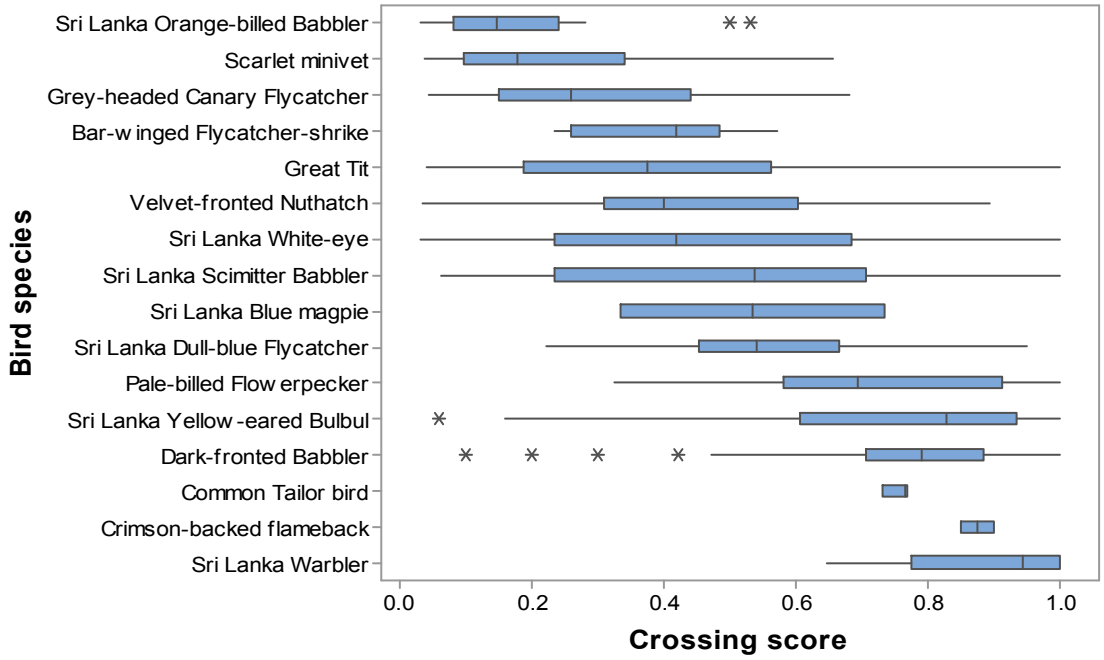

Fig. 3. Horizontal distribution pattern of 16 species in MSBFs.

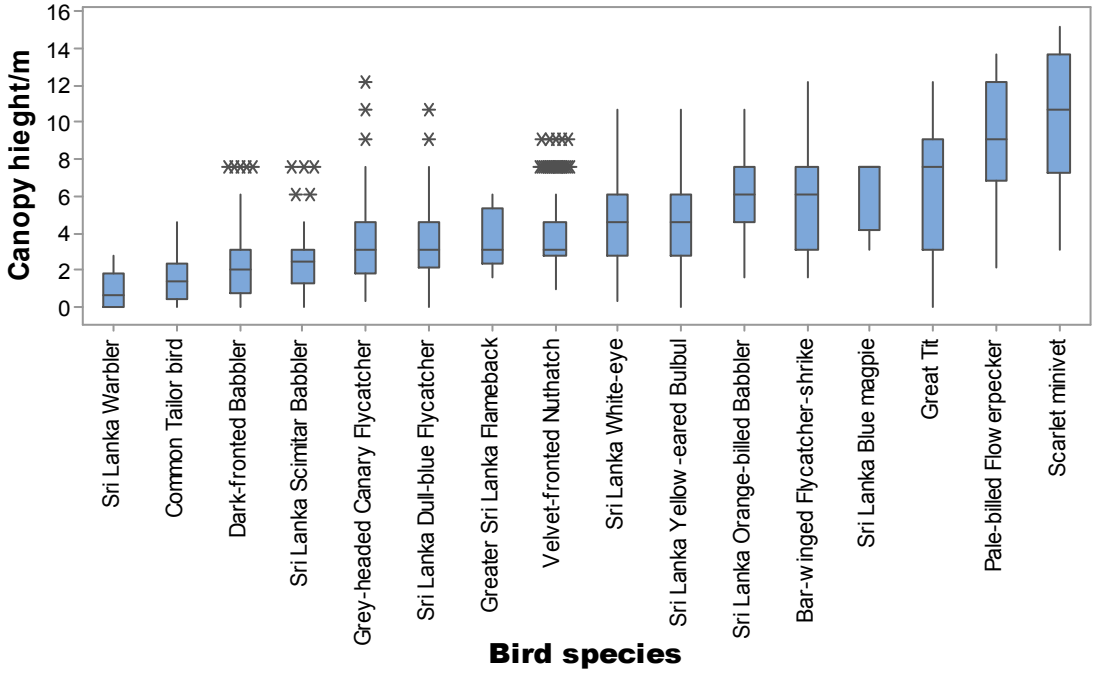

Fig. 4. Vertical distribution pattern of 16 species in MSBFs

When considering the occurrence of species, Sri Lanka White-eye, Sri Lanka Yellow-eared Bulbul and Great Tit had the highest occurrences (> 0.8). When flocking propensity was considered; Sri Lanka Blue Magpie, Grey-headed Canary Flycatcher, Sri Lanka Scimitar Babbler, Bar-winged Flycatcher shrike, Velvet-fronted Nuthatch and Great Tit had higher values (> 80%). However, some of the regular species were observed as nuclear species in the field occasionally when there were no obligate flocking species present in the flocks. This probability of acting as nuclear species reduces with decreasing flocking index value.

3.2. Structure of MSBFs

In the horizontal distribution, there were nine species that led MSBFs. Sri Lanka Orange-billed Babbler was the most specific leading species (100% of occasions led). Scarlet Minivet *Pericrocotus flammeus* was in the second place when leading occasions were considered (50%). Great Tit and Grey-headed Canary Flycatcher showed similar leading occasions. Sri Lanka White-eye, Sri Lanka Scimitar Babbler, Velvet-fronted Nuthatch and Dark-fronted Babbler also acted as leading species and Sri Lanka Yellow-eared Bulbul led minimum number of flocks. Sri Lanka Orange-billed Babbler had the least crossing score value (0.18 ± 0.15) and Sri Lanka Warbler *Elaphrornis palliseri* had the highest crossing score value (0.89 ± 0.12). Sri Lanka White-eye, Great Tit, Sri Lanka Scimitar Babbler and Velvet-fronted Nuthatch utilized the wide range of crossing score values of MSBFs (Fig. 3).

In the vertical distribution, average canopy height utilized by each species varied in the vertical scale. The Pale-billed Flowerpecker and Scarlet Minivet were users of the top canopy above 9 m. The Great Tit, Bar-winged Flycatcher-shrike *Hemipus picatus* and Sri Lanka Blue Magpie utilized 6.1–9 m canopy layer. Sri Lanka White-eye, Sri Lanka Yellow-eared Bulbul, Sri Lanka Orange-billed Babbler, Velvet-fronted Nuthatch, Grey-headed Canary Flycatcher, Sri Lanka Dull-blue Flycatcher *Eumyias sordidus* and Greater Sri Lanka Flameback utilized sub-canopy height around 3.1–6 m. Sri Lanka Scimitar Babbler, Dark-fronted Babbler and Common Tailorbird *Orthotomus sutorius* occupied the shrub layer within 1–3 m height. Sri Lanka Warbler utilized ground vegetation less than 1 m height. The canopy height utilization of the 16 species that were observed, significantly differed (H=710.85, df=15, $P < 0.05$) (Fig. 4).

3.3. Seasonal changes of MSBFs

The mean number of MSBFs in Southwest monsoon season (1.1±0.9) was higher than other monsoon seasons. The lowest mean number of MSBFs (0.7±0.2) was recorded in Northeast monsoon season. However, those values were not significantly different between the monsoon seasons ($F_{(3,6)}$=0.34 P=0.796). When seasonal variation was considered, S1, S2 and S3 had no significant difference in terms of flock number (H=4.37, df=3, P=0.224).

The values of flock size and species richness were varied with different monsoon seasons. There was a significant difference of species richness between seasons (H=11.32, df=3, P<0.05) and the flock size was significantly differed throughout the year ($F_{(3,79)=}$5.02, P<0.05). The 2nd inter monsoon season had a significantly higher flock size and species richness than other monsoon seasons (33.1± 8.8 and 7.8±1.2 respectively). The 1st inter monsoon had least number of flock size and species richness (20.9±7.7 and 5.7±1.5). The range between maxium and minimum values also fluctuated within seasons.

3.4. Seasonal fluctuations of environmental conditions

The highest temperature was recorded in the 1st inter monsoon season and the lowest was in the Southwest monsoon season. Temperature fluctuation between seasons had a significant difference (H=24.72, df=3, P < 0.05). Relative humidity varied seasonally recording the highest value in Southwest monsoon and lowest in 1st inter monsoon season. Those values also significantly differed (H=51.00, df=3, P < 0.05). Wind speed was significantly different between the four seasons (H=25.73, df=3, P < 0.05). However, Southwest monsoon season and 2nd inter monsoon season had higher wind speeds when compared to other two seasons. The canopy cover percentage did not differ significantly throughout the year ($F_{(3,53)}$=0.64, P=0.590). Northeast monsoon season had a relatively less canopy cover percentage than other three seasons. Litter depth also had no significant variation among four seasons (H=0.88 df=3, P=0.831). Northeast monsoon season had a relatively lower litter depth when compared to the other seasons. The highest rainfall was recorded in the 2nd inter monsoon season and the lowest rainfall was in Northeast monsoon season. However, rainfall was not significantly varying among monsoon seasons during the study period ($F_{(3,8)}$=2.71, P=0.116). The average annual temperature, relative humidity and wind speed had no significant difference among three study sites [(H=0.03, df=2, P=0.987), (H=5.84, df=2, P=0.054) and (H=1.15, df=2, P=0.563) respectively]. Canopy cover and litter depth were significantly differed between the sites ($F_{(2,54)}$=11.12, P < 0.05, H=10.01, df=2, P<0.005).

4. Discussion

The phenomenon of MSBFs is distributed throughout the world. However, the extremes of these flocks vary according to temperate, subtropical and tropical regions around the globe (Jayarathna *et al.* 2013). During the study period, there was no any special species which could be considered as a compulsory participant in these flocks. It further suggests that the minimum number of individuals of each species could be zero and higher in any given flock. In a previous study by Partridge & Ashcroft (1976) in HPNP, Sri Lanka White-eye has been recorded in all flocks and the range of individuals in flocks was mostly similar to the current study. Moreover, there were new species which were observed participating in MSBFs, namely Pale-billed Flowerpecker, Sri Lanka Dull-blue Flycatcher, Common Tailorbird and Sri Lanka Blue Magpie having newly joined to the previously recorded participatory species. Therefore, these results indicate that species composition of MSBFs vary during time periods.

MSBF can be described using flock size (number of individuals) and species richness (number of species). The flock size and species richness were evenly distributed throughout the park and there was no significant difference between the study sites. This could be the carrying capacity that is offered by these montane forests where the resource availability is not as great as that of the lowland forests. When considering about the species composition, some species were more abundant in particular sites. The Sri Lanka Blue Magpie and Greater Sri Lanka Flameback were observed only in one site as S2 and S1 respectively.

There was a positive correlation between the flock size and the species richness. It shows that the number of participatory individuals of each species was minimum and having around two

individuals of most species participating in the flocks as pairs. This factor has a considerable effect on the stability of flock composition throughout the year. This could be important to reduce intraspecific competition between individuals of the same species that participate in flocks. Some variations could be observed in this phenomenon due to accompanying of juveniles in MSBFs with the adults or at times of high food (insect) availability. If food availability is high, competition is reduced and the number of individuals of each species can be increased (Develey & Peres 2000).

Sri Lanka Orange-billed Babbler could be seen as a nuclear species in MSBFs which is an exception when flocking index values were considered. Furthermore, this species is the major nuclear species in the lowland tropical rainforest in Sri Lanka (Kotagama & Goodale 2004). In this study, Sri Lanka Orange-billed Babbler was observed in very low frequency in MSBFs. Moreover, they had low flocking propensity in MSBFs since they have a probability to form monospecific flocks without others (Jayarathna *et al.* 2013).

The participation of Sri Lanka Blue Magpie was a special finding in this study. Sri Lanka Blue Magpie was only observed in MSBFs in the study site of North Western flank (S2). They were observed very rarely and due to that their occurrence was very low. However, this species could be seen only in MSBFs not outside of the flocks making their flocking propensity 100%. The presence of Sri Lanka Blue Magpie specifically in S2 can be due to the forest connection North Western flank of HPNP has with the Peak Wilderness area which gives them local migratory access.

The Greater Sri Lanka Flameback, Common Tailorbird, Sri Lanka Warbler and Sri Lanka Dull-blue Flycatcher can be considered as territorial birds and they were participating in MSBFs when flocks move through their territories. These bird species could be seen as pairs. Sri Lanka Dull-blue Flycatcher could be observed as a species that used vocal sounds to announce their territory.

The Sri Lanka White-eye and Great Tit can be suggested as major and frequent nuclear species in the HPNP considering both abundance (>2.51) and flocking index (> 0.6). Other species such as the Grey-headed Canary Flycatcher, Sri Lanka Scimitar Babbler and Sri Lanka Yellow-eared Bulbul also had an alternative possibility to act as a nuclear species. Sri Lanka Scimitar Babbler had a conspicuous vocal sound and it could be used to attract other species. The species that were not mentioned here could be suggested as adherent species and they accumulate around the nuclear species. The effect of conspicuous vocal sounds on formation of MSBFs should be further studied.

The structure of MSBFs can be explained using vertical and horizontal distribution of flocks. The heights of vegetation which was used by each flocking species were used to identify the vertical distribution. The height of vegetation between species was significantly different and it was important to minimize the interspecific competition. The Sri Lanka Warbler used the ground vegetation and Scarlet Minivet used the top canopy for their foraging. The Sri Lanka Warbler, Common Tailorbird, Dark-fronted Babbler like ground vegetation users were indirectly helping the top canopy feeders by flushing the insects in ground level while they foraged. The Canopy/top canopy users such as flycatchers get advantage from this by sallying flying insects easily (Poulsen 1996).

According to horizontal distribution, there were two major flocking species as leaders and followers (Partridge & Ashcroft 1976). Leading species should direct the path of the flock and scan the predators in the surrounding. Most of the time, leading species such as the Scarlet Minivet (10.1 ± 3.6 m) and Great Tit (6.9 ±3.2 m) utilized high canopy heights. Leading ability was observed to be changing with the species. The records of Sri Lanka Orange-billed Babbler and Scarlet Minivet were less and they were not frequent flocking species. Due to that the Great Tit, Grey-headed Canary Flycatcher, Sri Lanka White-eye and Sri Lanka Scimitar Babbler had higher chance to lead MSBFs. In the absence of those species, the Velvet-fronted Nuthatch, Dark-fronted Babbler and Sri Lanka Yellow-eared Bulbul could lead the flocks.

Most of times, leading species were also observed to be nuclear species such as Sri Lanka Orange-billed Babbler, Great Tit, Grey-headed Canary Flycatcher, Sri Lanka White-eye and Sri Lanka Scimitar Babbler. It could be occurred due to the presence of higher number of individuals of these species in each flocks. However, the Sri Lanka Scimitar Babbler had less mean number of individuals per flock and

they had a conspicuous vocal sound and it may attract other following species. When the Scarlet Minivet leads the flock, another nuclear species such as Great Tit or Sri Lanka White-eye maintains cohesion of the flock since Scarlet Minivet do not had the sufficient ability to attract other species using gregarious and conscious behavior. But those species can detect predators easily than the following species. Those leading species emit alarm calls firstly. Therefore, it was not always an effort of a single leading species, but the contribution of several important species that made these MSBFs thrive.

The average number of flocks was relatively higher in Southwest monsoon season and lower in 1st inter monsoon season than other seasons although without any significant difference. It indicates that MSBFs had an evenly distributed flocking behavior throughout the year. According to monsoon seasons, these results indicated that the flock size and species richness varied within seasons having relatively a stable number of MSBFs.

According to location of HPNP in the central hills of Sri Lanka, North eastern flank is faced to winds of Northeast monsoon season. Other approachable flank is located at North western side of the park. Areas S3 and S2 covered those flanks. It was important to examine the effect of monsoon winds on bird flocks in those flanks. However, the average number of flocks did not show any significant difference in distribution. Due to that, the effect of monsoon winds on MSBFs distribution could be avoided. There were no significant differences on the average flock number in each study site between seasons. It gives evidence for even distribution of MSBFs in the HPNP without any seasonal barrier.

Seasonal fluctuations of environmental parameters were observed among four monsoon seasons. The lack of seasonal changes in the average flock number proves that seasonal changes of temperature and relative humidity do not affect their flocking behavior. The relative stability of the average number of MSBFs within the year could reject the effect of monsoon wind speed on flocking behavior. When comparing three sites in the HPNP, it shows similar environmental conditions within most of the area in the park except the canopy cover and litter depth.

Conservation

The composition of MSBFs comprised of sixteen species including eight endemics. From them, Sri Lanka Blue magpie was a vulnerable species and Sri Lanka Warbler, Sri Lanka Yellow-eared Bulbul, Sri Lanka Orange-billed Babbler and Sri Lanka Dull-blue Flycatcher could be observed as the near threatened species. Human visitation was having an effect on MSBFs. Bird flocks were disturbed in some instances when flocks cross the vehicle road or trail. On the other hand, human visitation influence to increment of the Large-billed Crow *Corvus macrorhynchos* population. These crow species change the habitats of MSBFs as a predator of breeding sites and exploiting other resources. However, Large-billed Crow was never observed with MSBFs. Second Inter monsoon season (October – November) can be identified as the most suitable time period for observations of MSBFs because of wealthy flock size and species richness. Leading species can be used as the indicators when MSBFs will reach to any area. Information generated by the study can be integrated with habitat management and conservation plans having MSBFs as conservation units. Furthermore, conservation measures should be integrated in ecotourism activities especially during holiday seasons.

Recommendation

Park management activities should be considered to minimize the disturbance from visitors as well as the growing population of Large-billed Crows. These findings can be used to encourage ecotourism activities integrating with the conservation measures. Sign boards can be displayed where any species is most abundant. Further studies may be required to study behavior of predator avoidance, interspecific communication via alarm calls and participation of arboreal mammals within MSBFs.

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Appendix 1. List of bird species and their IUCN status (Sources: Wijeyeratne 2015 & Anonymous 2020) U=Uncommon, E=Endemic, R=Resident, C=Common; VU=Vulnerable, NT=Near Threatened, LC=Least Concern.

Species	Oder	Family	Island-wide status	IUCN category
Greater Sri Lanka Flameback *Chrysocolaptes stricklandi*	Piciformes	Picidae	E	LC
Bar-winged Flycatcher-shrike *Hemipus picatus*	Passeriformes	Vangidae	U,R	LC
Scarlet Minivet *Pericrocotus flammeus*	Passeriformes	Campephagidae	R	LC
Sri Lanka Blue Magpie *Urocissa ornata*	Passeriformes	Corvidae	U,E	VU
Grey-headed Canary Flycatcher *Culicicapa ceylonensis*	Passeriformes	Stenostiridae	U,R	LC
Great Tit *Parus major*	Passeriformes	Paridae	R	LC
Sri Lanka Yellow-eared Bulbul *Pycnonotus penicillatus*	Passeriformes	Pycnonotidae	E	NT
Common Tailorbird *Orthotomus sutorius*	Passeriformes	Cisticolidae	C,R	LC
Sri Lanka Warbler *Elaphrornis palliseri*	Passeriformes	Locustellidae	U,E	NT
Sri Lanka White-eye *Zosterops ceylonensis*	Passeriformes	Zosteropidae	E	LC
Dark-fronted Babbler *Rhopocichla atriceps*	Passeriformes	Timaliidae	R	LC
Sri Lanka Scimitar Babbler *Pomatorhinus melanurus*	Passeriformes	Timaliidae	U,E	LC
Sri Lanka Orange-billed Babbler *Turdoides rufescens*	Passeriformes	Leiotrichidae	U,E	NT
Velvet-fronted Nuthatch *Sitta frontalis*	Passeriformes	Sittidae	R	LC
Sri Lanka Dull-blue Flycatcher *Eumyias sordidus*	Passeriformes	Muscicapidae	U,E	NT
Pale-billed Flowerpecker *Dicaeum erythrorhynchos*	Passeriformes	Dicaeidae	C,R	LC

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