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RESEARCH ARTICLE

Reptile species composition at three forest reserves in the Central Forest Spine ecological corridor B-SL1, Selangor, Malaysia

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ABSTRACT

Central Forest Spine (CFS) is an important initiative to reconnect fragmented forest areas in the Peninsular Malaysia. According to the master plan (PIRECFS 2022), 39 ecological corridors have been identified, including CFS B-SL1, which connects Raja Musa Forest Reserve, Bukit Tarek Forest Reserve, and Gading Forest Reserve in Selangor. A review of existing research on reptilian diversity in these reserves revealed a lack of studies, with some focusing on the Bukit Tarek Forest Reserve. This study aims to document the reptile species present in CFS B-SL1. Fieldwork was conducted in May, June, August, September, and October 2022, with two sampling sessions in each forest reserve. A total of 25 pitfall traps were used for five consecutive nights, and active searches were done for two nights per session. The study identified 18 species from nine families, with *Calotes emma* being the most frequently captured species (n=31). Gading Forest Reserve constitutes the highest number of species (12 sp.). The Agamidae family accounted for the highest families in B-SL1, which is 65.08%. Jaccard's similarity dendrogram indicated Gading Forest Reserve and Raja Musa Forest Reserve clustered together, although the similarity was below 0.4. Kruskal-Wallis test indicated no significant difference in reptile diversity across three forest reserves. The rarefaction curve indicates that more species could be discovered if the sampling effort were increased. Recommendation includes proposing buffer zones at the corridor and monitoring the usage of herbicides at the plantations within the corridor. The study suggests that more time and effort are needed to uncover additional reptilian species in these forest reserves.

1. INTRODUCTION

According to Pelan Induk Rangkaian Ekologi Central Forest Spine (PIRECFS) 2022, Vol 2 for Selangor State, ecological corridor B-SL1 comprises three forest reserves: Raja Musa Forest Reserve (RMFR), Bukit Tarek Forest Reserve (BTFR) and Gading Forest Reserve (GFR) (PLANMalaysia, 2022). The corridor covers 3,630 hectares and is located within the Hulu Selangor district of Selangor. This corridor holds about 2 billion cubic metres of water supply altogether, thus making it an important water catchment site for domestic water usage, especially for the agricultural sector in Selangor. B-SL1 connects the forest network at southern Negeri Sembilan and eastern Pahang, which are currently threatened by the development of agricultural activities along the riparian zone and the high density of residents residing within and around the corridors (70 villages). The PIRECFS 2022 further specified the percentages of land use within B-SL1. In 2010, the forested area was only 27.13% of 3,630 hectares. The area increased to 35.95% in 2015 before experiencing a slight reduction in 2019 (35.62%). The agricultural area covered 64.00% of the total area in B-SL1 in 2010 and decreased to 54.26% in 2019.

Some areas in B-SL1 are experiencing forest fragmentation, which can be observed mainly at BTFR. Continuous development could put BTFR at greater risk of becoming a forest island, and Delaney et al. (2010) found that small natural patches can lead to small population size and decreases in genetic diversity. Reptiles are one of the taxa that show sensitivity towards habitat loss and degradation. A meta-analysis by Keinath et al. (2017) suggested that reptiles exhibit higher sensitivity to habitat loss and fragmentation than birds, mammals, and amphibians. Perhaps this is caused by their small distributional ranges with high endemism compared to other vertebrates (Böhm et al., 2013; Meiri et al., 2018). Plus, reptiles are very sensitive to environmental changes (Lal & Nadim, 2021). It is crucial to protect and conserve this taxon, as reptiles play an important role in ecosystem function through gene dispersal, nutrient cycling, trophic action, and ecosystem engineering (de Miranda, 2017).

Malaysia houses a high abundance and diversity of reptiles. The National Policy on Biological Diversity 2022 - 2030 stated that there are 567 species of reptiles across Peninsular Malaysia, Sabah, and Sarawak (Ministry of Natural Resources, Environment and Climate Change, 2023). Research on reptiles in Malaysia shows a positive trend towards higher research output and the adoption of modern techniques (Chan & Grismer, 2021). However, the study also found that research on reptiles in Malaysia remains insufficient in several areas, including the need for general inventories in understudied regions like Borneo, a greater emphasis on lesser-studied groups such as snakes and turtles, focused research on conservation, ecology, and evolution, and an emphasis on genome-level data. The study further mentioned that Selangor is one of the states in Peninsular Malaysia that received less reptile research attention.

Literature searches regarding reptile research in the forest reserves of B-SL1 do not yield many results, except for two studies. Faradiana et al. (2019) recorded only four species of reptiles in BTFR, which are *Aphaniotis fusca*, *Cyrtodactylus peninsularis*, *Dryophiops rubescens* and *Malayopython reticulatus*. Shahfiz et al. (2021) conducted a herpetofauna study at Gading Forest Reserve (GFR) along with two other forest reserves to test the biological parameters in the classification of Environmentally Sensitive Area (ESA) and mentioned the combination of total herpetofauna species at the three reserves. The existing record suggests a lack of studies on reptile diversity conducted at these forest reserves. Thus, this study aims to generate a checklist of the reptile species and discuss the diversity between all reserves within CFS B-SL1.

2. MATERIALS AND METHODS

2.1. Study areas

The study took place at GFR (03°37'32.82" N, 101°36'47.86" E), BTFR (03°33'04.39" N, 101°31'46.22" E), and RMFR (03°26'01.98" N, 101°20'14.10" E) as shown in Figure 1. Gading Forest Reserve, situated along the Titiwangsa Range, is one of the largest forest complexes in Selangor, encompassing approximately 19,034.8 ha. It is designated as a double-gazetted area within Selangor State Park (Kaviarasu et al., 2023) and serves as an entirely protected water catchment area primarily covered by dense, mature lowland and hill dipterocarp vegetation. The study plot was constructed approximately 400 metres from the nearest forest edge, adjacent to some plantation areas. Figure 2 shows the land use around CFS B-SL1 in 2019.

Bukit Tarek Forest Reserve is a permanent reserve covering 7,946 hectares and comprising a combination of lowland and hill forests. Surrounding activities in the area include rubber tree cultivation, vegetable farms, fruit orchards, and fish farming. The present study took place at a forest patch of BTFR, located east of the North-South Expressway.

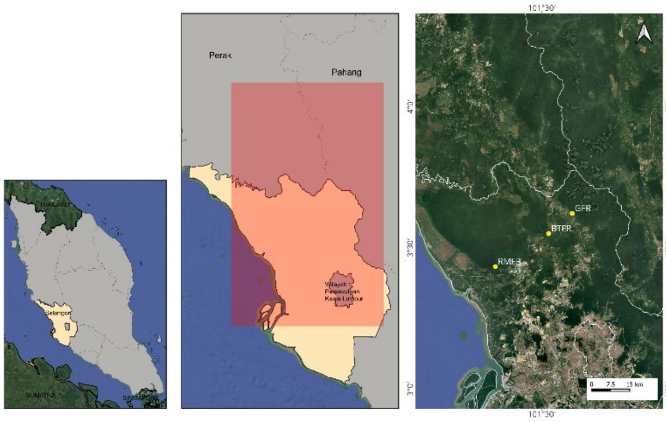

Figure 1: The map shows the location of the sampling sites (yellow pin) at RMFR, BTFR, and GFR within CFS B-SL1, Selangor.

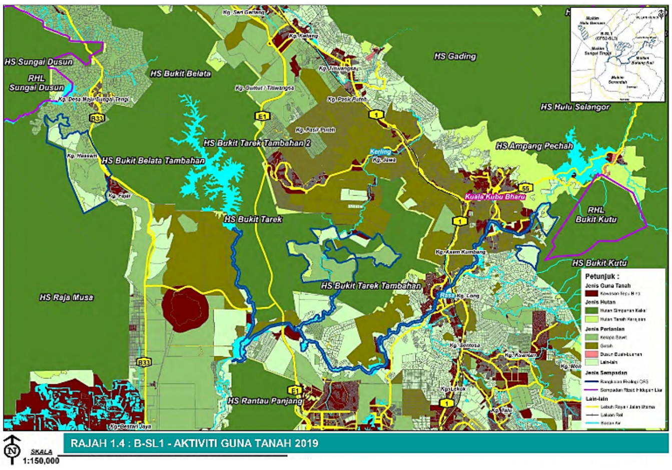

Figure 2: The map taken from PIRECFS 2022 Vol 2 Negeri Selangor shows the land use around CFS B-SL1 in 2019.

Raja Musa Forest Reserve is a part of Batang Berjuntai Forest Reserve, covering about 44,488 km^2 (Lim et al., 2009). Located in the Kuala Selangor district, it features highly disturbed scrubland with dense undergrowth and lower tree species, creating a thick under-canopy. The vegetation includes scrub and some secondary forests with tall trees and lush ground covers of palms, bamboo, bananas, gingers, and more. Additionally, several small and large streams flow through this part of the forest. The sampling site for this study was established in the peat swamp area, approximately 50 metres west of Pusat Kecemerlangan Hutan Paya Gambut Kompartment 73 and surrounded by oil palm plantation on the southern and western sides, with the northern side that connects to more extensive parts of RMFR.

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2.2. Data collection

Two sampling sessions were conducted at each forest reserve, as summarized in Table 1. Two methods were applied in this study adopted from Fauzi et al. (2023): pitfall traps and active search during the night. A 1-hectare (100m x 100m) plot was established at each site, consisting of 10 transect lines (labelled A–J) spaced 10 metres apart. Each plot contained a total of 25 pitfall traps, with five traps placed between pairs of transect lines (A–B; C–D; E–F; G–H; I–J), each 20 metres apart (15m, 35m, 55m, 75m, 95m). The traps were monitored for five consecutive nights during each session. Additionally, active searches were also conducted over two nights per session at each site, lasting two hours each night (from 2100 to 2300). The search was done near the water bodies and along the transect lines in the established plot for all forest reserves. Since the study plot for RMFR is located within a small forested area, an active search was conducted in the established plot for one night and northwards along the minor road surrounded by grasslands that leads to a watchtower and an open hall meant for birds observation on another night.

Table 1: The date of each sampling session for each study site

Forest Reserve	Date of sampling sessions	
	Session 1	Session 2
BTFR	30 May – 5 June 2022	20 – 26 June 2022
GFR	8 – 14 August 2022	5 – 11 September 2022
RMFR	3 – 8 October 2022	25 – 30 October 2022

2.3. Species identification

The individuals sighted during active searches were captured using bare hands or snake tongs, photographed, and measured. Measurements included snout-vent length (SVL) and total length (TL). Species identification was based on morphological features, body measurements, and distribution patterns. The reference used for species identification was the material by Das (2015) and Charlton (2020). Three representatives from each species were euthanized for voucher specimens, fixed in 10% formalin, and preserved in 70% ethanol. Liver samples were also collected and stored in acetone for future DNA analysis. For future reference, the preserved specimens were deposited in the Zoology Branch Specimen Collections at the Forest Research Institute Malaysia (FRIM). All collection procedures were conducted in accordance with the animal ethics procedure outlined in the research permit issued by the Department of Wildlife and National Parks (DWNP) and the Wildlife Conservation Act (WCA) 2010.

2.4. Data analysis

Abundance data for reptile species were collected from three forest reserves. The relative abundances of each species were calculated based on the sum of the number of individuals from each forest reserve. Diversity indices were computed using the Paleontological Statistics (PAST) software package version 4.17c (Hammer & Harper, 2001) with the number of observed individuals considered as one individual, with the purpose of providing a more inclusive measurement of reptile diversity while retaining the number of captured individuals. The analysis performed included Shannon index (H’), Menhinick index and species evenness (E).

Jaccard’s similarity coefficient dendrograms were generated based on the presence-absence data from this study using PAST software to illustrate the similarities of reptilian species composition among the three reserves. To ensure the robustness of the analysis, the Kruskal-Wallis test was performed on the Shannon index value of each sampling session to determine any significant difference in reptile diversity between the forest reserves. This non-parametric test was chosen due to its ability to handle differences in variance and non-normality, and the potential influence of a skewed abundance distribution in the results. A rarefaction graph was also generated using iNterpolation and EXTrapolation (iNEXT) Online software with a 95% confidence level, which allows for the calculation of expected species richness based on the given number of individual samples (Elena Schmitz & Rahmann, 2025).

3. RESULT AND DISCUSSION

3.1 Reptile diversity in CFS B-SL1

The study has recorded an overall of 63 individuals (both captured and observed) from 18 species and nine families of reptiles (Table 2) at B-SL1 from the present study. The highest number of species recorded was at GFR (S=12), while the lowest was at BTFR (S=9). The relative abundance of reptilian species in this corridor exhibited a range of 1.59% to 49.21%, with *Calotes emma* being the dominant species, accounting for a total of 31 recorded individuals. Out of all 18 species recorded, only *Heosemys spinosa* was classified as Endangered under the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species, and nine species were listed under Protected (P) according to the Wildlife Conservation Act (WCA) 2010. Only three species were recorded at all three forest reserves in CFS

B-SL1, which includes *C. emma*, *M. reticulatus*, and *Eutropis multifasciata*.

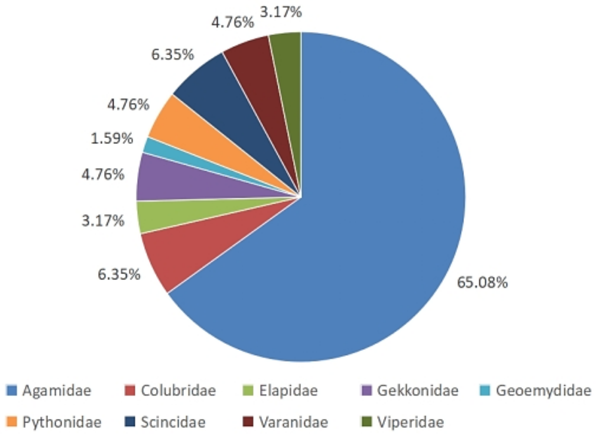

Figure 3: The relative abundance of reptilian species for each family (%) in CFS B-SL1 from the present study

Figure 3 shows a pie chart illustrating the relative abundance of species by family in CFS B-SL1. The Agamidae family accounted for the highest percentage of species abundance, representing 65.08% of the total. In contrast, the Geomydidae family had the lowest relative abundance, at only 1.59% and was recorded at only one forest reserve.

The Shannon index calculated shows that BTFR has the highest diversity of reptiles among the three forest reserves (H' = 2.462), while GFR has the lowest diversity (H' = 1.764), as summarised in Table 3. Although GFR and RMFR have a higher number of species and individuals than BTFR, the low Shannon index of both forest reserves was influenced by low evenness between the species, perhaps caused by the high number of *C. emma*. The individuals in the BTFR are more evenly distributed across species compared to other reserves, which influences its high diversity. Overall, the Shannon index for B-SL1 is 2.1980, which can be considered as low diversity based on the diversity classification scheme by Fernando (1998, unpublished data). The Kruskal-Wallis test resulted in no significant difference in reptile diversity across each sampling session, where $p > 0.05$ ($p = 0.8669$), indicating that reptile diversity across the three forest reserves is relatively similar.

Table 2: Summary of reptilian records at the three forest reserves in CFS B-SL1 from present study.

Family	Common Name	Scientific Name	IUCN Status	WCA 2010	Abundance				Relative abundance (%)
					BTFR	GFR	RMFR	B-SL1	
Agamidae	Earless Agamid	*Aphaniotis fusca*	LC	NE	3		1	4	6.35
	Green Crested Lizard	*Bronchocela cristatella*	LC	NE		1	1	2	3.17
	Forest Garden Lizard	*Calotes emma*	LC	P	1	20	10	31	49.21
	Oriental Garden Lizard	*Calotes versicolor*	LC	NE	1	1		2	3.17
	Black-bearded Flying Dragon	*Draco melanopogon*	LC	P	1			1	1.59
	Giant Forest Dragon	*Gonocephalus grandis*	LC	P			1	1	1.59
Colubridae	Asian Vine Snake	*Ahaetulla prasina*	LC	P		1		1	1.59
	Gold-ringed Cat Snake	*Boiga melanota*	LC	P		1	1	2	3.17
	Painted Bronzeback	*Dendrelaphis pictus*	LC	NE		1		1	1.59
Elapidae	Blue Coral Snake	*Calliophis bivirgatus*	LC	NE		1		1	1.59
	King Cobra	*Ophiophagus bungarus*	VU	P			1	1	1.59
Gekkonidae	Taylor's Bow-fingered Gecko	*Cyrtodactylus quadrivirgatus*	LC	P	1		1	2	3.17
	Smith's Green-eyed Gecko	*Gekko smithii*	LC	NE		1		1	1.59
Geomydidae	Spiny Turtle	*Heosemys spinosa*	EN	P	1			1	1.59
Pythonidae	Reticulated Python	*Malayopython reticulatus*	LC	NE	1	1	1	3	4.76
Scincidae	East Indian Brown Mabuya	*Eutropis multifasciata*	LC	NE	1	1	1	4	6.35
Varanidae	Common Water Monitor	*Varanus salvator*	LC	NE		2	1	3	4.76
Viperidae	Wagler's Pit Viper	*Tropidolaemus wagleri*	LC	P	1	1		2	3.17
				Total number of species	**9**	**12**	**10**	**18**	
				Total number of individuals captured	**6**	**30**	**10**	**46**	
				Total number of individuals (captured + observed)	**11**	**33**	**19**	**63**	
				Total number of families	**6**	**8**	**7**	**9**	

Notes: LC = Least Concern; VU = Vulnerable; EN = Endangered; NE = Not Evaluated; P = Protected.

Table 3: The diversity indices of reptile composition at the three forest reserves within CFS B-SL1 from present study.

Diversity indices	BTFR	GFR	RMFR	B-SL1
Species richness (S)	9	12	10	18
Number of individuals (N)	11	33	18	63
Dominance (D)	0.0546	0.3636	0.2632	0.2499
Shannon (H')	2.4620	1.7640	1.9690	2.1980
Menhinick	2.7140	2.0890	2.2940	2.2680
Evenness (E)	1.3030	0.4861	0.7166	0.5002
Chao-1 Estimator	34.4500	23.6400	44.1100	22.5900

Jaccard's similarity coefficient dendrogram (Figure 4) clustered together GFR and RMFR at similarities of 0.3750, while the similarity between BTFR and the two other forest reserves is at 0.3125 (GFR) and 0.3571 (RMFR). This indicates the low similarity of reptile species between all reserves.

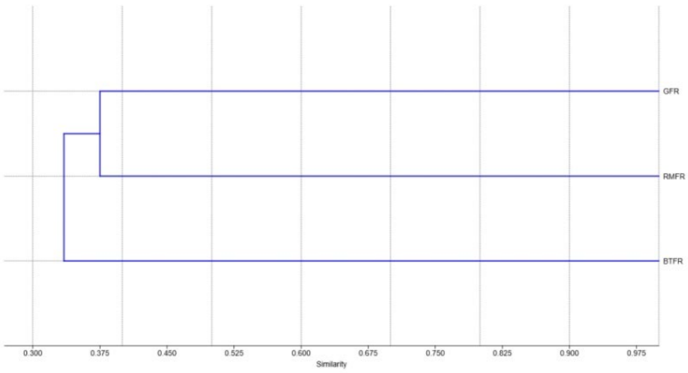

Figure 4: Jaccard's similarity coefficient dendrogram of reptilian assemblages at the three forest reserves for the present study.

The rarefaction curve plotted shows the expected species richness of reptilian species for all three reserves (Figure 5). Several species discovered in this study were shown as in Figure 6, 7 and 8.

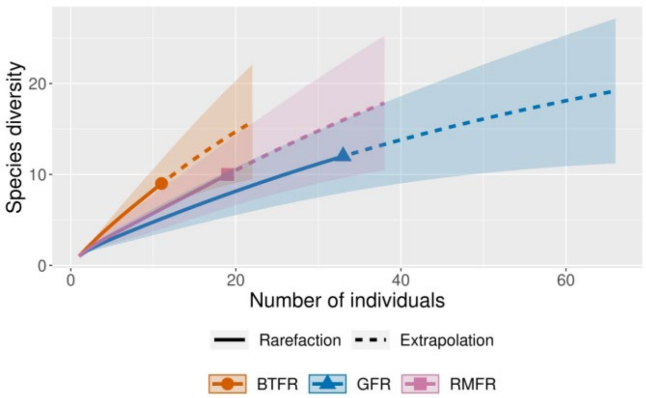

Figure 5: Rarefaction curves for reptile species richness at BTFR, GFR and RMFR within the ecological corridor CFS B-SL1 for the present study.

3.2 Ecological insights into the reptile community of CFS B-SL1

Among the three forest reserves, BTFR has the lowest record in terms of both the number of species and individuals, though its Shannon diversity index is the highest. The possible explanation for this finding is that the sampling location of this study within BTFR is composed of a small forest patch bordered by variations of other land uses and the North-South Expressway (Figure 2). The Jaccard's similarity coefficient dendrogram further supported this finding, where BTFR was not clustered together with RMFR and GFR, suggesting the possibility of slight differences in reptile species composition between forest islands and forest patches that are still connected to larger forest areas. The lack of forest connectivity could also influence the low similarity coefficient between all three forest reserves. Since reptiles already have low dispersal ability, especially for smaller species (Araújo & Pearson, 2005; Doherty et al., 2020), the absence of connectivity would further inhibit reptile movement within CFS B-SL1.

The high number of *C. emma* at GFR and RMFR can be correlated to their distribution, which is widespread and common (Wogan et al., 2021). This species can be found in forests, including degraded forests. It expresses diurnal behaviour and occurs on forest floors as well as in arboreal situations. This species also usually forages on the upper surface of understory vegetation and the forest floor. According to Majumder and Agarwala (2015), the diet of this species consists of invertebrates such as grasshoppers, ants, termites, cockroaches, beetles, variations of moth species, and low-flying butterflies, and soil-dwelling insects along with their larvae. Its nature as an insectivore may indicate the abundant presence of insects in GFR and RMFR, and insects play many critical roles in ecosystems, such as being involved in many trophic levels of food webs, decomposition and nutrient cycling, and acting as pollinators for many flowering plants (Kalita & Das, 2023).

Besides *C. emma*, the other two species found at all reserves are *E. multifasciata* and *M. reticulatus*. These two species were classified as habitat generalist species (Badli-Sham et al., 2019). *Eutropis multifasciata* is a widespread diurnal species, often found on forest edges and around human settlements (Janssen & Sy, 2022). *Malayopython reticulatus* inhabits diverse habitats, ranging from the water's edge in the forest, dry open forest, grasslands, rocky scrub, swamp and marshes, within plantations and urban areas (Das, 2021; Burger, 2022). The presence of a habitat generalist species could indicate habitat alteration due to their ability to tolerate the disturbance (Devictor et al., 2008; Tabarelli et al., 2012) and utilise a wide array of resources, which leads to an increase in competition with habitat specialists (Nordberg & Schwarzkopf, 2018). However, the prediction on the level of disturbance in a certain habitat requires careful analysis of the abundance of both habitat generalists and specialists.

Figure 6: Spiny Turtle (*Heosemys spinosa*).

There are six and four species of snake recorded at GFR and RMFR, respectively, while BTFR only recorded two species. Snakes are suspected to be sensitive to habitat disturbances due to their need for specific habitat requirements (de Fraga et al., 2018), thermal constraints, and limited mobility (Fitch & Shirer, 1971), though their responses to habitat loss and fragmentation in the tropics are still poorly understood (Palmeirim et al., 2021). However, one of the aspects that require attention is the role of the snake as a predator for non-volant small mammals. According to Das, Ahmed and Lim (2015), 19 out of 26 venomous land snakes in Malaysia feed primarily on rodents. Faradiana et al. (2019) and Munian et al. (2020) recorded a total of 12 species of rodents in BTFR, and the latter study recorded the same number of rodent species in GFR. Lim et al. (2009) successfully documented 17 species of rodents in RMFR. The smaller snake communities recorded from this study might not be able to control the population of rodents in CFS B-SL1, which poses a significant risk to the agricultural sector and might cause the emergence of zoonotic disease (Azhar & Abu Bakar, 2021).

The presence of *H. spinosa* in BTFR indicated the significance of conserving the forest reserve due to its status as an Endangered species. Cota et al. (2021) stated that this species is considered Endangered as its population has been estimated to be reduced by 50-80% in the last three generations (51 years) due to many threats: consumption trade, pet trade, and degradation of its lowland rainforest habitat. This semi-aquatic species may also have been affected by the disruption of forest hydrology caused by selective logging (Sharma & Tisen, 2000).

Figure 7: Reticulated Python (*Malayopython reticulatus*).

Figure 8: Water Monitor Lizard (*Varanus salvator*).

3.3 Recommendations

The rarefaction curve of a population provides the expected number of recorded species as a function of sampling effort. Deng et al. (2015) explained that the slopes of the curve indicates whether the study will benefit from the sampling effort. The curve generated for reptiles in all reserves has not yet reached the asymptote, indicating that the study would yield more results if more sampling effort were made. The sampling method implemented in this study can be improved; the pitfall trap deployed can be increased in terms of its effectiveness in capturing the reptilian species that inhabit forest floor if drift fence and funnel traps are applied together with pitfall trap, though these trapping techniques still exhibit bias based on geographical location, habitat, and the species being considered (Ali et al., 2018). These improvements would help in generating more precise data on reptilian assemblages in CFS B-SL1.

Ecological corridor management designed specifically for reptile conservation should be implemented in CFS B-SL1. Since CFS B-SL1 mostly constitutes the riparian habitat, the buffer zone along the habitat should be proposed. The managers can adopt the proposed buffer zone by Semlitsch and Bodie (2003), which is 142–289 metres from streams. Apart from that, an animal crossing or an underpass should be constructed on the road located within the corridor. Gregory et al. (2021) suggested that an earthen rather than a concrete or metal floor be used for culverts. The same study also mentioned that the construction of animal crossings should consider suitable habitat within the crossing; rows of stumps or branches would provide cover for reptiles.

Besides, the corridor management should also focus on the agricultural practices near the corridor. Several parts of CFS B-SL1 are adjacent to rubber plantations (Figure 2), and the riparian habitat within the corridor faced a risk of herbicide leakage. Herbicide is used heavily in rubber plantations in Malaysia for weed control purposes, and among the herbicides used by rubber planters is glyphosate (Burgos & Ortuoste, 2018; Balaji et al., 2023). Sparling et al. (2006) have discovered that exposure of Red-eared Slider to high concentrations of glyphosate negatively affects the embryos and early hatchlings, such as reduced hatching success, lower weight and increased genetic damage. Though the study concluded that glyphosate poses a low risk to the species tested under normal field operations, the authors still stressed the cautionary steps to be taken during the application of this herbicide. Thus, the proper usage of the herbicides in the plantations near the corridor needs to be monitored to prevent negative chemical effects on aquatic reptiles.

4. CONCLUSION

In conclusion, 18 species of reptiles were recorded in CFS B-SL1 from the present study, with BTFR exhibiting the highest reptile diversity among the three forest reserves. However, no significant differences in reptile diversity were found among the reserves. The similarity of reptilian species among the three forest reserves can be considered low, probably influenced by the scarcity of landscape connectivity, which further affected reptile dispersal ability between fragmented landscapes. The presence of Endangered and Protected species in this corridor substantiates the justification for conserving this area. The sampling intensity should be increased in terms of effort and period of study to discover more reptilian species in this ecological corridor. Finally, the managers can consider implementing the conservation efforts specifically designed for reptiles in the management of this ecological corridor.

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