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Foraging Behavior of Endemic Dull-Blue Flycatcher (*Eumyias sordidus*) in Tropical Montane Cloud Forest Habitats of Sri Lanka

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Abstract: ***Foraging behavior of endemic dull blue flycatcher was studied from July 2015 to July 2017 at the cloud forests, cloud forest die back forests and grasslands of the Horton Plains National Park located on the southern plateau of the central highlands of Sri Lanka. In each habitat three 100m fixed length transects were placed using Global Positioning System and the foraging individuals were observed with a binocular. Total of 1694 foraging attempts were recorded during the study period. 60.14% of all foraging attempts were observed in the cloud forest habitat. 34.17% was recorded in the cloud forest dieback habitat and 5.7% was recorded in the grassland habitat. Food searching behaviors of E. sordidus differed significantly among the three habitats (ANOVA, p<0.05). E. sordidus explored 0.07 ± 0.06 meters per second in search of food. They made 3.25 ± 1.56 (M ± SD) foraging attempts per minute. Flying (53.8 %) was the most common food searching behaviour followed by hopping (46.2%) when moving between foraging sites. There were more near-perch movements (69.41%) compared to aerial movements (30.59%) to capture the prey. Gleaning was the major near-perch attack method (42.15%) of E. sordidus. This was followed by lunging (21.74%), reaching (15.16%), probing (13.15%), flaking (5.35%), pulling (1.4%) and hanging (1.05%). Sallying (61.8%) was the major aerial attack method. This was followed by leaping (29.2%), flutter chasing (4.6%), screening (2.8%) and flush pursuing (1.6%). Mean foraging height of E. sordidus was 4.18±2.77m (M±SD) above ground and mean distance to the canopy above the bird was 3.01±1.76m (M±SD). Seven substrates were utilized by E. sordidus to capture their prey. Utilized substrates were, Air 503 attempts (30.6%), ground 432 attempts (26.3%), leaves 264 attempts (16.1%), moss 227 attempts (13.8%), twigs 109 attempts (6.6%), trunks 71 attempts (4.3%) and flowers 38 attempts (2.3%). Gulp was the major food handling technique (45.13%) of E. sordidus. They also utilized Mash (22.33%), snap (13.2%), rub (9.61%), Beat (7.97%), bite (1.03%) and shake (0.73%) techniques. E. sordidus diet consisted of prey (97.03%) and fruits (2.97%). Rubus ellipticus, Rubus indicus and Rubus rugosus were the main feeding plants of E. sordidus. Present study indicated that the preferred habitat is the cloud forest habitat and provided important information with regard to the foraging behaviour of this endemic bird.***

Keywords: Dull-blue Flycatcher, Foraging, Endemic Insectivore, Montane Cloud Forest

1. Introduction

How and where birds obtain their food has been central to the study in the field of avian ecology [1]. Quantifying these components of a species foraging strategy can explain niche relationship [2], patterns of habitat use [3], community structure [1] and may help in conservation efforts [4]. Sri Lanka Dull-blue flycatcher, *Eumyias sordidus* (Walden, 1870), is a small passerine bird in the flycatcher family Muscicapidae. It is an endemic resident breeder confined to the hills above 2,000 feet of Sri Lanka. However, there are reports of individuals occasionally descending to much lower altitudes, like Sinharaja, Kandy and along rivers in the dry zone [5]. Its' global population size has not been quantified, but the species is described as abundant in the central province of Sri Lanka [6]. This species has a very small global range, and although it remains common in suitable habitats and can tolerate modified habitats, its distribution and population size are likely to have been negatively affected by habitat loss and degradation. It has been categorized under the status of Near Threatened (NT) category [7]. Little is known about the foraging behavior of this endemic bird although its general ecology has been studied previously [5]. Absence of a scientific investigation about this species foraging habits makes it impossible to determine the current status of its population and habitat preference. Therefore, the present study was devised to fill this important gap of knowledge in the ecology of this endemic bird.

Plate 1: *E. sordidus* individual in cloud forest habitat.

2. Materials and Methods

2.1 Study site

The study was conducted at the Horton Plains National Park (HPNP) from July 2015 to July 2017 located on the southern plateau of the central highlands of Sri Lanka at the coordinates 6° 48' 0" North, 80° 48' 0" East (maplandia.com, 2016). It is a part of the highest peneplain of Sri Lanka situated between 2100 – 2600m above sea level [8]. HPNP experiences subtropical monsoon climate with mean annual rainfall of 2150 mm [9]. The weather is dictated by strong winds and persistent cloud cover [10]. The mean annual temperature is 15°C. A total of 77 species of vascular plants, 64 bird species, 20 species of herpetofauna and 19 mammal species have been recorded from HPNP [9]. It covers an area of 3160 ha that comprises of upper montane cloud rain forests, wet patana Grassland and a narrow ecotone belt in between. The cloud forest comprises of cloud forest die-back areas [11]. Cloud forests encompasses about 1236ha, cloud die back habitat about 956ha and the grassland approximately about 806 ha [12].

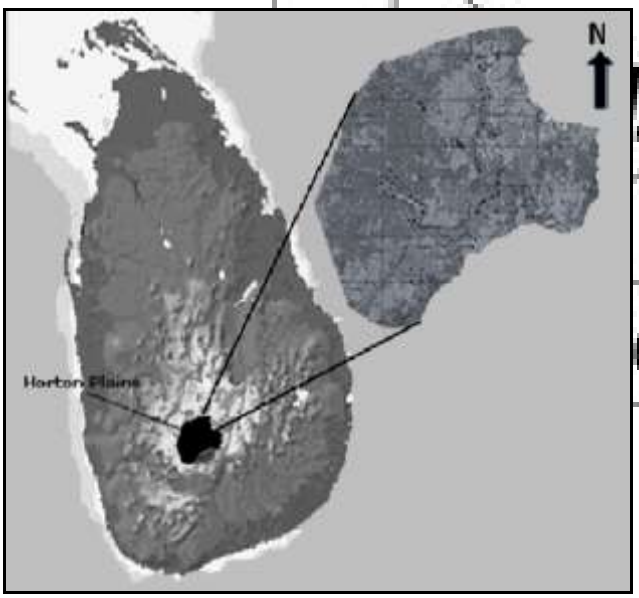

Plate 2: Location of HPNP in Sri Lanka. (Map modified by DWC, 2007)

2.2 Census of Dull-blue Flycatchers (*Eumyias sordidus*)

Three main habitats namely Cloud forest habitat, Cloud Forest Die Back habitat and Grassland habitat was identified in the HPNP. In each habitat three 100m fixed length transects were placed using Global Positioning System (Garmin Etrex euro handheld GPS receiver). Foraging individuals were observed directly or if the bird was feeding at a distance, with a binocular (NikonTM - Monarch, 10 x 50) in the First Inter Monsoon Season (FIMS) (March to April), South West Monsoon Season (SWMS) (May to September), Second Inter Monsoon Season (SIMS) (October to November) and North East Monsoon Season (NEMS) (December to February). The birds were studied from 0600h to 1800h, on three consecutive days per month. Opportunistic observations were used to supplement the data.

2.3 Foraging behavior of Dull-blue Flycatchers

Food searching behavior when moving between foraging sites was categorized as flying and hopping behavior. When birds were observed searching for food distance covered per unit time was determined by recording the distance between the first observation point to the final observation point where the bird approached a particular food. To find out the actual distance, the observer followed the path of the bird using coordinates of a Global Positioning System (GPS) device (GarminTM eTrex 10). Then the distance was divided by the time to calculate the distance travelled per minute in search of food.

2.4 Prey Attack behavior

Prey attack behavior was subdivided into two categories as near-perch movements and aerial movements. Near-perch movements were subdivided into two categories as surface movements and sub-surface movements. Surface movements were identified as; gleaning, reaching, hanging, and lunging. Gleaning meant picking food items from a nearby substrate, including the ground, which can be reached without full extension of legs or neck. Reaching meant extending completely the legs or neck upwards, outwards, or downwards. Hanging meant using legs and toes to suspend the body below the feet to reach food that cannot be reached from any other perched position. Lunging meant using rapid leg movements rather than flights to approach the prey when the food item is beyond the range of "reach". Sub-surface movements were identified as Probing, Flaking and pulling. Probing meant inserting bill into moss to capture hidden food. Flaking meant brushing aside loose substrate with

sideways, sweeping motions of the bill. Pulling meant dislodging or removing the section of substrate to capture the prey.

Aerial movements were identified as leaping, sallying, flutter-chasing, flush-pursuing and screening. Leaping meant launching into the air to reach a food item too far for a reach but too close for a sally. Sallying meant flying from a perch to attack a food item. Flutter-chasing meant dislodging prey from the substrate and chasing the prey for catching. Flush-pursuing meant flushing prey from a hiding place and pursuing flying or falling prey. Screening meant capturing prey while flying continuously [13].

2.5 Food handling techniques

Food handling techniques were categorized as gulp, snap, mash, shake, beat, rub and bite [13]. "Gulp" meant swallow upon capture without any noticeable manipulation other than being held briefly by the bill. "Snap" meant to pinch momentarily usually between tips of mandibles and usually kill before further handling. "Mash" meant to squeeze and move around between the mandibles before swallowing; sometimes, juices or pulp are squeezed out of the food and solid portions discarded [14]. "Shake" meant to shake food item violently to remove undesirable parts. "Beat" meant to beat food item against a hard substrate [15]. "Rub" meant to rub food along the substrate (usually to remove distasteful substances or undesirable portions such as hair and stingers [16]. "Bite" meant to bite and remove a section of food item [17].

2.6 Foraging site

The foraging site was categorized as general habitat, vertical position, horizontal position, foliage density and the precise substrate from which the food was taken. General habitats were the major habitats where the foraging behavior was observed. In vertical position category there were three main subcategories (i) height-above-ground and (ii) distance to canopy (above bird) (iii) height of the individual plant, which the bird was foraging. Relative position in the foliage column was calculated by the height above ground at which a bird was recorded, divided from the height of the canopy at that point. The horizontal position was subdivided into inner, middle and outer positions of the bird at the tree or bush. Foliage density at the point of foraging observation was recorded using a qualitative scale. This is a scale from "0" to "5" of increasing foliage density within a one meter radius around the bird: "0" = no vegetation within the imaginary 1m sphere; "1" = very low vegetation density within the sphere (e.g., 95-99% of all light passes through sphere); "2"= low density, 75-95% of light passes; "3" = moderate density, 25-75% of all light passes; "4" = high density, only 5-25% of light passes; and "5" = extremely dense, 0-5% of light passes [13]. Seven Foraging substrates of *E. sordidus* were identified as air, ground, leaves, mosses, twigs, trunks and flowers. The plants which *E. sordidus* consumed fruits were identified using field guides [19].

2.7 Data analysis

Microsoft Excel™ was used to store data and to construct graphical illustrations. Minitab 17™ was used for statistical analysis. Pearson correlation was applied to find out relationships between variables. ANOVA analysis was used to find differences among variables.

3. RESULTS

A total of 1694 foraging attempts were recorded during the study period. 60.14% of all foraging attempts were observed in the Cloud Forest habitat. 34.17% was recorded in the Cloud Forest Dieback habitat and 5.7% was recorded in the Grassland habitat (Figure.2).

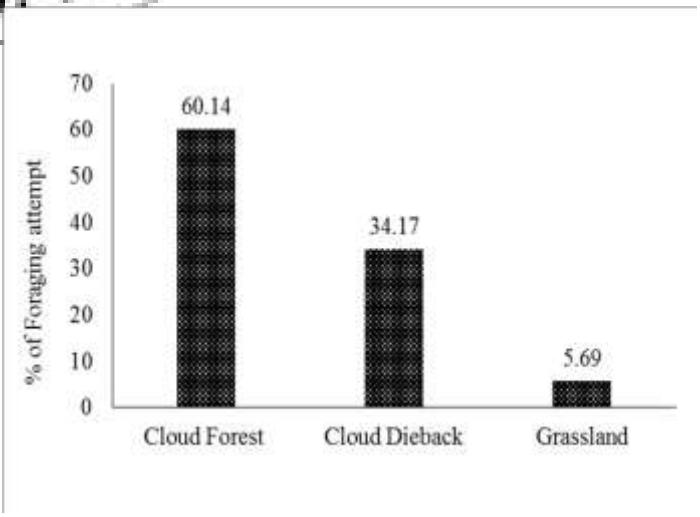

Figure 1: Percentage of foraging attempts recorded among

habitats.

Food searching behaviors of *E. sordidus* differed significantly among the three habitats (ANOVA, p=0.001). *E. sordidus* explored 0.07 ± 0.06 meters per second in search of food. They made 3.25 ± 1.56 (M ± SD) foraging attempts per minute. Flying (53.8 %) was the most common food searching behavior followed by hopping (46.2%) when moving between foraging sites.

There were more near-perch movements (69.41%) compared to aerial movements (30.59%) to capture the prey.

Gleaning was the major near-perch attack method (42.15%) of *E. sordidus*. This was followed by lunging (21.74%), reaching (15.16%), probing (13.15%), flaking (5.35%), pulling (1.4%) and hanging (1.05%) (Table 1).

Table 1: Near perch attack movements of *E. sordidus*

	Gleaning	Reaching	Hanging	Lunging	Probing	Flaking	Pulling
CFH	29.34%	9.86%	0.94%	12.46%	4.48%	2.47%	0.59%
CFDH	8.85%	5.30%	0.11%	9.28%	7.32%	2.88%	0.46%
GLH	3.96%	0%	0%	0%	1.35%	0%	0.35%
TOTAL	42.15%	15.16%	1.05%	21.74%	13.15%	5.35%	1.40%

CF-Cloud Forest Habitat, CFDH-Cloud Forest Dieback Habitat, GLH-Grassland Habitat

Sallying (61.8%) was the major aerial attack method. T[illegible] screening (2.8%) and flush pursuing (1.5%). was followed by leaping (29.2%), flutter chasing (4.6%),

Table 2: Arial attack movements of *E. sordidus*.

	Leaping	Sallying	Flutter chasing	Flush pursuing	Screening
CFH	31.5 %	66.34 %	1.2 %	0.8 %	0.2 %
CFDH	30.5 %	56.6 %	8.1 %	3.1 %	2.1 %
GLH	0 %	44.8 %	19.8 %	0 %	35.4 %
TOTAL	29.2 %	61.8 %	4.6 %	1.5 %	2.8 %

CF-Cloud Forest Habitat, CFDH-Cloud Forest Dieback Habitat, GLH-Grassland Habitat

Mean foraging height of *E. sordidus* was 4.18±2.77m (M±SD) above ground and mean distance to the canopy above the bird was 3.01±1.76m (M±SD). They preferred trees with 6.04±2.75m (M±SD) height, 0.73±0.41m (M±SD) average diameter-at-breast height and 1.71±0.71m (M±SD) average trunk height in the montane forest habitat. There was a positive correlation between foraging height of the bird and height of the plant (Pearson correlation = 0.892, P-Value < 0.05).Utilized Relative foraging position of *E. sordidus* in the foliage column was 1.33 ± 0.17 m (Table 3).

Table 3: Observed foraging habitat characteristics of *E. sordidus*.

Average foraging habitat characteristics	Value (Mean±Standard Deviation)
Foraging height	4.18±2.77m
Distance to the canopy above the bird	3.01±1.76m
Preferred tree height	6.04±2.75m
Diameter-at-Breast Height (DBH)	0.73±0.41m

Majority of the birds (41.53 %) foraged at the "outer" horizontal position of the plants. "inner" horizontal position was used for foraging by 35.59% of birds. "Middle" horizontal position (22.88%) was utilized by least number of birds (Figure 2).

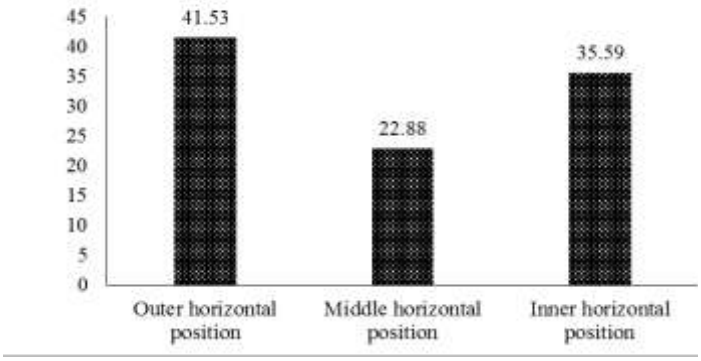

Figure 2: Horizontal foraging position of *E. sordidus* at the foliage of Cloud Forest habitat.

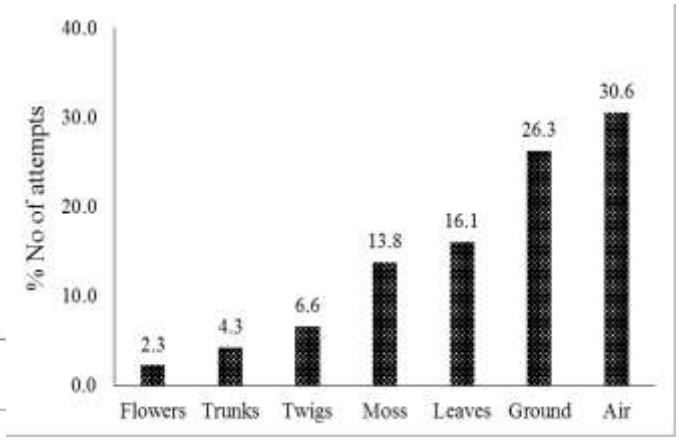

Figure 4: Number of prey capture attempts of *E. sordidus* in different substrates.

E. sordidus highly utilized (39.41%) moderate dense foliage cover for foraging. They used low dense foliage (22.89%) and extremely light foliage (15.25%) more compared to dense foliage (11.02%), light foliage (9.75%) and highly dense foliage (1.68%) for foraging (Figure 3).

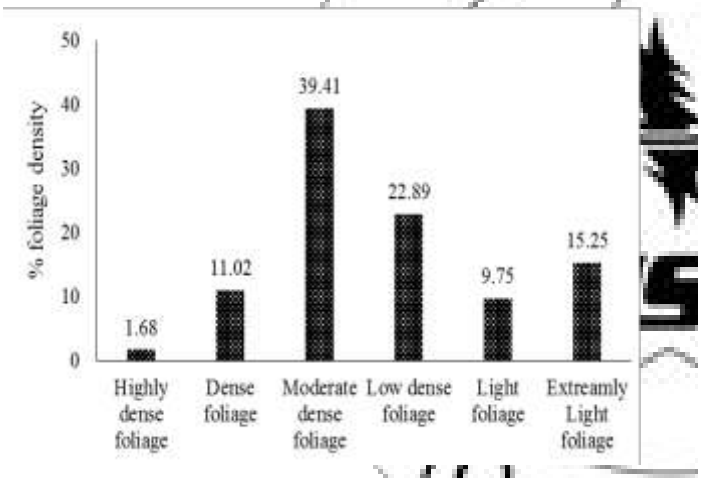

Figure 3: Foliage density of the foraging plants of *E. sordidus*.

Gulp was the major food handling technique (45.13%) of *E. sordidus*. They also utilized Mash (22.33%), snap (13.2%), rub (9.61%), Beat (7.97%), bite (1.03%) and shake (0.73%) techniques occasionally (Figure 5).

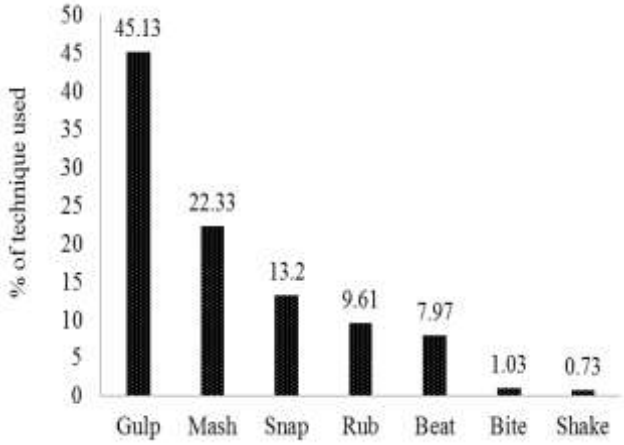

Figure 5: % of food handling techniques of *E. sordidus*

Seven substrates were utilized by *E. sordidus* to capture their prey. Utilized substrates were, Air 503 attempts (30.6%), ground 432 attempts (26.3%), leaves 264 attempts (16.1%), moss 227 attempts (13.8%), twigs 109 attempts (6.6%), trunks 71 attempts (4.3%) and flowers 38 attempts (2.3%) (Figure 4).

E. sordidus diet consisted of prey (97.03%) and fruits (2.97%). *Rubus ellipticus*, *Rubus indicus* and *Rubus rugosus* were the main feeding plants of *E.sordidus*. The birds perched and picked fruits without sallying (76%) and occasionally some individuals ate only a portion of the fruit without removing it from the plant (24%) (Table 4).

Table 4: % of foraging plant species of *E. sordidus*.

Plant Species	Foraging observations %
Rubus ellipticus	65.38
Rubus rugogus	19.23
Rubus indicus	15.39

Plate 3: Ripen fruits of *Rubus ellipticus* and *Rubus rugogus*.

4. DISCUSSION

Studying the foraging behavior and identifying foraging sites of a bird species is important for their conservation. Present study revealed that cloud forests are the most preferred habitat of *E. sordidus* and that the grassland is the least preferred habitat. High number of attempts made while flying to capture prey indicated that this bird is dependent more on flying insects and that it is a fly catcher. Studying the food capture methods are because differences in food captured may provide information on niches, the morphology of the bill, and energetics [13]. This species is known to be a very active forager which uses specific movements to search for and catch, insects. Leaves were the most frequently searched substrate by *E. sordidus* apart from air and ground. The use of leaves as a foraging substrate is probably related to the more food availability in leaves. However, the air was frequently used by *E. sordidus* may be due to their small light body probably allowed them to be more successful in fast sallying in the air.

Comparatively high near-perch movements compared to aerial movements to capture the prey may have been due to various reasons such those found in cold climates where the sun shine is low and persistent rain and mist cover force the insect prey to hide under leaves etc rather than fly in to open sky. Present study also indicated that gleaning was the major near-perch attack method of *E. sordidus*. This too could be due to prey being rather inactive in the cold climatic conditions of the Horton Plains National park. Remsen & Robinson, 1990 observed that the majority of maneuvers performed by most foliage and ground searching birds are "gleans.". Remsen, 1985 observed that the reason for such behavior is because “gleaning” is apparently the most cost-effective maneuver in terms of energy expenditure. Dull-blue flycatchers take a wide range of invertebrate prey, including flying, ground and vegetation-dwelling species. This diverse prey base, in conjunction with the variety of foraging techniques used by the species, indicates significant flexibility in the diet. Such flexibility and range in the diet may be advantageous in the face of variable conditions from habitat to habitat and among environmental seasons. Finding of the present study also indicated that E. sordidus utilized prey items along with fruits of three plant species belong to family Rosaceae which is indigenous to the montane cloud forests. Therefore this species can be considered as a foraging generalist in the montane cloud forest habitats. Present study also revealed that seven substrates were utilized by *E. sordidus* to capture their prey that included air, ground, leaves, moss, twigs, trunks and flowers. Out of these substrates air was the most preferred and flowers were the least preferred. This again indicates that this species is a fly capture species that prefers to hunt the flying insects.

Food handling method is important, to study cost-benefit ratio, of any food type, to study adaptive morphology [16] and to study plant frugivore interactions [20]. Gulping was the major food handling technique of *E. sordidus*. Remsen & Robinson (1990) observed that the predominant food handling technique of most insectivorous and frugivorous birds is gulping and the finding of this study tally with those observations. Recent studies have indicated that the methods used by birds in searching for food, leading up to prey capture, and the factors that influence these searching patterns may be particularly important for understanding bird diets and ultimately community structure. *E. sordidus*

preferred the cloud forest habitat for foraging. This could be due to the reason that their food plants and food substrates were present in higher number at the cloud forest and cloud forest die-back compared to the grassland habitat. The species such as *Calophyllum walkeri*, *Syzygium sp*. *Elaeocarpus coriaceous*, *Strobilanthes sp*. and *Sarcococca brevifolia*, *Neolitsea fuscata*, *Cinnamomum ovalifolium*, *Rhododendron arboretum*, and *Glochidion pycnocarpum* which were utilized heavily by *E. sordidus* were present in higher numbers within the cloud forest.

They preferred moderate foliage density compared to extreme conditions of minimum and maximum foliage densities. They preferred to sit atop the leaves when they were feeding and rarely used to feed on leaf tops. This species highly utilized outer horizontal position of the plants which is important to place the foraging bird in categories with respect to foliage and branch geometry [13].

Spatial distribution of *E. sordidus* in a montane cloud forests provided insights to their niche relationship, pattern of habitat use and community structure. Previous studies conducted about the distribution of *E.sordidus* in the montane cloud forest of Horton Plains National Park [19, 1934] revealed the cloud forest habitat as the preferred habitat of this species [21].

Present study documented the prey substrates, fruit consumption and foraging behaviour only at the protected montane cloud forest habitats. It is unknown whether the same patterns hold true at sub-urban or urban areas where this species is known to inhabit sporadically [5]. The wide variety of invertebrate prey taken by flycatchers provides many potential avenues for accumulating environmental toxins. Adjacent invertebrate rich habitats such as Eucalyptus plantations, Tea plantations and vegetable cultivation lands may provide good food sources for the flycatchers. Additional research is needed on the level of harmful compounds present in the food base, and potential impacts to Dull-blue Flycatchers. Therefore, it is important to protect the vegetation of the tropical montane cloud forests to ensure the well-being of this important bird species.

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