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Caption: Stripe-backed Weasel *Mustela strigifrons*. Medium—digital, Software—procreate, Device—iPad + Apple pencil © Dhanush Shetty.



## Diversity and distribution of avifauna at Warathenna-Hakkinda Environmental Protection Area in Kandy, Sri Lanka

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**Abstract:** The present study was carried out in the recently established Warathenna-Hakkinda EPA in the Kandy District, Sri Lanka to investigate the avifaunal diversity and conservation threats. Sampling was conducted in two main habitat types: river islands and riverine forests. Both point count (10 m radius) and line transect (200 m long) methods were utilized and maximum of 30 minutes was used to sample the birds in each point. Food habit, niche type, endemism, abundance, and diversity indices (Shannon & Margalef) were calculated to compare the two habitats in this area. A total of 74 bird species belonging to 61 genera and 35 families were encountered from the study site. Among these, seven species are endemic: Sri Lanka Grey Hornbill, Sri Lanka Green Pigeon, Sri Lanka Wood Pigeon, Sri Lanka Hanging Parrot, Crimson-fronted Barbet, Yellow-fronted Barbet, and Sri Lanka Hill Mynah; while six were migratory: Green Sandpiper, Common Sandpiper, Indian Pitta, Asian Brown Flycatcher, Yellow Wagtail, and Grey Wagtail and the rest were non-endemic natives. Most of them were canopy and sub canopy dwellers associated with riverine forests and islands. According to the National Red List of Sri Lanka, three species, the Sri Lanka Wood Pigeon, Sri Lanka Hill Mynah, and Alpine Swift, are listed as threatened. Ardeidae, Alcedinidae, Columbidae, Accipitridae, and Apodidae were the most species rich families in this habitat. Out of the sampled species, 31% and 25% of the birds were carnivores and insectivores, respectively, while 5% were nectarivores. According to the avifauna, the riverine forests are more diverse (Shannon index  $H' = 2.55$ ; Margalef's index  $M = 10.92$ ) than the river islands ( $H' = 2.29$ ;  $M = 5.07$ ) in this landscape. The variety of habitats along the Mahaweli River at Warathenna appears to aid in sustaining a rich bird community and this Environmental Protection Area will help create a safe haven for the birds.

**Keywords:** Birds, conservation threats, endemic species, riverine forests, Kandy District, river islands, Warathenna-Hakkinda.

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## INTRODUCTION

Sri Lanka and the Western Ghats of India is considered a global biodiversity hotspot due to the high diversity and species endemism (Bossuyt et al. 2004). Sri Lanka, which is a tropical island located in the Indian Ocean between longitudes 79.65E and 81.88E and latitudes 5.90N and 9.86N experiences a year round tropical climate with average temperatures of 27–28 °C and a relatively constant day length (Wijesundara & de Silva 2005). The precipitation in the island is largely governed by the south-west and north-east monsoons (Ashton et al. 1997; Gunatilleke et al. 2008). Sri Lanka is renowned for the diversity and endemism of its vertebrate fauna, including its diverse avifauna (de Silva Wijeyeratne 2014; Weerakoon 2015).

Sri Lanka is home to 240 breeding resident species, 216 purely migrant species, and 72 vagrant species of birds. Of the total 453 species, 27 are endemic, and six are proposed as endemics (Gunawardena & Weerakoon 2012), while 43 species, including five winter migrants are considered endemic to the southern Asian region (Kotagama & Wijeyasinghe 1998; Kotagama 2000; Santiapillai & Wijesundara 2002; Rasmussen & Anderson 2005; Wijesundara & de Silva 2005; Chandrasiri et al. 2018). According to the National Red List (MOE 2012), 46 of the breeding species on the island are nationally threatened, including 10 Critically Endangered, 15 Endangered, and 21 Vulnerable bird species. The country is divided into six avifaunal zones and two sub zones by considering the distribution patterns of the resident birds. The six major avifaunal zones are Highlands Avifaunal Zone, Wet Forest Avifaunal Zone, Uva Avifaunal Zone, Marine Avifaunal Zone, Palk Bay Coastal Avifaunal Zone, and Rakwana Hill Avifaunal Zone. The two sub zones are Wet Lowland Avifaunal Sub-Zone, and Wet Mid-Hill Avifaunal Sub-Zone (Kotagama 1993; MoMD&E 2019). This study was conducted to investigate the avifaunal diversity in the Warathenna-Hakkinda Environmental Protection Area (EPA) in the Kandy district located in the Wet Forest Avian Zone (Harrison & Worfolk 1999; MoMD&E 2019).

Warathenna-Hakkinda EPA was declared in 2017 after the findings of rare, endemic flora and fauna from this area. This EPA has an extent of 0.61 km<sup>2</sup> extending from the Halloluwa suspension bridge in the north to the Gatambe Bridge in the south, and bordered by the Peradeniya-Halloluwa-Katugastota Road on one side and the “Srimath Kuda Rathwatthe Mawatha”, “Deveni Rajasinghe Mawatha”, and the Colombo-Kandy Road on the other side of the river (Sri Lanka 2017:

4/81.VI). This EPA encompasses an approximately 2 km stretch of the Mahaweli River, all its river islands in this stretch referred to as the Hakkinda river islands, as well as the surrounding riverine forests and Kandyan home gardens. Only a handful of studies thus far have looked at the biodiversity in this area including the diversity of dragonflies and fish (Samarawickrama et al. 2012; Kumara & Samarawickrama 2017; Thilakarathne et al. 2019). The present study aimed to evaluate the species composition of the bird community in this EPA.

## MATERIALS AND METHODS

### Description of the study site

Mahaweli river is the longest river in Sri Lanka. It originates from the central highlands and flows through the wet, intermediate and dry zones of the country (Fernando 1990). The study was conducted along a 2 km stretch of the Mahaweli River in the Kandy District starting from the Gatambe main bridge (7.45N, 80.10E) to the Dodangwela Suspension Bridge (7.46N, 80.10E), from June 2016 to May 2017. This area falls within the Warathenna-Hakkinda Environmental Protection Area (EPA). The banks of the Mahaweli River along this stretch of the study site consists of riverine forests patches and river islands that were distinguished according to the geomorphological features and the vegetation characteristics.

Vegetation of the riverine forests and river islands consists of both native endemic and non-endemic plant species as well as higher number of exotic species due to the high influence of anthropogenic activities. In the riverine forests, plant species such as, *Terminalia arjuna*, *Neolitsea cassia*, *Mesua thwaitesii*, *Dillenia indica*, *Barringtonia racemosa*, *Horsfieldia iryaghedhi*, *Glochidion zeylanicum*, *Ficus tsjahela*, *Ficus benghalensis*, *Ficus racemosa*, *Symplocos cochinchinensis*, *Spathodea campanulata*, *Alstonia macrophylla*, *Michelia champaca*, *Caryota urens*, and *Bambusa vulgaris* were frequently encountered. In the approximately 20 river islands in the EPA (the largest of which has an extent of about 3.2 ha), plant species such as *Leea indica*, *Schefflera stellata*, *Ficus hispida*, *Ficus tinctoria*, *Ficus exasperata*, *Pandanus kaida*, *Syzygium jambos*, *Mimosa pigra*, *Clusia rosea*, *T. arjuna*, *D. indica*, *M. thwaitesii*, *N. cassia*, *Terminalia catappa*, and *Macaranga peltata* were recorded. Members of the genera *Lagenandra* (*L. praetermissa*) and *Cryptocoryne* (*C. undulata*, *C. beckettii*, *C. walkeri*, and *C. parva*) were seen in the shallow waters around the river islands. Furthermore, the exotic free floating

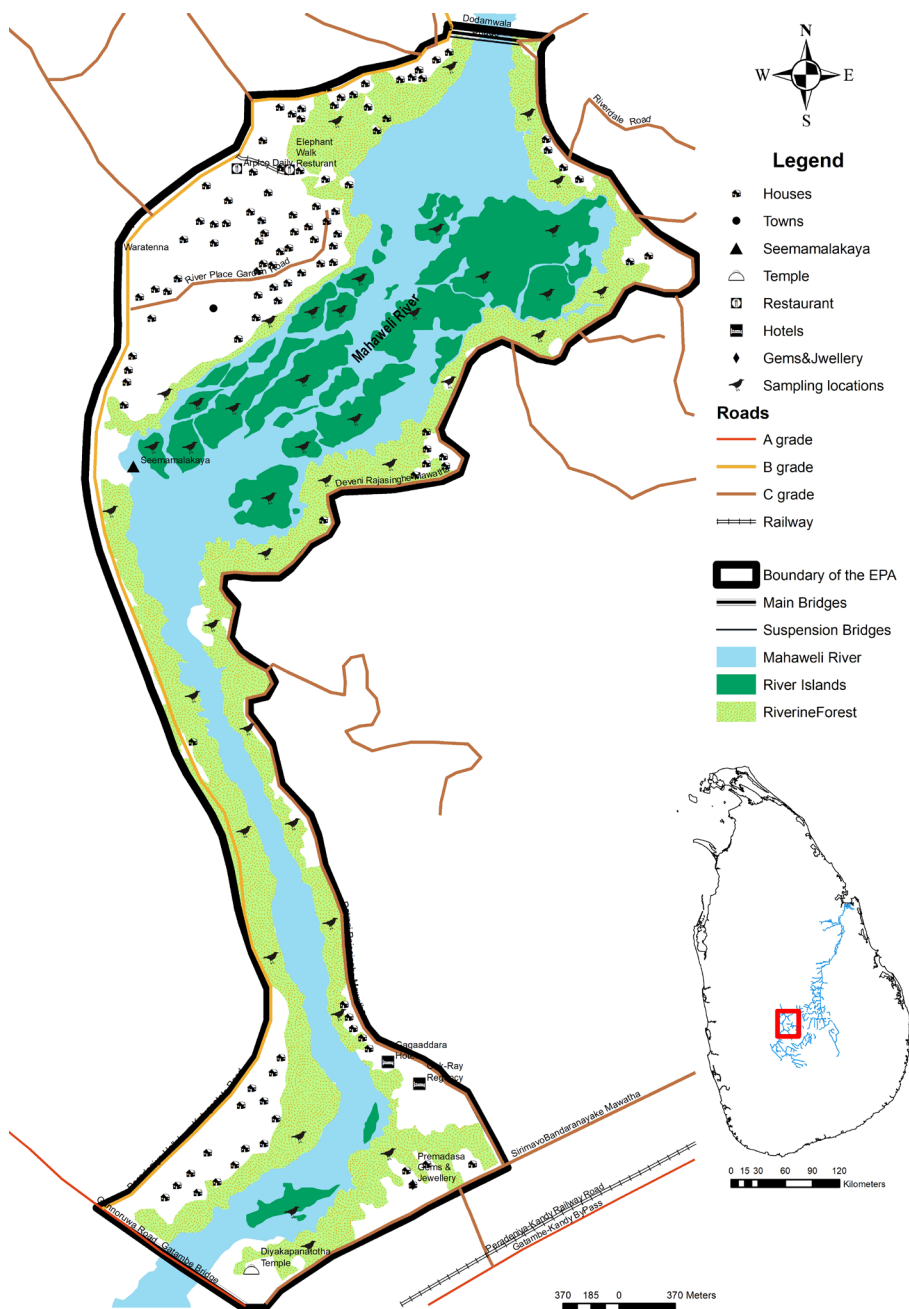


Figure 1. Map of Warathenna-Hakkinda EPA starting from the Gatambe main bridge (7.45N, 80.10E) to the Dodangwela Suspension Bridge (7.46N, 80.10E).

*Eichhornia crassipes* was seen in areas with slow moving water.

The sampling of avifauna was carried out in 17 river islands and 24 riverine forest patches. Sampling locations were marked using a portable global positioning system (GPS) (Magellan eXplorist 110) and sampling points were separated by a minimum distance of 150 m (Figure 1).

#### Survey of avian fauna along the declared EPA

Field sampling was carried out twice a week during the study period. Systematic random sampling method was used to record the birds from this EPA, and sampling was conducted along two main roads on either side of the Mahaweli River, the Peradeniya-Halloluwa-Katugastota Road (2.5 km) on the west and the “Srimath Kuda Rathwatthe Mawatha” and “Deveni Rajasinghe Mawatha” (3 km) on the east. Eighteen 200 m line



transacts were sampled along the two main roads within the EPA. Two 10 m radius points along each 200 m line transect were established to record the birds along the riverine forest. A point count method (5 m radius) was carried out in the river islands and along river banks to record bird species. A maximum of 30 minutes was spent in each site during both point count and line transect methods. Birds were observed using direct observations with the aid of 10 × 42 binoculars (Nikon, Monarch) and identified using available field guides (e.g., Harrison, 2011; Warakagoda et al. 2012) as well as through vocalizations. Opportunistic and incidental observations were also recorded during the survey. With the aid of previously published records (Henry 1971; Ali & Ripley 2001), the recorded birds were categorized according to their dietary habits. The conservation status of identified bird species was classified according to the National Red List 2012 of Sri Lanka (MOE 2012). The counting was conducted at 0630–0930 h and 1530–1830 h when most of the birds are active. The bird species, their abundance, and forest strata where they were observed were recorded in the field.

### Data analysis

Data on avifauna were analyzed for riverine forests and the river islands. The species richness, family richness, endemism, migratory percentages, relative abundance, and the diversity were calculated using R version 3.6.1 (R Core Team 2014). Pooled t-test was carried out to determine the significance of the two habitats under 95% confidence intervals using R version 3.6.1 (R Core Team 2014). The difference among different micro-habitats/strata was evaluated using one-way ANOVA using Tukey comparison under 95% confidence limits in R studio version 3.6.1 (R Core Team 2014). The relative abundance was calculated as follows.

$$\text{Relative abundance } (p_i) = \frac{\text{Number of individuals in a particular species}}{\text{Total Number of sampled individuals in all species}}$$

The rarefaction curve, endemism, family representation and national conservation status were plotted using SigmaPlot-10. Chao 2 and second order Jackknife 2 richness estimators were calculated in EstimateS software (Version 9.1.0) (Chao et al. 2005) to estimate the predicted species richness in the EPA. Species diversity was measured using Shannon diversity index. The proportional abundance of species was used to determine the Shannon diversity index ( $H'$ ) and the species richness was used to determine Margalef's diversity index using R version 3.6.1 (R Core Team 2014) for comparison of avifaunal diversity between riverine forests and river islands. Jaccard similarity index was

calculated using R version 3.6.1 (R Core Team 2014) to estimate the degree of similarity between the two habitat types.

$$\text{Shannon - Weiner index } (H') = - \sum p_i \ln p_i$$

$$\text{Margalef index } (M) = \frac{S - 1}{\ln N}$$

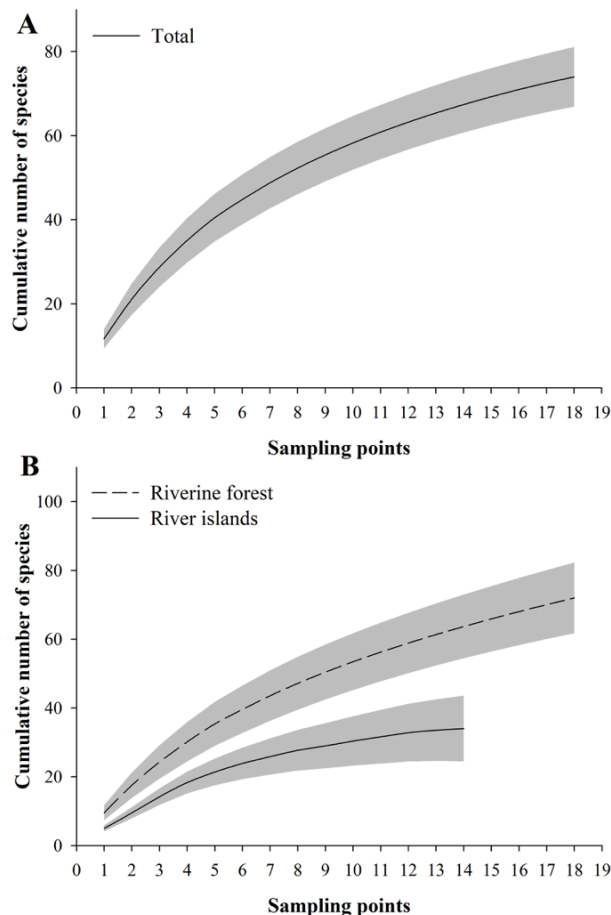
Where,  $p_i$  = Relative abundance of a species,  $S$  = Number of species (species richness), and  $N$  = Total number of individuals

$$\text{Jaccard Index } (C_j) = \frac{j}{(a + b - j)}$$

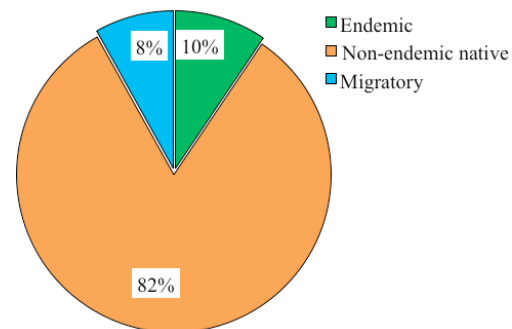
Where,  $j$  = Number of species found in both sites,  $a$  = Number of species in site A, and  $b$  = Number of species in site B

### RESULTS

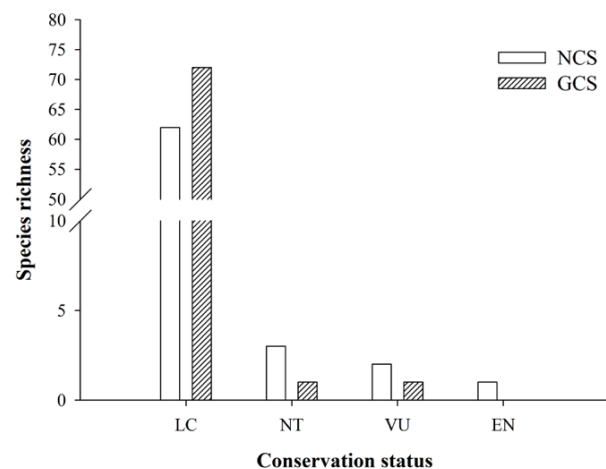
A total of 666 individuals belonging to 74 bird species, 61 genera and 35 families were encountered during the study (Table 1, Image 1,2). The species based rarefaction curve, with lower and upper limits, did not reach the asymptote, which implied that more sampling effort was needed. According to the Chao 2 and Jackknife 2 estimates, the species richness could be 88 and 104, respectively (Figure 2A,B). Seven species: Yellow-fronted Barbet *Psilopogon flavifrons*, Crimson-fronted Barbet *Psilopogon rubricapillus*, Sri Lanka Green Pigeon *Treron pompadora*, Sri Lanka Wood Pigeon *Columba torringtoniae*, Sri Lanka Hill Mynah *Gracula ptilogenys*, Sri Lanka Hanging Parrot *Loriculus beryllinus*, and Sri Lanka Grey Hornbill *Ocyrceros gingalensis* (Image 2A) encountered during the study are endemic, while six: Grey Wagtail *Motacilla cinerea*, Yellow Wagtail *Motacilla flava*, Asian Brown Flycatcher *Muscicapa dauurica*, Indian Pitta *Pitta brachyura* (Image 2I), Common Sandpiper *Actitis hypoleucos*, and Green Sandpiper *Tringa ochropus*) are migratory (Figure 3). However, majority of the sampled birds were non-endemic native resident birds. Since this is a riverine system, 24% of the encountered species were water associated birds while 76% were terrestrial birds. The most species-rich family was Ardeidae (herons and egrets; Image 1C,E,F) with seven species. Other than that, Alcedinidae (kingfishers – four species; Image 1A, B), Columbidae (pigeons – five species), Accipitridae (raptors – four species), and Apodidae (swifts – four species) were the most common families represented in the EPA. Of the recorded families, 43% were represented by only a single species. Although the species richness



**Figure 2.** Species based rarefaction representation of the birds recorded from Warathenna-Hakkinda EPA from 2016 to 2017 with 95% lower and upper boundaries: A—Total species richness | B—Species richness between riverine forests and river islands.



**Figure 3.** Endemism of the birds recorded from Warathenna-Hakkinda EPA



**Figure 4.** National conservation status (NCS) and Global conservation status (GCS) of the bird species recorded from Warathenna-Hakkinda EPA: LC—Least Concern | NT—Near Threatened | VU—Vulnerable | EN—Endangered.

was highest in Ardeidae, Columbidae, Alcedinidae, Accipitridae, and Apodiade families, the highest number of individuals in this ecosystem and hence the dominant families were Ardeidae (15% of relative abundance), Phalacrocoracidae (12% of relative abundance), and Sturnidae (11% of relative abundance; Table 1).

Out of the total number of species encountered, three species are listed under the categories of Vulnerable (VU) and Endangered (EN) according to the National Red List (MOE 2012). Of the remaining species, three are listed as Near Threatened (NT) and the rest of the 63 species are listed as Least Concern (LC). Of the recorded species, Alpine Swift is in the EN category while the Sri Lanka Wood Pigeon and Sri Lanka Mynah are listed as VU (MOE 2012). However, according to the global conservation status, the Sri Lanka Wood Pigeon is considered to be VU, Sri Lanka Hill Mynah as NT while the rest of the 72 species are considered to be LC. The LC category species were the most abundant (99% of

relative abundance) in this ecosystem while VU species were the least abundant (0.3% of relative abundance; Table 1 and Figure 4).

According to the food habits, the encountered birds in the EPA included carnivores, omnivores, insectivores, piscivores, frugivores, nectarivores, and granivores. The species richness of the birds among the food habit categories was significantly different ( $F = 1.45$ ;  $p < 0.05$ ). Of these, most species were categorized as carnivores (31%) and insectivores (25%) while nectarivores (5%) were the lowest in this riverine system. In addition, the highest numbers of individuals were recorded from carnivores and omnivores (35% and 26% of relative abundance, respectively) while the least number of individuals were recorded from nectarivores (Figure 5).

Forests can be defined by four vertical forest strata namely, canopy, sub canopy, understory and the ground layer. Some of the bird species in the EPA were encountered from a single layer while others were

**Table 1. Recorded bird species, their conservation status, forest strata, food habit and relative abundance in riverine forests and river islands in Warathenna-Hakkinda EPA, Kandy.**

Family	Scientific Name	Common Name	NCS/ GCS	Stratum	Food habit	RA/%	Rarity	Abundance		
								RI	RF	p Value
Accipitridae	<i>Accipiter badius</i>	Shikra	LC/LC	Canopy	Carnivores	0.3	R	1	1	-
Accipitridae	<i>Haliaeetus leucogaster</i>	White-bellied Sea Eagle	LC/LC	Canopy	Carnivores	0.6	C	2	2	-
Accipitridae	<i>Haliastur indus</i>	Brahminy Kite	LC/LC	Canopy	Carnivores	0.9	C	2	4	-
Accipitridae	<i>Spilornis cheela</i>	Crested Serpent Eagle	LC/LC	Canopy	Carnivores	0.6	C	1	3	-
Alcedinidae	<i>Alcedo atthis</i>	Common Kingfisher	LC/LC	Sub canopy, Canopy	Carnivores	0.3	R	0	2	-
Alcedinidae	<i>Ceyx erithaca</i>	Oriental Dwarf Kingfisher	NT/LC	Sub canopy, Canopy	Carnivores	0.3	R	1	1	-
Alcedinidae	<i>Halcyon smyrnensis</i>	White-throated Kingfisher	LC/LC	Sub canopy, Canopy	Carnivores	1.2	C	1	7	-
Alcedinidae	<i>Pelargopsis capensis</i>	Stork-billed Kingfisher	LC/LC	Sub canopy, Canopy	Carnivores	1.95	C	4	9	0.54
Apodidae	<i>Aerodramus unicolor</i>	Indian Swiftlet	LC/LC	Canopy, Sub canopy	Insectivores	0.75	C	3	2	-
Apodidae	<i>Apus melba</i>	Alpine Swift	EN/LC	Canopy, Sub canopy	Insectivores	0.6	C	0	4	-
Apodidae	<i>Apus nipalensis</i>	House Swift	LC/LC	Canopy, Sub canopy	Insectivores	1.5	C	0	10	-
Apodidae	<i>Cypsiurus balasensis</i>	Asian Palm-Swift	LC/LC	Canopy, Sub canopy	Insectivores	0.45	C	0	3	-
Ardeidae	<i>Ardea alba</i>	Great Egret	LC/LC	Sub canopy, Ground	Carnivores	0.15	R	0	1	-
Ardeidae	<i>Ardea intermedia</i>	Intermediate Egret	LC/LC	Sub canopy, Ground	Carnivores	5.26	VC	5	30	0.27
Ardeidae	<i>Ardeola grayii</i>	Indian Pond Heron	LC/LC	Sub canopy, Ground	Carnivores	0.6	C	0	4	-
Ardeidae	<i>Bubulcus ibis</i>	Cattle Egret	LC/LC	Sub canopy, Ground	Carnivores	3	C	10	10	0.61
Ardeidae	<i>Egretta garzetta</i>	Little Egret	LC/LC	Sub canopy, Ground	Carnivores	5.41	VC	11	25	0.34
Ardeidae	<i>Ixobrychus cinnamomeus</i>	Cinnamon Bittern	NT/LC	Sub canopy, Ground	Carnivores	0.15	R	0	1	-
Ardeidae	<i>Nycticorax nycticorax</i>	Black-crowned Night Heron	NT/LC	Ground	Carnivores	0.3	R	1	1	-
Bucerotidae	<i>Ocyrceros gingalensis</i> <sup>£</sup>	Sri Lanka Grey Hornbill	LC/LC	Sub canopy, Canopy	Frugivores	0.3	R	1	1	-
Campephagidae	<i>Pericrocotus cinnamomeus</i>	Small Minivet	LC/LC	Sub canopy, Understory	Insectivores	0.6	C	0	4	-
Campephagidae	<i>Pericrocotus speciosus</i>	Scarlet Minivet	LC/LC	Sub canopy, Understory	Insectivores	1.65	C	5	6	0.52
Charadriidae	<i>Vanellus indicus</i>	Red-wattled Lapwing	LC/LC	Ground	Omnivores	0.6	C	0	4	-
Chloropseidae	<i>Chloropsis aurifrons</i>	Golden-fronted Leafbird	LC/LC	Sub canopy, Understory	Frugivores	0.6	C	2	2	-
Chloropseidae	<i>Chloropsis jerdoni</i>	Jerdon's Leafbird	LC/LC	Sub canopy, Understory	Frugivores	0.75	C	2	3	-
Cisticolidae	<i>Prinia inornata</i>	Plain Prinia	LC/LC	Sub canopy, Understory	Insectivores	0.3	R	0	2	-
Cisticolidae	<i>Prinia socialis</i>	Ashy Prinia	LC/LC	Sub canopy, Understory	Insectivores	0.45	C	0	3	-
Columbidae	<i>Chalcophaps indica</i>	Emerald Dove	LC/LC	Sub canopy, Understory	Frugivores	0.3	R	0	2	-
Columbidae	<i>Columba livia</i>	Feral Pigeon	-/LC	Sub canopy, Understory	Granivores	1.5	C	0	10	-
Columbidae	<i>Columba torringtoniae</i> <sup>£</sup>	Sri Lanka Wood Pigeon	VU/VU	Sub canopy, Understory	Frugivores	0.3	R	0	2	-
Columbidae	<i>Streptopelia chinensis</i>	Spotted Dove	LC/LC	Sub canopy, Understory	Granivores	1.05	C	0	7	-
Columbidae	<i>Treron pompadora</i> <sup>£</sup>	Sri Lanka Green Pigeon	LC/LC	Sub canopy, Understory	Frugivores	0.3	R	0	2	-





Family	Scientific Name	Common Name	NCS/ GCS	Stratum	Food habit	RA/%	Rarity	Abundance		
								RI	RF	p Value
Corvidae	<i>Corvus splendens</i>	House Crow	LC/LC	Sub canopy, Understory	Omnivores	7.81	VC	5	47	0.09
Cuculidae	<i>Centropus sinensis</i>	Greater Coucal	LC/LC	Understory, Ground	Carnivores	0.45	C	2	1	-
Cuculidae	<i>Eudynamis scolopaceus</i>	Asian Koel	LC/LC	Sub canopy, Understory	Frugivores	1.05	C	1	6	-
Dicaeidae	<i>Dicaeum erythrorhynchos</i>	Pale-billed Flowerpecker	LC/LC	Sub canopy, Understory	Nectarivores	2.25	C	2	13	-
Dicruridae	<i>Dicrurus caerulescens</i>	White-bellied Drongo	LC/LC	Sub canopy, Understory	Insectivores	0.9	C	0	6	-
Estrildidae	<i>Lonchura malacca</i>	Black-headed Munia	LC/LC	Sub canopy, Understory	Granivores	0.75	C	0	5	-
Estrildidae	<i>Lonchura punctulata</i>	Scaly-breasted Munia	LC/LC	Sub canopy, Understory	Granivores	2.4	C	0	16	-
Estrildidae	<i>Lonchura striata</i>	White-rumped Munia	LC/LC	Sub canopy, Understory	Granivores	2.1	C	0	14	-
Hirundinidae	<i>Cecropis hyperythra</i>	Sri Lanka Swallow	LC/LC	Canopy, Sub canopy	Insectivores	0.45	C	0	3	-
Motacillidae	<i>Motacilla cinerea</i> <sup>M</sup>	Grey Wagtail	-/LC	Ground	Carnivores	0.3	R	0	2	-
Motacillidae	<i>Motacilla flava</i> <sup>M</sup>	Yellow Wagtail	-/LC	Ground	Carnivores	0.15	R	0	1	-
Muscicapidae	<i>Copsychus saularis</i>	Oriental Magpie-Robin	LC/LC	Sub canopy, Understory	Insectivores	0.9	C	0	6	-
Muscicapidae	<i>Cyornis tickelliae</i>	Tickell's Blue Flycatcher	LC/LC	Sub canopy, Ground	Insectivores	0.15	R	0	1	-
Muscicapidae	<i>Muscicapa dauurica</i> <sup>M</sup>	Asian Brown Flycatcher	-/LC	Sub canopy	Insectivores	0.15	R	0	1	-
Nectariniidae	<i>Cinnyris asiaticus</i>	Purple Sunbird	LC/LC	Sub canopy, Understory	Nectarivores	1.5	C	4	6	0.48
Nectariniidae	<i>Cinnyris lotenius</i>	Loten's Sunbird	LC/LC	Sub canopy, Understory	Nectarivores	0.3	R	0	2	-
Nectariniidae	<i>Leptocoma zeylonica</i>	Purple-rumped Sunbird	LC/LC	Sub canopy, Understory	Nectarivores	1.95	C	3	10	0.42
Oriolidae	<i>Oriolus xanthornus</i>	Black-hooded Oriole	LC/LC	Sub canopy, Understory	Frugivores	1.2	C	1	7	-
Paridae	<i>Parus major</i>	Great Tit	LC/LC	Sub canopy, Understory	Omnivores	0.75	C	0	5	-
Passeridae	<i>Passer domesticus</i>	House Sparrow	LC/LC	Sub canopy, Understory	Granivores	0.6	C	0	4	-
Phalacrocoracidae	<i>Microcarbo niger</i>	Little Cormorant	LC/LC	Sub canopy, Ground	Carnivores	11.11	VC	37	37	0.51
Phalacrocoracidae	<i>Phalacrocorax fuscicollis</i>	Indian Cormorant	LC/LC	Sub canopy, Ground	Carnivores	0.45	C	0	3	-
Picidae	<i>Chrysocolaptes stricklandi</i>	Crimson-backed Goldenback	-/LC	Sub canopy, Understory	Insectivores	0.15	R	0	1	-
Picidae	<i>Dinopium benghalense</i>	Lesser Goldenback	LC/LC	Sub canopy, Understory	Insectivores	0.15	R	0	1	-
Pittidae	<i>Pitta brachyura</i> <sup>M</sup>	Indian Pitta	LC/LC	Understory	Insectivores	0.15	R	0	1	-
Psittacidae	<i>Loriculus beryllinus</i> <sup>E</sup>	Sri Lanka Hanging Parrot	LC/LC	Sub canopy, Understory	Frugivores	0.15	R	0	1	-
Psittacidae	<i>Psitta culakrameri</i>	Rose-ringed Parakeet	LC/LC	Sub canopy, Understory	Frugivores	1.2	C	5	3	0.71
Pycnonotidae	<i>Iole indica</i>	Yellow-browed Bulbul	LC/LC	Sub canopy, Understory	Omnivores	1.2	C	0	8	-
Pycnonotidae	<i>Pycnonotus cafer</i>	Red-vented bulbul	LC/LC	Sub canopy, Understory	Omnivores	3.15	C	7	14	0.19
Rallidae	<i>Amaurornis phoenicurus</i>	White-breasted Waterhen	LC/LC	Ground	Carnivores	0.3	R	0	2	-
Ramphastidae	<i>Psilopogon flavifrons</i> <sup>E</sup>	Yellow-fronted Barbet	LC/LC	Canopy, Understory	Frugivores	1.2	C	2	6	-
Ramphastidae	<i>Psilopogon rubricapillus</i> <sup>E</sup>	Crimson-fronted Barbet	LC/LC	Canopy, Understory	Frugivores	0.6	C	0	4	-
Ramphastidae	<i>Psilopogon zeylanicus</i>	Brown-headed Barbet	LC/LC	Canopy, Understory	Frugivores	1.35	C	2	7	-

Family	Scientific Name	Common Name	NCS/ GCS	Stratum	Food habit	RA/%	Rarity	Abundance		
								RI	RF	p Value
Scolopacidae	<i>Actitis hypoleucos</i> <sup>M</sup>	Common Sandpiper	LC/LC	Ground	Carnivores	1.35	C	2	7	-
Scolopacidae	<i>Tringa ochropus</i> <sup>M</sup>	Green Sandpiper	- /LC	Ground	Carnivores	0.3	R	2	0	-
Sittidae	<i>Sitta frontalis</i>	Velvet-fronted Nuthatch	LC/LC	Sub canopy	Insectivores	0.15	R	1	0	-
Sturnidae	<i>Acridotheres tristis</i>	Common Mynah	LC/LC	Sub canopy, Understory	Omnivores	5.71	VC	0	38	-
Sturnidae	<i>Gracula ptilogenys</i> <sup>E</sup>	Sri Lanka Hill Mynah	VU/NT	Canopy, Sub canopy	Omnivores	0.45	C	2	1	-
Sturnidae	<i>Gracula religiosa</i>	Lesser Hill Mynah	LC/LC	Canopy, Sub canopy	Omnivores	5.26	VC	24	11	0.21
Sylviidae	<i>Orthotomus sutorius</i>	Common Tailorbird	LC/LC	Sub canopy, Understory	Insectivores	1.95	C	2	11	-
Timaliidae	<i>Turdoides affinis</i>	Yellow-billed Babbler	LC/LC	Sub canopy, Understory	Insectivores	3.9	C	0	26	-
Zosteropidae	<i>Zosterops palpebrosus</i>	Oriental White-Eye	LC/LC	Sub canopy, Understory	Omnivores	0.6	C	0	4	-

<sup>M</sup>—Migratory birds | <sup>E</sup>—Endemic birds and rest of the birds were non-endemic native birds | NCS—National conservation status | GCS—Global conservation status | LC—Least Concern | NT—Near Threatened | EN—Endangered | VU—Vulnerable | RA—Relative abundance | R—Rare | C—Common | VC—Very common | RI—River islands | RF—Riverine forests.



Image 1. Some of the water associated birds recorded from the Warathenna-Hakkinda EPA: A—White-throated Kingfisher | B—Stork-billed Kingfisher | C—Indian Pond Heron | D—Little Cormorant and Indian Cormorant | E—Little Egret | F—Intermediate Egret. © Tithira Lakkana.

encountered from multiple layers such as canopy-sub canopy, canopy-understory, sub canopy-understory, sub canopy-ground and understory-ground. Most of the bird species were encountered from the canopy and sub canopy layers in the forest. According to the forest strata analysis, most of the birds were recorded from the sub canopy-understory layer (47% of total sampled species) while understory and understory-ground dwellers (15% of sampled species in each strata) were the least species rich forest strata in this ecosystem. The species richness among the nine combinations of the four main strata of the forest layer was significantly different ( $F = 2.97$ ;  $p < 0.05$ ) (Figure 6). The abundance of species was highest in sub canopy-understory (50%) and sub canopy-ground (26% relative abundance) while the least abundance was recorded from the understory (0.15% relative abundance).

During sampling of the river islands, 136 individuals belonging to 34 species in 20 families were recorded while riverine forest patches recorded 510 individuals belonging to 72 species in 34 families (Image 2B). All seven endemic species recorded during the study were observed in the riverine forests as well as six migratory species except Green Sandpiper and 60 non-endemic natives. On the other hand, three endemics (Sri Lanka Grey Hornbill, Yellow-fronted Barbet, and Sri Lanka Hill Mynah) and two migratory species (Common Sandpiper and Green Sandpiper) and 29 non-endemic natives were recorded from the river islands (Table 1). However, the species richness was not significantly different between the two habitats ( $t = -2.13$ ,  $p > 0.05$ ). Green Sandpiper and Velvet-fronted Nuthatch *Sitta frontalis* were the only two species not recorded from riverine forest although they were present in river islands. Swift, Munia, Wagtail, and woodpecker species were absent in the river islands in the EPA (Table 1). However, the species abundance between the two habitats were significantly different ( $t = -3.89$ ,  $p < 0.05$ ). Yet, the relative abundance of the individual species between two habitats were not significantly different. The highly abundant species in riverine forests were the House Crow *Corvus splendens*, Common Mynah *Acridotheres tristis*, Little Cormorant *Microcarbo niger* (Image 1D), Intermediate Egret *Ardea intermedia* (Image 1F), Yellow-billed Babbler *Turdoides affinis* (Image 2G), and Little Egret *Egretta garzetta* (Image 1E) (47, 38, 37, 30, 26, and 25 individuals, respectively) while Little Cormorant and Southern Hill Mynah *Gracula religiosa* (37 and 24 individuals, respectively) were highly abundant in river islands. The least common species in riverine forest were Greater Coucal *Centropus sinensis*, Sri Lanka Hill Mynah, Great Egret *Ardea alba*, Cinnamon

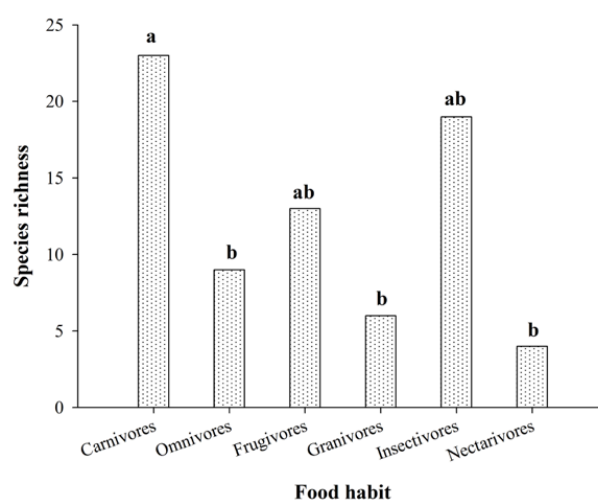


Figure 5. The food habits of sampled bird communities in Warathenna-Hakkinda EPA (a and b letters denote the significance level of the data).

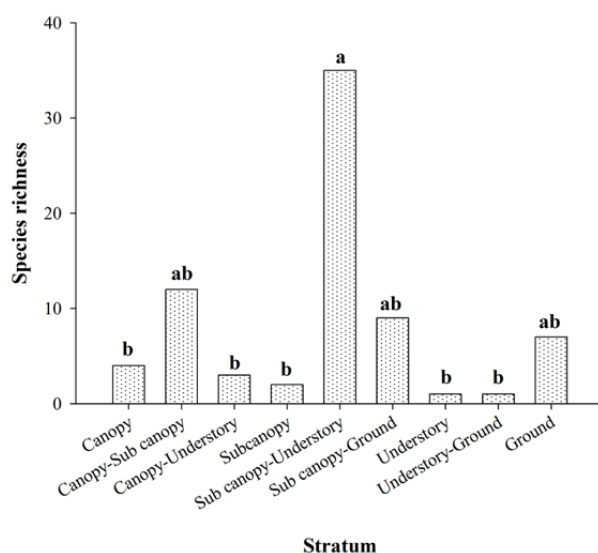


Figure 6. Distribution of encountered bird species along the forest strata in Warathenna-Hakkinda EPA; a and b denote the significance of the values. (a and b letters denote the significance level of the data).

Bittern *Ixobrychus cinnamomeus*, Yellow Wagtail, Asian Brown Flycatcher, Tickell's Blue Flycatcher *Cyornis tickelliae*, Crimson-backed Goldenback *Chrysocolaptes stricklandi*, Lesser Goldenback *Dinopium benghalense*, Indian Pitta, and Sri Lanka Hanging Parrot while Velvet-fronted Nuthatch, Crested Serpent Eagle *Spilornis cheela*, Asian Koel *Eudynamis scolopaceus* (Image 2D), White-throated Kingfisher *Halcyon smyrnensis* (Image 1A), and Black-hooded Oriole *Oriolus xanthornus* were the least abundant species in river islands. Shikra *Accipiter badius*



(Image 2C), Oriental Dwarf Kingfisher *Ceyx erithaca*, Black-crowned Night Heron *Nycticorax nycticorax*, and Sri Lanka Grey Hornbill showed low abundance in both habitats in the EPA (Table 1).

Both Shannon-Wiener and Margalef's diversity indices were highest in riverine forests ( $H' = 2.55$ ;  $M = 10.92$ ) compared to the river islands ( $H' = 2.29$ ;  $M = 5.07$ ). According to the Jaccard index the two habitats showed 43% similarity. According to the food habits of the sampled species, the highest species richness and abundance was recorded from carnivores in both river island and riverine forest habitats (82 individuals 15 species and 154 individuals 22 species, respectively; Table 1), whereas the lowest species richness and abundance was recorded from nectarivores in both these habitats (9 individuals 3 species and 31 individuals 4 species, respectively).

## DISCUSSION

Riverine forest habitats along the Mahaweli River provide shelter for diverse animal communities (Sinha et al. 2019). Due to the high heterogeneity of the habitats in riverine ecosystem, it is home to a variety of mammals, birds, reptiles, amphibians, and many invertebrate communities. However, the bird diversity in the Warathenna-Hakkinda EPA has not been investigated to date. Data on avifauna in this EPA may be useful for future conservation efforts and ecotourism.

Rarefaction graphical representations are used to determine the sampling effort. The statistical significance of this curve is revealed using 95% upper and lower confidence limits (Colwell & Coddington 1994). This curve for the present study is close to leveling off (i.e., not completely leveled off); hence, it indicates the requirement of more sampling effort. However, according to the published literature this graphical representation does not directly reveal the total species richness (Magurran 2004). Therefore, more commonly used and statistically powerful Chao 2 and Jackknife 2 methods are used to estimate the predicted species richness in the EPA (Colwell & Coddington 1994; Colwell et al. 2012). Since this study was conducted during the daytime, the study possibly missed the nocturnal species and may account for the lower number of species in relation to the estimated numbers of 88 and 104 species in Chao 2 and Jackknife 2.

The 74 species of birds recorded from the EPA represents about 16% of the island's total bird species. This indicate that the species richness in this EPA is higher

than those reported in many other areas around Kandy city limits (Karunaratna 1986; Wijesundara & Santiapillai 2001; Ellepola 2014; Weerakoon 2015; Hettiarachchi & Wijesundara 2017). However, the bird species richness in Warathenna-Hakkinda EPA is lower than what is recorded in the Gannoruwa Forest Reserve (84 species) which is located adjacent to the EPA with an extent of 2.1 km<sup>2</sup> (Rathnayake et al. 2016). The Warathenna-Hakkinda EPA is a mere 0.61 km<sup>2</sup> area with not only riverine forest and river islands but also Kandyan home gardens surrounding human habitation. Hence, this area is highly affected by anthropogenic influences compared to the Gannoruwa Forest Reserve.

This EPA harbors about 28% of the islands breeding residents (out of the 240 breeding residents in Sri Lanka) and 3% of the 213 migratory bird species in Sri Lanka. In addition, it represents 26% of endemic bird species of the island (MOE 2012; Gabadage et al. 2015), while only 11 endemic species have been recorded from the Gannoruwa forest (Rathnayake et al. 2016). The number of endemic species is a measure that can predict the amount of human influence (Linder 1995; BirdLife International 2008; Hettiarachchi & Wijesundara 2017). Typically, undisturbed natural forests in the wet zone harbor many endemic species. For example, 16 species in the forests of the Knuckles mountain range, 12 species in the Horton Plains National Park, 23 species in the Sinharaja forest reserve, and 33 species in the Samanala Nature Reserve (Bambaradeniya et al. 2003; Karunaratna et al. 2011; Subasinghe & Sumanapala 2014; Chandrasiri et al. 2018).

Ardeidae, Alcedinidae, some Accipitridae, and some Apodidae are considered as water-bird families (Abie et al. 2019; Sinha et al. 2019), while Sturnidae, Estrildidae, and Columbidae families are highly associated with human habitations (Silva et al. 2017; Bellanthudawa et al. 2019). The abundance of both these two groups in the EPA hence can be correlated to its positioning along the Mahaweli River and the surrounding human settlements. Similar results have been obtained from a previous study carried out in Hantana forest, where the most abundant species was the Common Mynah, followed by Black Crow, and Yellow-billed Babbler (Wijesundara & Santiapillai 2001). On the other hand, most of the other wet zone forest as well as the forest located within the Kandy city limits (Udawattakele Forest Reserve) has more forest dwelling individuals and species such as Swallows, Swifts, Barbets, forest Babblers, Bulbuls, and Hill Mynahs (Bambaradeniya et al. 2003; Wijesundara & Silva 2005; Karunaratna et al. 2011; Subasinghe & Sumanapala 2014; Rathnayake et al.



**Image 2.** Some of the terrestrial endemic, non-endemic native and migratory birds recorded from the Warathenna-Hakkinda EPA: A—Sri Lanka Grey Hornbill | B—Yellow-browed Bulbul | C—Shikra | D—Asian Koel | E—House Sparrow | F—Feral Pigeon | G—Yellow-billed Babbler | H—Pale-billed Flowerpecker | I—Indian Pitta. © Tithira Lakkana.

2016; Hettiarachchi & Wijesundara 2017; Chandrasiri et al. 2018).

The forest strata the birds inhabit correlate with their food habits. Most of the frugivores (leaf birds, barbets and hill mynahs) and insectivores are observed in the canopy and sub canopy forest layers while most of the piscivores are found on the ground layer and omnivores are encountered from sub canopy, understory and ground layers during the present survey. A large number of carnivores, are recorded from the EPA because this

is a water associated habitat. But our findings were contrary to the study carried out in Udawatta-kele, which is a secondary forest in Kandy (Ellepolle 2014; Weerakoon 2015) and the Knuckles range (Subasinghe & Sumanapala 2014), where they record a large number of insectivores and frugivores. A previous study carried out in the hill country of Sri Lanka documented that the insectivores (Sri Lanka Bush Warbler, Common Tailorbird), frugivores (Yellow-fronted Barbet), and nectarivores (Purple Sunbird) showed a marked



preference for primary montane forests while carnivores preferred primary montane forests and grassland-forest interface where they can easily spot their prey species (Wijesundara & Silva 2005).

Although there is a difference in both the diversity and distribution of birds between the two habitats studied in the EPA, a large number of common bird species (43% of sampled birds) are recorded from both the habitats. This is possibly because there is very little distinction between these two habitats in terms of floristic characteristics. Several studies have shown that the bird distribution and diversities highly depend on the heterogeneity of the habitats (Bambaradeniya et al. 2003; Wijesundara & Silva 2005; Karunarathna et al. 2011; Subasinghe & Sumanapala 2014; Weerakoon 2015; Rathnayake et al. 2016; Hettiarachchi & Wijesundara 2017; Chandrasiri et al. 2018). The higher bird diversity in the riverine forests in the EPA may be attributed to the availability of relatively more distinct habitats.

Since the Warathenna-Hakkinda EPA is surrounded by human habitation, a number of anthropogenic activities have a direct impact on the EPA. Construction and expansion of human habitation, logging, garbage, and sewage dumping can lead to the deterioration and loss of biodiversity in this EPA. Given the high diversity of flora and fauna, including birds, as indicated in this study, this area requires effective conservation planning, including proper landscape management strategies, strengthening of existing national environmental rules and policies, continuous monitoring programs, public education and awareness programs for safeguarding the biodiversity in this EPA.

## CONCLUSIONS

A total of 74 bird species belonging to 61 genera and 35 families were encountered from the Warathenna-hakkinda EPA, which represent 16% of the island total bird species, 28% of the islands breeding residents, 3% of the migratory bird species and 26% of endemic birds of Sri Lanka. The variety of habitats provided by the riverine forests and river islands along the Mahaweli River of the EPA appears to aid in sustaining a rich bird community. However, since this EPA is located within the densely populated city of Kandy, it faces immense population pressures. Therefore, effective conservation planning including continuous monitoring programs, proper landscape managing strategies, strengthening of existing environmental policies, as well as educational and awareness programs are essential to minimize threats and safeguard the biodiversity in the EPA.

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