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Frugivory of Yellow-eared Bulbul (*Pycnonotus penicillatus*) and Seasonal Variation of Fruiting Phenology in Tropical Montane Cloud Forests of Horton Plains National Park, Sri Lanka

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ABSTRACT

This study was conducted on a frugivorous bird species, Yellow-eared Bulbul (Pycnonotus penicillatus) which is an endemic and threatened species, at Horton Plains National Park (HPNP), from September 2015 to November 2017. Direct methods as focal animal sampling and faecal analysis were used to identify food items of P. penicillatus. Feeding plants were identified using field guides. To find out the fruit phenology, ten individuals per plant species were tagged. Fruit cover was estimated in the each tagged tree. According to the present findings, P. penicillatus mainly consumed, 16 species of feeding plants belonging to eleven families. Among them six endemic, eight native and one introduced species were observed. P. penicillatus consumed Rubus ellipticus as their major fruit source. There were seeds of nine plant species were identified by faecal analysis. Maximum ripen fruit cover was recorded from Solanum mauritianum in the northeast monsoon season, first inter-monsoon season and second inter-monsoon season. However, in the southwest monsoon season highest ripen fruit cover was recorded from Berberis ceylanica. There was a correlation between number of feeding attempts and ripen fruit cover, of Symplocos bractealis, S. mauritianum and Strobilanthes viscosa. Moreover, there was a correlation between number of feeding attempts and number of trees in fruiting, of Elaeocarpus coreaceus, Passiflora tripartita, Eugenia mabaeoides and S. viscosa. The present study has revealed importance of the floral community to the P. penicillatus. Therefore, it is important to recommend monitoring protocols about the seasonal variations of fruiting phenology in and around HPNP, which are harbouring a large variety of feeding plants of the threatened birds species such as P. penicillatus for conservational purposes.

KEYWORDS: *Frugivory, Yellow-eared Bulbul, Horton Plains National Park, Seasonal Variation, Tropical Montane Cloud Forest*

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1. INTRODUCTION

Ecological interactions between plants and birds are the main phenomena of evolutionary aspects such as co-evolution. Therefore, interactions such as frugivory is an important role in the lives of many passerine birds (Estrada & Fleming, 2012). Moreover, the term "frugivore" is used for the animals whose diets include a substantial portion of fruits at least during some seasons (Moermond & Denslow, 1985). They usually consume fleshy fruits, including berries, drupes, pomes, aggregated fruits, multiple fruits, and accessory fruits(Lopes *et al*, 2016).In many incidents fleshy fruits are eaten by birds, which obtain a reward as a result of digesting the pulp and take the seeds away from the parent plant to be later discarded in conditions suitable for germination (Herrera, 1984). Fruit-eating birds are distributed among a large variety of families of birds (Howe, 1986: Wheelwright, 1985). Only a few species of birds eat fruits throughout their lifetime (Moermond & Denslow, 1985). Most of the birds complete their fruit diets with different, relatively protein-rich foods (Wheelwright, 1985), and those birds that do feed solely on fruits as adults usually feed insects to their juveniles (Moermond & Denslow, 1985). Moreover, ability to digest fruit is believed to be an important limitation on the evolution of the interaction between plants bearing fleshy fruits and frugivorous birds (Herrera 1984). From previously studied 8918 terrestrial bird species a total of 1230 species (14%) were classified as frugivorous and moreover, most frugivorous birds (50%) are found within the perching birds (Passeriformes) (Kissling *et al*, 2009). Therefore, the role of passerines is a very important ecological role, especially as seed dispersal agents. Some researchers have found that small passerines dispersed most seeds within short distances (Jordano *et al*., 2007). Furthermore, phenology is the study of periodic plant and animal life cycle events and how these are influenced by seasonal and interannual variations in climate (Demarée, 2011).

Frugivory is a part of the diet of all bulbul species (Corlett, 1998). Fukui (1995) conducted laboratory experiments on the brown-eared bulbul *Hypsypetes amaurotis* by using 20 food plant species. The results demonstrated three phenomena. There were no seeds were injured by passing through the bulbul's gut. The seeds that had passed through the bulbul's gut were still able to germinate and fruit pulp has reduced germination ability. Other studies done on frugivory of bulbul species include nutritional analysis of frugivorous bulbuls have been carried out by Izhaki, (1992).

The Yellow-eared Bulbul (Passeriformes: Pycnonotidae), a bird species endemic to Sri Lanka, occurs in forest and nearby gardens, at middle and higher elevations, generally 900-2000m, where it is common to abundant in suitable habitats. It is an endemic threatened bird, assessed under IUCN global conservation status in the Near Threatened (NT) category, and according to the national conservation status *P. penicillatus* is categorized as a Vulnerable (VU) bird in the National Red List (MOE, 2012). Distribution of *P. penicillatus* throughout the country is already studied (Harrison & Worfolk, 2011; MOE, 2012). Moreover, ecology about this species has generally studied in the history (Henry, 1998). Some other ecological aspects such as distribution (Chandrasiri & Mahaulpatha, 2016) and

foraging behaviour of *P. penicillatus* was studied recently by Chandrasiri & Mahaulpatha (2017).

The present research was conducted in Tropical Montane Cloud Forests (TMCF) of Sri Lanka, at the Horton Plains National Park (HPNP) situated at Central highlands (Somasekaram, 1988). There is a significant change in the vegetation of highland forests in Sri Lanka at about 1,500m elevation (Gunatilleke & Pethiyagoda, 2012). Considering the specific characteristics of the vegetation, these forests are classified as Tropical Montane Cloud Forests (Aldrich *et al.*, 1997). Canopies of the trees are well adapted to capture water from clouds, a phenomenon is known as cloud stripping. The amount of water reaching from the cloud stripping is higher than the water supply from rainfall (Gunatilleke & Pethiyagoda, 2012). Furthermore, when compared with lowland rainforests, cloud forests can be easily distinguished by shorter canopy trees with gnarled branches, dense compact crowns; and small, closely- spaced, leathery, hard, waxy leaves. Moreover, the trees of the highland forests are closely spaced than those of lowland rain forests and soil is waterlogged, wet and highly organic (Hamilton *et al*., 1995). The forests of HPNP are dominated by the endemic *Calophyllum walkeri* in associated with many plant varieties of Myrtaceae and Lauraceae (Aldrich *et al.*, 1997). This area is protected under the Department of Wildlife Conservation of Sri Lanka (Green, 1990).

Although, *P. penicillatus* is a common frugivore in the highlands of Sri Lanka (BirdLife International, 2016), there is a research gap and there is only a handful of information about their selection of feeding plants. Therefore, the present study was carried out to find out more detailed information about the fruiting plant preference and fruiting phenology of preferred plants of this endemic bird.

2.MATERIALS AND METHODS

The study area, HPNP is located at 6°47'-6°50'N, 80°46'-80°50'E (Green, 1990) in Nuwara Eliya District. The HPNP occupies an area of 3,160 ha and contiguous with Peak Wilderness Sanctuary to the west (DWC, 2007; Pethiyagoda, 2012). Elevation of the HPNP ranges from 1800m to 2389m and Kirigalpota is the highest point (Aldrich *et al.*, 1997). There are three main habitats at the HPNP, which were previously identified as: Cloud Forest, Cloud Forest Die-back and Grasslands (DWC, 2007). The Cloud Forest is distributed in an area of 1,236 ha with an undisturbed old-growth forest which is low in height (15-20 m) with compared to lowland rain forests(Ashton *et al.*, 1997) and the canopy trees are characteristically gnarled and twisted, due to the lower temperatures and high winds. The Cloud Forest Die-back was distributed in an area of about 956 ha with the dead canopies. The type of habitat, which is considered as grassland contain mainly alpine flora of the montane grasslands locally known as 'wet pathana' (Gunatilleke & Gunatilleke, 1990). This habitat contains Dwarf Bamboo, Tussock Grass and Carpet Grass (DWC, 2007). Grassland habitat is distributed in an area of 806 ha of the National Park. The present research was conducted from September 2015 to November 2017 in three consecutive days per month.

Previously Chandrasiri and Mahaulpatha (2016) has reported that, Cloud Forest and Cloud Forest Die-back were the main

habitats occupied by the Yellow-eared Bulbul. Furthermore, Chandrasiri and Mahaulpatha (2017) has mentioned that, maximum number of foraging observations (95%) were recorded from the forest habitat and only 5% were recorded from grassland habitat. Within first three months a preliminary study was carried out to plot the feeding areas and observation of feeding plants of *P.penicillatus*. Moreover, this study was limited to the forest habitats where the cloud forest habitat and cloud forest die-back habitat were situated. Nine, 100 m fixed line transacts of 20 m width, were geolocated in the forest habitats by using a global positioning system device (GPS- Garmin eTrex 20x). In the preliminary study from September 2015 to November 2015, typical field notes, or "*Ad Lib*. Sampling" (Altman, 1974) was carried out to find out foraging attempts of the bird. From December 2015 to November 2017, focal animal sampling method was carried out to record the number of feeding attempts and at the meantime the particular plant species was identified by observing through a pair of binoculars (Nikon Monarch™ 10×50). To ascertain the feeding plants, faecal sampling methods were carried out. Fruit trees where the feeding behaviour was observed, were identified to the species level using field guides (Ashton *et al,* 1997). Faecal samples which were collected at the field were immediately stored in 70% ethanol and preserve for further laboratory studies. At the laboratory, the samples were analysed and the seeds observed were separated using a modified petri dish (Green & Tyler, 1989) and these seeds were observed under a binocular microscope (Olympus™ CX31), and identified using reference collections. To find out the fruiting phenology, ten individuals per each identified plant species were geolocated by the GPS. All the ripen fruits were observed through a spotting scope (Nikon Monarch™ 20-60x82 ED) in three branches from each tagged tree. This method was carried out in every month and ripen fruit percentage was estimated (Wheelwright, 1985). Monthly observations were summarized in to seasonal data. The weather conditions experienced during a 12-month period were characterized into four climate seasons according to Chandrapala (1996). These seasons were identified as: first inter-monsoon season (March- April), southwest-monsoon season (May-September), second inter-monsoon season (October-November) and northeast-monsoon season (December-February).

Data were analysed using Microsoft Excel™. Since the data were nonparametric, Spearman Rank Correlation was calculated in Minitab-17 ™. The results were considered significant at α=0.05. . The correlation between number of feeding attempts and ripen fruit cover and the correlation between number of feeding attempts and number of trees in fruiting was calculated.

3. RESULTS

According to the present data, *P. penicillatus* has mainly consumed, sixteen species of feeding plants belonging to ten families, which are further described in following table 1.

Table 1. A description of feeding plant species of *P. penicillatus*

Plant Species	Family	Origin	Habit
Rubus ellipticus	Rosaceae	Native	Shrub
Solanum mauritianum	Solanaceae	Native	Shrub
Symplocos bractealis	Symplocaceae	Endemic	Tree
Sarcococca brevifolia	Buxaceae	Native	Tree
Rhodomyrtus tomentosa	Myrtaceae	Native	Shrub to small tree
Rubus leucocarpus	Rosaceae	Native	Shrub
Passiflora tripartita	Passifloraceae	Introduced	Vine
Berberis ceylanica	Berberidaceae	Endemic	Shrub
Cestrum fasciculatum	Solanaceae	Introduced	Shrub
Elaeocarpus coreaceus	Elaeocarpaceae	Native	Tree
Solanum lasiocarpum	Solanaceae	Native	Shrub
Rubus indicus	Rosaceae	Native	Shrub
Callophyllum walkeri	Guttiferae	Endemic	Tree
Syzygium rotundifolium	Myrtaceae	Endemic	Tree
Eugenia mabaeoides	Myrtaceae	Endemic	Shrub to small tree
Strobilanthes viscosa	Acanthaceae	Endemic	Shrub

Among them six species are endemic to Sri Lanka. Eight species of them are native plants. Moreover, they consumed *Passiflora tripartite* (Plate 3), which was introduced to Sri Lanka. These fruits were distributed in every layer of the forest from shrub to trees. Many of the plant species were distributed within the shrubs profile. (Figure 1).

1-*Rubus ellipticus*,2-*Solanum mauritianum*,3-*Symplocos bractealis*,4-*Sarcococca brevifolia*, 5-*Rhodomyrtus tomentosa*,6-*Rubus leucocarpus*,7-*Passiflora tripartita*,8-*Berberis ceylanica*,9-*Cestrum fasciculatum*,10-*Elaeocarpus coreaceus*, 11-*Solanum lasiocarpum*,12-*Rubus indicus*,13-*Callophyllum walkeri*,14-*Syzygium rotundifolium*,15-*Eugenia mabaeoides*,16-*Strobilanthes viscosa*, * vines- distributed in the canopy level

Figure 1. Vegetation profile within Tropical Montane Cloud Forests of Horton Plains National Park (Modified diagram from Ashton *et al*., 1997)

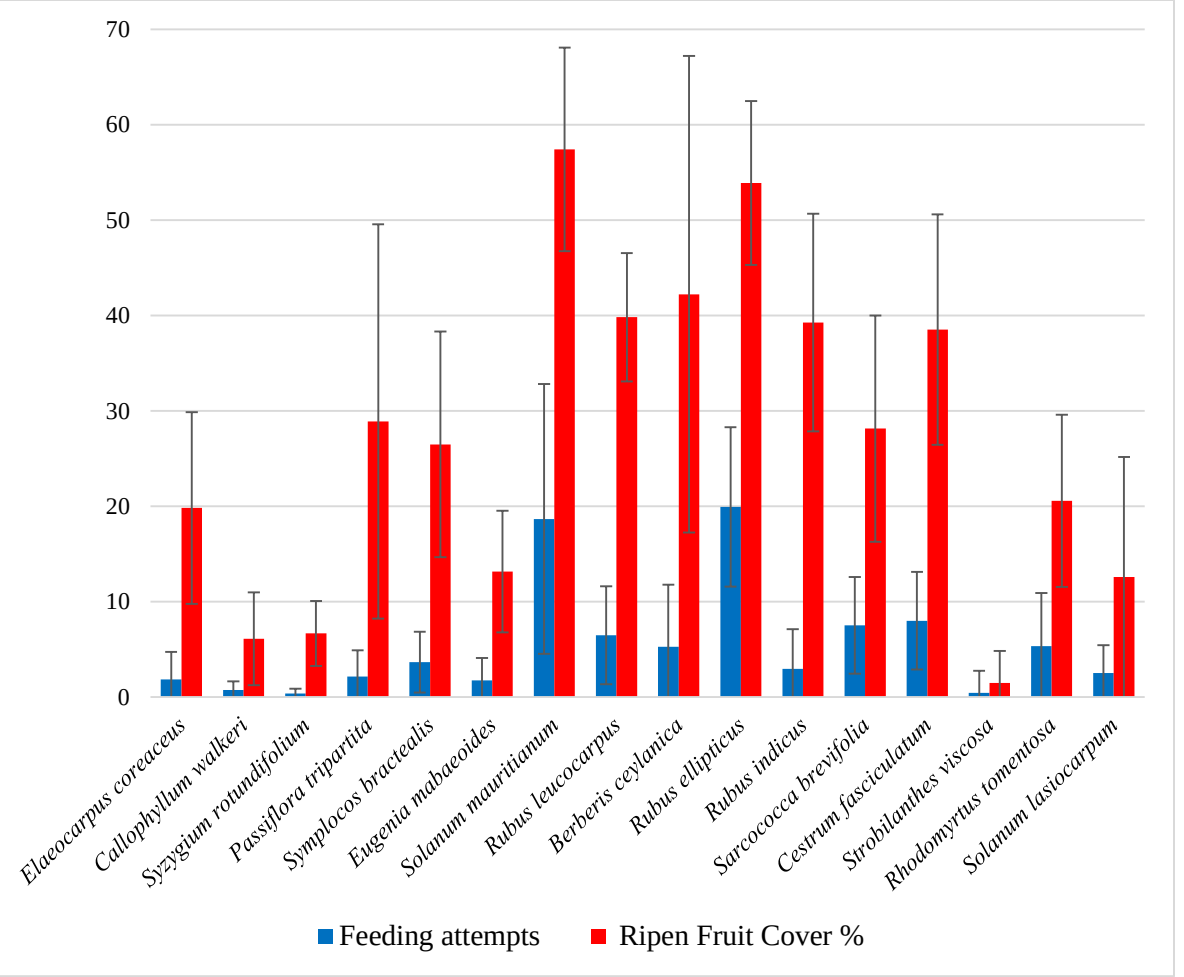

Figure 2. Feeding attempts of *P. penicillatus*

P. penicillatus preferred *R. ellipticus* as its major fruit source (Figure 2). The overall maximum number of feeding attempts (Plate 01) were recorded by *R. ellipticus*{19.93± 8.35 (Mean ± Standard Deviation)} during the study period. Moreover, *S. mauritinum* (Plate 2) is consumed to a considerable extent 18.67 ± 14.14(M ± SD)}. During most of their feeding attempts, *C. fasciculatum* (Plate 4) {8.00± 5.11 (M ± SD)} and *S. brevifolia* {7.52 ± 5.06 (M ± SD)} were consumed. Foraging fruits within other plant species such as *R. leucocarpus*, *R. tomentosa*, *B. ceylanica* and *S. bractealis* were also observed in higher values in the field.

Plate 1. *P. penicillatus* is feeding on a *R. ellipticus* fruit

Plate 2. *P. penicillatus* is feeding on a *S. mauritinum* fruit

Plate 3. *P. penicillatus* is feeding on a *P. tripartita* fruit fruit

Plate 4. *P. penicillatus* is feeding on a *C. fasciculatum*

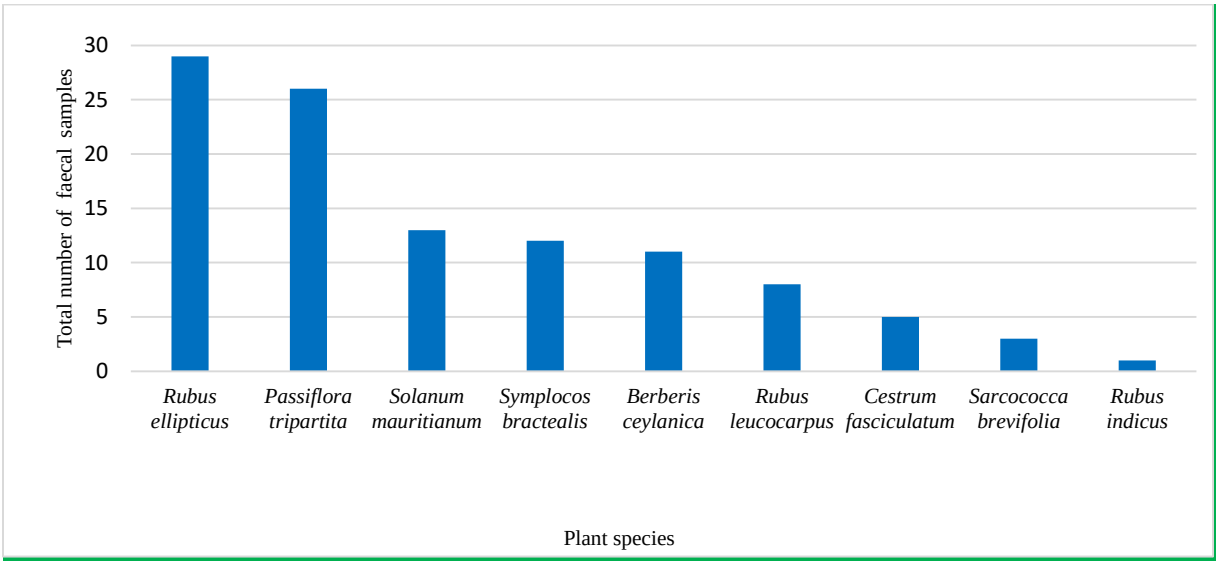

Figure 3. Food plants of *P. penicillatus* revealed by the presence of seeds in the faecal samples

Within the study 108 faecal samples were collected (Figure 3). Seeds of nine plant species were identified in the laboratory. Maximum number of samples were contented with *R. ellipticus* and *P. tripatrita*. Furthermore, *S. mauritianum, S. bractealis, B. ceylanica, R. leucocarpus* and *C. fasciculatum* were observed to a lesser extent, respectively. *S. brevifolia* and *R. indicus* were recorded in the least number of the faecal samples.

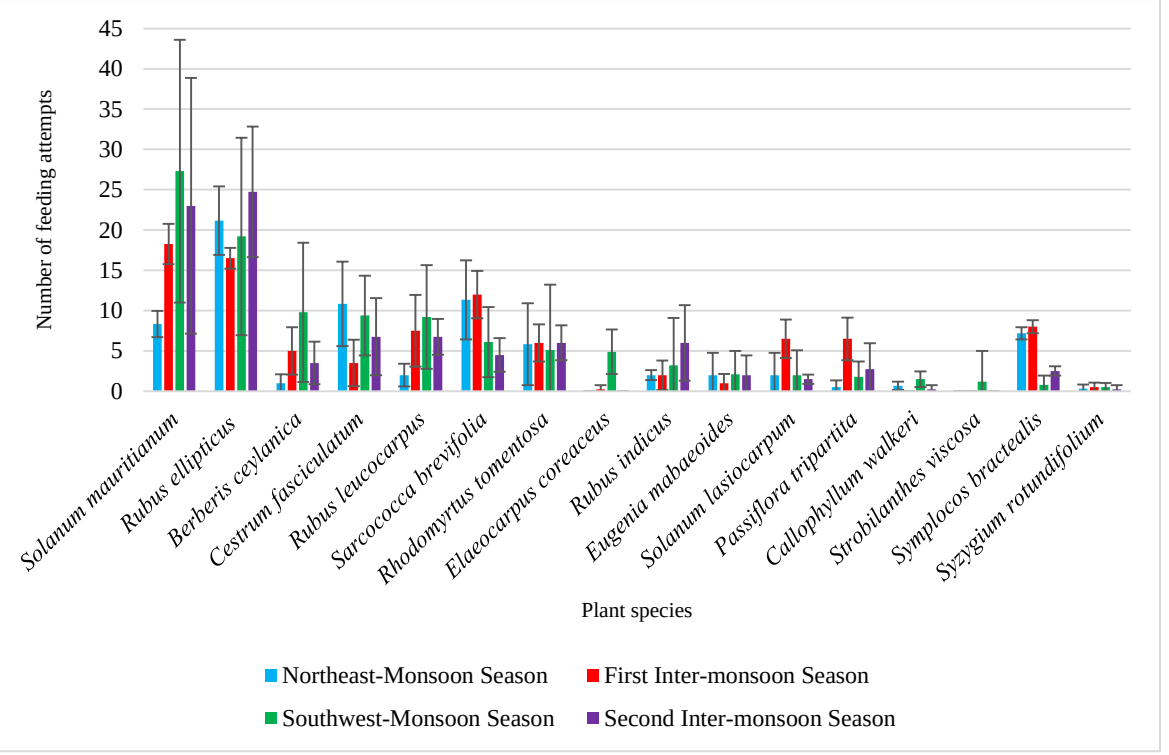

Figure 4. Seasonal variation of feeding attempts of *P. penicillatus* on different plant species

The *P. penicillatus* was feeding on 13 plant species within the four seasons (Figure 4). In the northeast monsoon season {21.16±4.26 (M±SD)} and second inter-monsoon season {24.75±8.0984 (M±SD) they highly consumed *R. ellipticus*. In the first inter-monsoon season {18.25±2.5 (M±SD)} and southwest monsoon season {27.3±16.31 (M±SD)}, *S. mauritianum* was the major feeding plant.

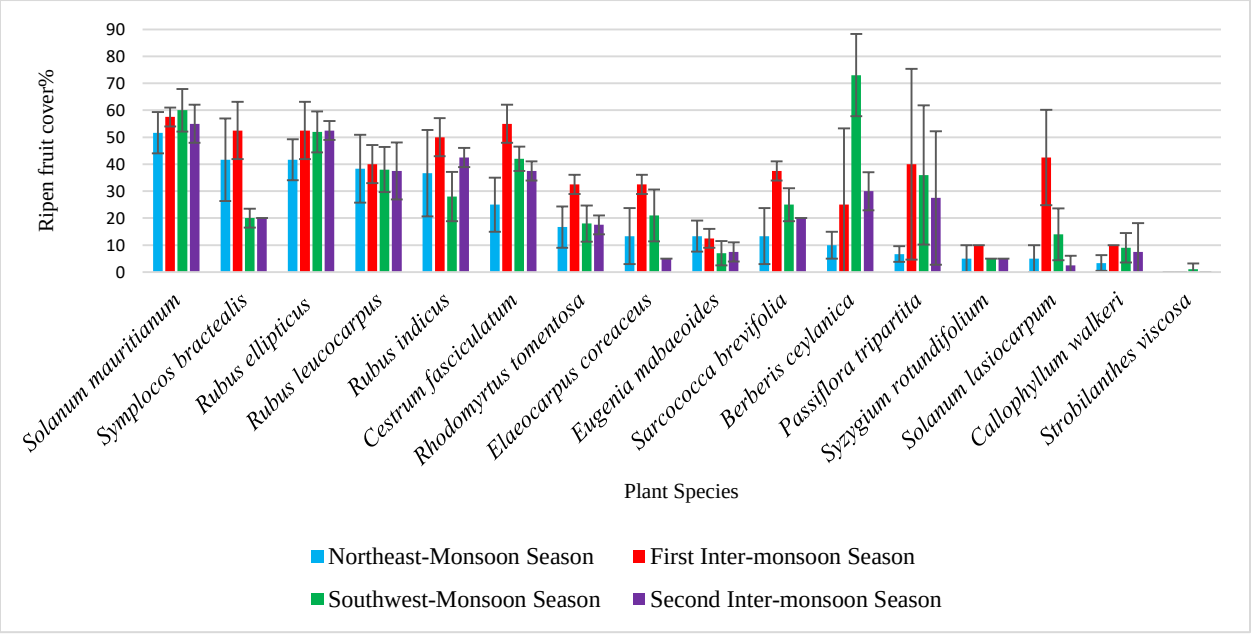

Figure 5. Seasonal variation of ripen fruit cover % of different plant species

The maximum ripen fruit cover was recorded from *S. mauritianum* (Figure 5) during the northeast monsoon season {51.67±7.64 (M±SD)}, first inter-monsoon season {57.5±3.54 (M±SD)} and second inter-monsoon season {55±7.07 (M±SD). However, in the southwest monsoon season highest ripen fruit cover was recorded from *B. ceylanica* {73±15.24795068 (M±SD). The ripen fruit cover of *S. viscosa* {1.0 ± 2.2 (M±SD)} which is less significant, was observed only at southwest-monsoon Season. All the plant species had ripen fruits in every seasons except *S. viscosa* (Figure 6).

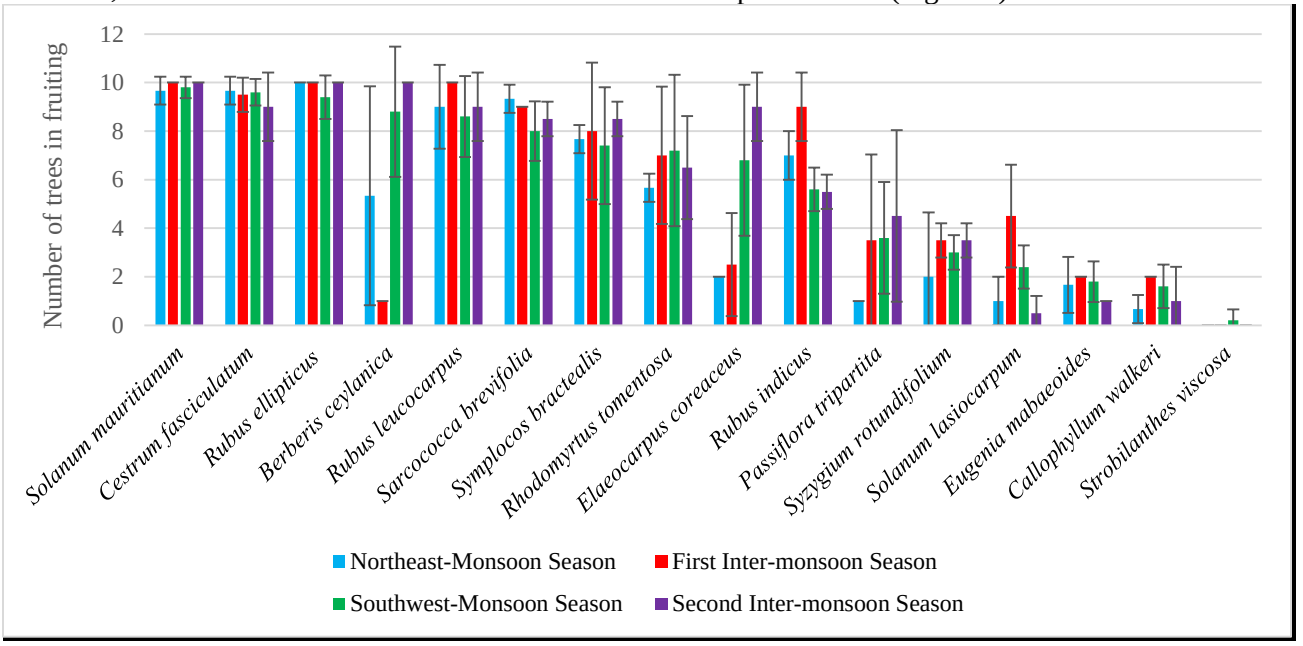

Figure 6. Seasonal variation of trees in fruiting of different plant species

Table 2. Correlation between the number of feeding attempts and ripen fruit cover

Plant Species	Spearman Rank Correlation between number of feeding attempts and ripen fruit cover	*p*-value	Spearman Rank Correlation between number of feeding attempts and number of trees in fruiting	*p*-value
Elaeocarpus coreaceus	0.277	0.162	0.463	0.015*
Syzygium rotundifolium	0.277	0.163	0.238	0.233
Passiflora tripartita	0.361	0.064	0.487	0.010*
Symplocos bractealis	0.403	0.037*	0.010	0.960
Eugenia mabaeoides	0.213	0.287	0.380	0.050*
Solanum mauritianum	0.551	0.003*	0.218	0.275
Solanum lasiocarpum	0.230	0.249	0.263	0.185
Rubus leucocarpus	0.292	0.139	0.340	0.083
Berberis ceylanica	0.320	0.104	0.236	0.236
Rubus ellipticus	-0.014	0.945	0.324	0.099
Rubus indicus	0.229	0.250	0.141	0.484
Sarcococca brevifolia	-0.030	0.884	0.303	0.125
Cestrum fasciculatum	-0.049	0.809	0.294	0.136
Strobilanthes viscosa	0.452	0.018*	0.452	0.018*
Rhodomyrtus tomentosa	0.321	0.102	0.272	0.170
Callophyllum walkeri	0.263	0.185	0.325	0.099

* *p*-value<0.05 = there is a significant association between variables

There was a positive correlation between number of feeding attempts and ripen fruit cover, of *S. bractealis* (Spearman Rank Correlation= 0.403, *p*-value = 0.037), *S. mauritianum* (Spearman Rank Correlation=0.551, *p*-value =0.003) and *S. viscosa* (Spearman Rank Correlation=0.452, *p*-value =0.018). Moreover, there was a correlation between number of feeding attempts and number of trees in fruiting, of *E. coreaceus* (Spearman Rank Correlation=0.463, *p*-value =0.015), *P. tripartita* (Spearman Rank Correlation=0.487, *p*-value =0.010), *E. mabaeoides* (Spearman Rank Correlation=0.380, *p*-value =0.010) and *S. viscosa* (Spearman Rank Correlation=0.452, *p*-value =0.018).

5. DISCUSSION

Both the direct observations and faecal analysis methods, confirmed that ripen fruits of *R. ellipticus* was the major food of *P. penicillatus*. It is a common scenario that the brambles of genus *Rubus* are common in high elevations above 1500m and that many species of birds feed on ripen berries. Most members of this family are shrubs or small trees, and their fruits are small and succulent. Therefore, they provide food for the smaller, comparatively unspecialized frugivores (Snow, 1981). In this study three important bramble species (*R.ellipticus, R. leucocarpus* and *Rubus indicus*) were identified as food sources of *P. penicillatus.* One variety of bramble *R. leucocarpus* var. *leucocarpus* is endemic to Sri Lanka. These brambles are commonly distributed in the highlands of Sri Lanka, and it has been reported previously that they form a crucial part of diet of the birds (Pethiyagoda, 2012).

The bulbuls highly consumed fruits of endemic plants such as *S. bractealis*, *B. ceylanica*, *C. walkeri*, *S. rotundifolium* and

E. mabaeoides since those plants are abundant in the forest habitat (DWC, 2007). However, it has been observed *P. penicillatus* feeding on *P. tripartita* (banana passion fruit) which is an introduced plant species now classified under invasive species by Weber (2017). They can smother forest margins and forest regrowth (Weber, 2017) therefore in the future this plant species will be a threat to the growth of other plants at HPNP. According to the results of the present study *P. penicillatus* is mostly feeding on endemic and native plants. Therefore, eradication of *P. tripartita* will not affected the feeding ecology of *P. penicillatus.* Furthermore, Davis (2011) has mentioned that, the birds do not care whether their fruit sources are native or exotic.

In the faecal sample analysis, there were no multiple seed types recorded from any faecal sample. This may be due to the fact that birds mostly attempt to fulfil their dietary needs from one fruit plant during a single feeding bout. The Yellow-eared Bulbul has a wide range of fruits, distributed in every stratum of the forest, ranging from the bushes, which belong to the understory, and some trees (*C. walkeri*) belong to emergent layer (Ashton *et al,* 1997).

Most species of the plants had ripen fruit throughout the year. This is a great opportunity to tropical frugivorous birds such as *P. penicillatus*. Compared with the temperate highlands most fruits are unavailable from April to August (Herrera, 1984). However, the tropical highlands have ripen fruits throughout every season of the year (Kitamura *et al.,* 2002). Therefore, they had sufficient amount of fruit supply within four seasons to fulfil their diet. Thus, they do not need to migrate over long distances to find food.

The results of significant correlation between number of feeding attempts and ripen fruit cover, of *S. bractealis*, and *S. mauritianum* should be because of these plants are commonly distributed in the forest habitats (DWC, 2007). However, the correlation with *S. viscosa* has also recorded in this study. This may be because of the seasonal availability of the fruits of this Nelu species in every year. It is different from the other *Strobilanthes* species, which the *S. viscosa* is flowering annually. Furthermore, there was a correlation between number of feeding attempts and number of trees in fruiting, of *E. coreaceus*, *P. tripartita*, *E. mabaeoides* and *S. viscosa*. These plants had seasonal variation of fruiting phenology.

These researches are useful for ecological studies. Since the tropical forest systems are being rapidly transformed into commercial plantations and farmlands (Chapman *et al.*, 2005). Therefore, it is important to recommend long term monitoring of the seasonal variations of fruiting phenology in and around HPNP, as recommended by Newbery *et al.* (1998). The area harbours a large variety of feeding plants of the threatened birds such as *P. penicillatus*. Furthermore, the Yellow- eared Bulbuls may act as an important seed dispersal agent in the tropical montane cloud forests of HPNP. Therefore, construction of phenology calendars is recommended for the protection of floral community in the habitats, as recommended by Sulistyawati, *et al.* (2012). Appropriate attention of the authorities is important, and it would benefit and enhance the quality of the forest management strategies.

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