BIODIVERSITAS
Volume 23, Number 11, November 2022
Pages: 5574-5584

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d231105

Diversity amphibians and reptiles at Sungai Kerteh mangrove forest, Terengganu, Malaysia

NURULHUDA ZAKARIA[1,♥], MOHAMAD IKMAL HAKIM ALLAHUDIN[1], SITI NUR SYAZA MA'AD[1], AZRUN AMIRUDIN SULAIMAN[1], NUR AIN ABDULLAH[1,] MOHAMMAD IZUAN MOHD ZAMRI[1], MAZRUL ASWADY MAMAT[1], MUHAMMAD YAZID DERAMAN[2]

[1]Faculty of Science and Marine Environment, Universiti Malaysia Terengganu. 21030 Kuala Nerus, Terengganu, Malaysia.
Tel.: +60-9-6683720, Fax.: +60-9-6683190, ♥email: nurul_huda@umt.edu.my
[2]Malaysian Nature Society, ecoCare Environmental Education Centre. Kampung Labohan, 24300 Kertih, Kemaman, Terengganu, Malaysia

Manuscript received: 8 September 2022. Revision accepted: 27 October 2022.

Abstract. *Zakaria N, Allahudin MIH, Ma'ad SNS, Sulaiman AA, Abdullah NA, Zamri MIM, Mamat MA, Deraman MY. 2022. Diversity amphibians and reptiles at Sungai Kerteh mangrove forest, Terengganu, Malaysia. Biodiversitas 23: 5574-5584.* Malaysia has various ecosystems, including mangrove forests, that can support a rich number of amphibians and reptiles. However, amphibians and reptiles remain understudied, especially in mangrove forests. The main objective of this study was to determine the diversity of amphibians and reptiles in the mangrove forest of Sungai Kerteh. The sampling was conducted from 19th until 21st August 2019 by using the Visual Encounter Survey (VES) method along 2 km^2 area of Sungai Kerteh. A total of 53 individuals were recorded belonging to 12 species (5 amphibian species and 7 reptile species). For amphibians, three families were recorded, with the family Dicroglossidae being the most abundant, with 13 individuals. For reptiles, eight families were recorded with the family Agamidae being the most abundant with 18 individuals. *Fejervarya cancrivora* (11 individuals; Family Dicroglossidae) was the most abundant amphibian species, while *Leiolepis belliana* (14 individuals; Family Agamidae) was the most abundant reptile species. There was no significant difference between the diversity of reptiles (H': 1.6975) and amphibians (H': 1.2643) (t: -1.6835, p>0.05). This study provides the first checklist of amphibians and reptiles species that will be helpful in identifying existing herpetofauna species and possible endangered or rare species in the Sungai Kerteh mangrove forest, which will help contribute to the conservation efforts of the herpetofauna in this area.

Keywords: Brackish, estuary, herpetofauna, mangrove, Visual Encounter Survey

INTRODUCTION

Malaysia is one of the countries that is located nearest to the equator and have conditions such as optimum sunlight and precipitation to support tropical rainforests. The tropical rainforest in Malaysia is one of the most complex forests in existence that is not only rich in the number of species but also rich in terms of habitat diversity and ecosystem diversity (Jaafar et al. 2012). Being one of the world's 12th most biologically diverse countries in the world (Nazir and Mohd-Yunus 2007), Malaysia has various ecosystems and habitats that are able to support a rich number of herpetofauna species that remain active throughout the year. Herpetofauna is a group of organisms that includes amphibians and reptiles. Herpetofauna plays a vital role in the environment as a reliable form of biological control and indicator (Hammond et al. 2015). Herpetofauna is also important as they are the mid-level organisms of the food web (Talib et al. 2020), contribute to nutrient cycling, bioturbation (mostly tadpoles eating materials at benthic causing physical, structural changes to the habitat), seed dispersal (seed dispersed by frugivorous reptiles and through ingestion of frugivorous preys), as well as their roles as preys and predators in the ecosystem (Cortés-Gómez et al. 2015).

The mangrove ecosystem is one of the ecosystems found in Malaysia. Mangrove ecosystems are ecologically and economically vital (Lee et al. 2014). Mangrove forests in Malaysia have been diminishing from approximately 700,000 hectares in 1975 to 572,00 hectares in 2000 (Omar et al. 2018). The mangrove ecosystem that is situated at the interface of sea and land provides multiple ecosystem services, such as offering foods habitats and becoming nursery sites for a myriad of different organisms and including herpetofauna (Igulu et al. 2014). Mangrove ecosystems is biologically active with a high primary productivity rate which allows the ecosystem to support diverse species of organisms and complex food webs (Muro-Torres et al. 2019; Warui et al. 2020). Organic matters from mangroves provide major important nutrients for aquatic communities (Abrantes et al. 2015). These aquatic communities support higher trophic organisms and eventually benefit local people as local communities heavily rely on aquatic animal protein such as fish and crustaceans. Amphibian larvae may fall prey to other predaceous insects and fish and eventually, fish will be consumed by humans as it is a crucial source of protein (Akinrotimi et al. 2015; Kloskowski et al. 2020). Dzung et al. (2020) stated that with the increase in salinity, there is a decrease in the number of herpetofauna species. With this, it poses a higher threat to the balance of the food web in mangrove forests if herpetofauna populations in mangrove forests are lost, as this will eventually affect the local communities, which are reliant on an aquatic source of protein for income and consumption.

Currently, there is an estimation of 267 species of amphibians (Norhayati 2017) and 392 species of reptiles in Malaysia (Grismer and Quah 2019; MyBis 2022). In Terengganu alone, 67 amphibian species and 107 reptile species are recorded, equivalent to approximately 61% of amphibians and 34% of reptile species recorded from Peninsular Malaysia (Nur et al. 2017). Currently, there is only one previous study on the herpetofauna in Terengganu's mangrove forest (Badli-Sham et al. 2019). To date, there is no research that has been previously done on the diversity of herpetofauna in the mangrove forest of Sungai Kerteh, Kemaman, Terengganu. Hence, this study will be the first study on the herpetofauna of Sungai Kerteh, Kemaman. The main purpose of carrying out this study is to fill the gap in research of the diversity of herpetofauna in Sungai Kerteh, Kemaman, Terengganu that is still lacking.

By closing the gap in knowledge of the existing herpetofauna diversity in Sungai Kerteh, Terengganu, it will add more information on the diversity of herpetofauna in Malaysia, especially from mangrove ecosystem. Additionally, the first checklist of herpetofauna species of mangrove forest in Sungai Kerteh will be provided. This species checklist will be beneficial to any further ecological studies, biodiversity assessments, conservation reports, and other documentation and analyses relating to herpetofauna diversity (Munisamy et al. 2020). This study will be helpful in identifying existing herpetofauna species and possible endangered or rare species in this mangrove ecosystem which will help contribute to the conservation efforts of the herpetofauna in this area. With the information obtained from this study, herpetofauna conservation and mangrove forest preservation can be prioritized. This information will be useful for stakeholders to take action on improving the condition of this mangrove area in order to protect the herpetofauna species dwelling there. Apart from that, the findings from this study will be useful for other organizations to do further research, especially in long-term monitoring of the herpetofauna, studying the impacts of pollution to the herpetofauna, and giving awareness about the conservation of herpetofauna to the local people and the industry operators.

MATERIALS AND METHODS

Study area

The survey was performed from 19th August 2019 until 21st August 2019 by a group of five surveyors in the 2 km^2 of mangrove forest of Sungai Kerteh, Kemaman, Terengganu (latitude 4.5263°N and longitude 103.4441°E). Kemaman is a district that is located in the southeastern part of the Terengganu state. Sungai Kerteh is a coastal river estimated to be 23 km in length and originates from the hilly terrain about 350 m above sea level and runs through the mangrove forest and enters the sea just north of Kerteh Town (Shaari et al. 2020). Figure 1 depicts the location of Terengganu in Peninsular Malaysia and a map of Sungai Kerteh, which was the study site. The study site is an area of brackish waters covered with mangrove forest along the Sungai Kerteh (Figure 2). The river of Sungai Kerteh recorded a pH of the value of 5.47-6.05 (Siti et al. 2022), with heavy metals such as arsenic, mercury, lead, zinc, chromium, copper, nickel and cadmium exceeding threshold limit by National Water Quality Standard for Malaysia (NWQS) (Sukri et al. 2017). According to Siti et al. (2022), the salinity level of this brackish water is also recorded to be 22.14-27.44 ppt. Around here, there is a facility named Pusat Pendidikan Alam Sekitar ecoCare, Kerteh, Sungai Kerteh, Kemaman, Terengganu that is being managed by the Malaysian Nature Society (MNS).

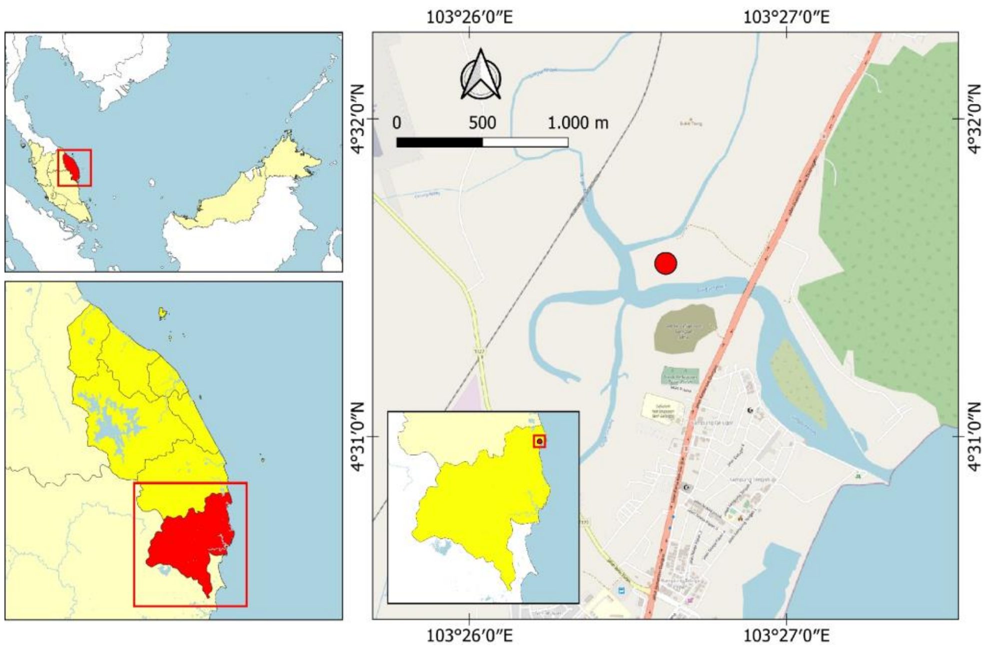

Figure 1. Survey location Sungai Kerteh, Kemaman district, Trengganu, Malaysia (Map modified from Shaari et al. 2020)

Figure 2. One of the sampling sites in Sungai Kerteh, Terengganu, Malaysia

Figure 3. Night sampling session using the VES method

Procedures

Data collection

Visual Encounter Survey (VES) is an active time-constraint surveying method where the herpetofauna is actively searched in a set period of time (Figure 3). The sampling time was set two to three hours per session three times a day.

Morning session samplings was done for three hours from 09:00 h to 12:00 h, evening sessions for two hours from 14:00 h to 16:00 h and night sessions for three hours from 20:00 h to 23:00 h. Due to the different active periods of herpetofauna in the day and night, three sessions of samplings were required throughout the day to maximize the probability of recording both diurnal and nocturnal herpetofauna species.

Herpetofauna was actively searched with the aid of a sweep net and snake tong on the forest trails, under the rock, on the tree, in riverine, and in water bodies. Headlamps was used at night to aid visibility in the dark. A sweep net was used to help capture the animals, especially amphibians, as they are very slippery, thus making them easily escape, and very delicate and can be easily injured if handled recklessly with bare hands. Snake tongs, on the other hand, provided safer conditions and helped handle snakes that may be venomous and can strike. Each of the captured animals was placed in a separate plastic bag with some water to prevent desiccation and some air and leaves to prevent from the bag being completely flattened and possibly killing the animals. The animals were brought back to the field station for measurement, identification, and photographing purposes and then were released back into the wild. Measurements of body parts were taken by using an electronic digital Vernier caliper that is highly accurate up to 0.01 mm and the weight of each individual was taken by using a mini scale. All the measurements were recorded in a datasheet. Identification process of the observed and collected specimens was done by referring to Uetz and Stylianou (2018), AmphibiaWeb (2019), Das (2021) and Norhayati (2017). Each of the individuals was photographed using a Canon DSLR camera for further reference or identification purposes.

Data analysis

Species diversity (Shannon index and Simpson index), species richness (Margalef index and Menhinick index) and species evenness (Peilou Evenness index) were calculated using Paleontological Statistics Software (PAST 4.0). Species Accumulation Curve (SAC) is used to describe how the number of species increases as sampling effort rises. SAC is a useful tool for comprehending the species composition and predicting species abundance of survey plots and frequently employed in community and biodiversity surveys (Rong et al. 2020). This SAC graph is also used to determine the completeness of the sampling effort (Deng et al. 2015). When the curve reaches an asymptote when all samples are plotted into the graph, this will indicate that the sampling effort is completed (Deng et al. 2015). Rarefaction is used to calculate the expected species richness for a given number of individual samples based on the construction of so-called rarefaction curves (Colwell et al. 2012). Rarefaction involves selection from a specified number of samples that is equal or less than the number of samples in the smallest samples, and then the samples are randomly discarded until the remaining number of samples is equal to the set threshold (Willis 2019). Thus, based on these subsamples created, which all have the same size, a comparison of diversity can be done "fairly" now as these sample sizes are of the same size (Weiss et al. 2017). Ecosim Professional software was used to plot this curve. Species Accumulation Curve (SAC) and Rarefaction curve were plotted using Paleontological Statistics Software (PAST 4.0). The diversity t-test that used Shannon and Simpson diversity indices was run using Paleontological Statistics Software (PAST 4.0).

RESULTS AND DISCUSSION

Composition of species

A total number of 53 individuals were recorded from 13 different species of amphibians and reptiles, which consist of five species of amphibians and eight species of reptiles (Table 1). Five amphibian species were identified belonging to three different families, namely Bufonidae (two species: *Duttaphrynus melanostictus* and *Phrynoidis asper*), Dicroglossidae (two species: *Fejervarya cancrivora* and *Fejervarya limnocharis*), and Rhacophoridae (one species: *Polypedates leucomystax*). Eight species of reptiles were identified belonging to five families; Agamidae (two species: *Calotes versicolor* and *Leiolepis belliana*), Gekkonidae (one species: *Hemidactylus frenatus*), Homalopsidae (two species: *Cerberus rynchops* and *Hypsiscopus plumbea*), Scincidae (two species: *Eutropis multifasciata* and *Subdoluseps bowringii*) and Varanidae (one species: *Varanus salvator*). *Fejervarya cancrivora* (Figure 4) recorded the highest species abundance for amphibians, with 11 individuals, and *Leiolepis belliana* (Figure 5), with 14 individuals for reptiles.

A pie chart for the relative abundance of species according to the families was plotted for both amphibians and reptiles. For amphibians, family Dicroglossidae recorded the highest percentage of relative species abundance, with 68.42% of amphibian species belonging to that family meanwhile family Rhacophoridae showed the lowest relative abundance, with only 10.53% (Figure 6). For reptiles, family Agamidae displayed the highest relative abundance with 52.94% of individuals recorded and the family with the lowest relative species abundance was Varanidae with 2.94% (Figure 7).

Diversity indices

Table 2 depicts the diversity indices calculated for amphibians, reptiles and herpetofauna (amphibians and reptiles). For the amphibians' species diversity, the value for Simpson and Shannon diversity indices were 0.62 and 1.26, respectively. For the species richness, which was calculated using Margalef and Menhinick indices, the value obtained were 1.36 and 1.15, respectively. Lastly, for species evenness, calculated using Peilou's index, the species evenness value was recorded as 0.79. For the reptiles, the species diversity indices value obtained for Simpson and Shannon diversity indices were 0.76 and 1.70, respectively. Species richness values obtained from Margalef and Menhinick indices were 1.99 and 1.37, and respectively, meanwhile, the species evenness was 0.82. The amphibian and reptile species recorded were combined as herpetofauna and the diversity indices were calculated once again. The Simpson and Shannon diversity indices obtained were 0.85 and 2.20, respectively.

Meanwhile, for species richness, Margalef and Menhinick indices once again were used to calculate the species richness of herpetofauna in the study area. A value of 3.02 was obtained for the Margalef index and 1.79 was obtained for the Menhinick index. Peilou's index showed that the species' evenness was 0.86. From the diversity t-test analysis that was performed using Shannon and Simpson indices value, there was no significant difference between the diversity of amphibians and the diversity of reptiles at Sungai Kerteh (Shannon index: t: -1.68, d.f.: 39, $p>0.05$ and Simpson index: t: -1.14, d.f.: 28, $p>0.05$).

Table 1. Species checklist of amphibians and reptiles recorded in Sungai Kerteh, Kemaman, Terengganu, Malaysia, with the IUCN Red List status and year of the last assessment

Class, family	Species name	Common name	Local name	Abundance	IUCN Red List status	Year assessed
Amphibia						
Bufonidae	*Duttaphrynus melanostictus*	Asian common toad	Katak puru biasa	2	LC	2004
	Phrynoidis asper	River toad	Katak puru sungai	2	LC	2020
Dicroglossidae	*Fejervarya cancrivora*	Crab-eating frog	Katak bakau	11	LC	2004
	Fejervarya limnocharis	Boie wart frog	Katak padi	2	LC	2004
Rhacophoridae	*Polypedates leucomystax*	Four-lined tree frog	Katak pokok berjalur empat	2	LC	2004
Reptilia						
Agamidae	*Calotes versicolor*	Common garden lizard	Sesumpah kuning	4	LC	2019
	Leiolepis belliana	Butterfly lizard	Not available	14	LC	2017
Gekkonidae	*Hemidactylus frenatus*	Common house gecko	Cicak rumah ekor duri	2	LC	2019
Homalopsidae	*Cerberus rynchops*	Dog-faced water snake	Ular air muka anjing	2	LC	2009
	Hypsiscopus plumbea	Boie's mud snake	Ular air sawah	7	LC	2009
Scincidae	*Eutropis multifasciata*	Many-lined sun skinks	Mengkarung matahari	1	LC	2018
	Subdoluseps bowringii	Bowring's supple skink	Mengkarung Bowring	3	LC	2019
Varanidae	*Varanus salvator*	Monitor lizard	Biawak air	1	LC	2018

Note: LC: Least Concerned

Figure 4. *Fejervarya cancrivora*

Figure 5. *Leiolepis belliana*

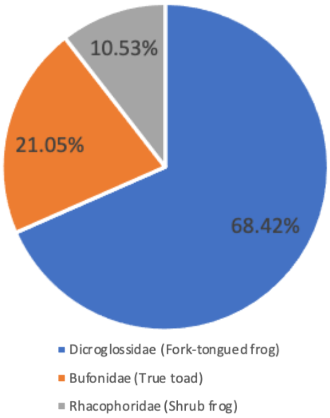

Figure 6. Relative abundance of amphibians according to family

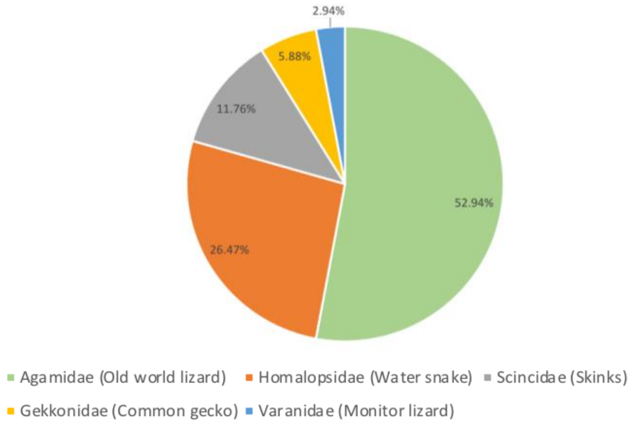

Figure 7. Relative abundance of reptiles according to family

Species Accumulation Curve (SAC)

Species accumulation curves were plotted for amphibians and reptiles separately (Figure 8). Species accumulation curves for both groups did not reach asymptotes indicating that more species can be recorded with more sampling efforts.

Rank Abundance Curve (RAC)

Rank abundance curve (RAC) that shows the dominance of animals in the community was plotted for both amphibians and reptiles. The curve of amphibians showed a higher steepness compared to reptiles suggesting that amphibians had a lower evenness and higher dominance compared to reptiles (Figure 9). For amphibian species, *Fejervarya cancrivora*, which had the highest ranking, dominated the area with 11 individuals recorded. The rest of the species recorded for amphibians (*Duttaphrynus melanostictus*, *Phrynoidis asper*, *Fejervarya limnocharis*, and *Polypedates leucomystax*) were only represented by two individuals each at species rank two to rank five. For reptiles, *Leiolepis belliana* dominated the area, with 14 individuals recorded. *Eutropis multifasciata* and *Varanus salvator* were the singleton species (represented by only one individual) for reptiles.

Rarefaction curve

The rarefaction curve was plotted to show the expected species richness of the sample (Figure 10). The broken lines indicate the 95% of confidence interval of the curve. The 95% confidence interval of amphibians and reptiles that were plotted in the rarefaction curves did not entirely overlap with each other, indicating that the difference between the groups was not statistically significant

Table 2. Diversity indices for amphibians, reptiles and herpetofauna at Sungai Kerteh, Terengganu, Malaysia

		Amphibians	**Reptiles**	**Herpeto-fauna**
Number of species		5	8	13
Number of individuals		19	34	53
Species diversity	Simpson 1-D	0.62	0.76	0.85
	Shannon, H	1.26	1.70	2.20
Species richness	Margalef	1.36	1.99	3.02
	Menhinick	1.15	1.37	1.79
Species evenness	Equitability	0.79	0.82	0.86

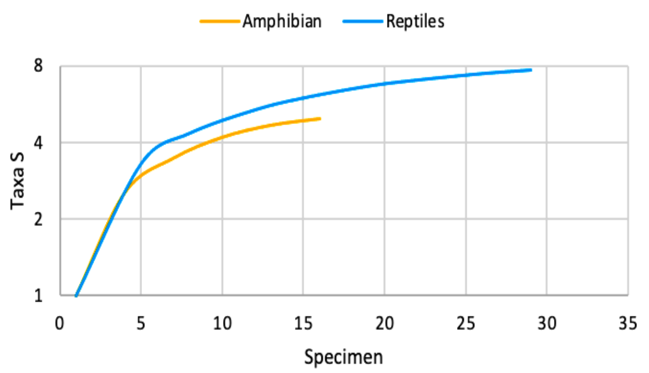

Figure 8. Species Accumulation Curve (SAC) plotted for amphibians and reptiles at Sungai Kerteh, Terengganu, Malaysia

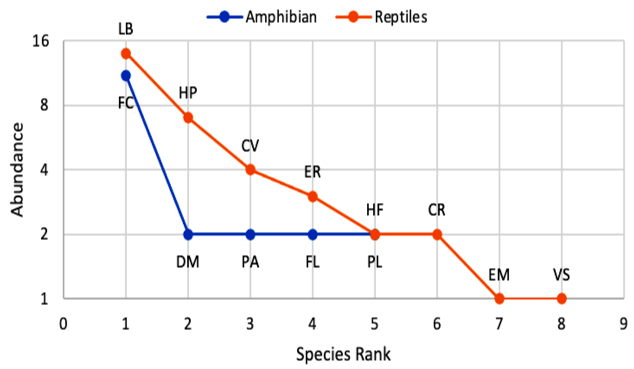

Figure 9. Rank Abundance Curve (RAC) plotted for amphibian and reptile species recorded at Sungai Kerteh, Terengganu, Malaysia. Note: FC: *Fejervarya cancrivora*; DM: *Duttaphrynus melanostictus*; PA: *Phrynoidis asper*; FL: *Fejervarya limnocharis*; PL: *Polypedates leucomystax;* LB*: Leiolepis belliana;* HP*: Hypsiscopus plumbea;* CV*: Calotes versicolor;* ER*: Subdoluseps bowringii;* HF*: Hemidactylus frenatus;* CR*: Cerberus rynchops;* EM*: Eutropis multifasciata;* VS*: Varanus salvator*

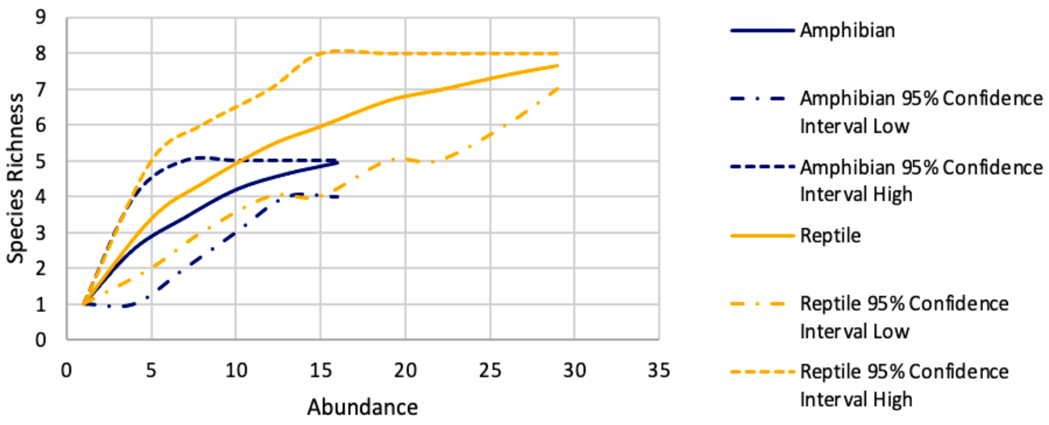

Figure 10. Rarefaction curves for amphibians and reptiles at Sungai Kerteh, Terengganu, Malaysia

Herpetofauna species diversity

There is a limited number of a study conducted on herpetofauna in mangrove forests of Peninsular Malaysia (e.g. Badli-Sham et al. 2019; Talib et al. 2020). Table 3 shows the checklist of herpetofauna species recorded from mangrove forests in Peninsular Malaysia. The study by Talib et al. (2020) at Delta Tumpat, Kelantan, had recorded the highest percentage of similarity in terms of species composition with this study, with five species out of a total of 23 species recorded (21.7%). These five species were *Duttaphrynus melanostictus*, *Fejervarya cancrivora*, *Calotes versicolor*, *Leiolepis belliana* and *Hemidactylus frenatus*.

When comparing all the study sites as mentioned in Table 3, the species present in most of the study sites were amphibian species, such as *Duttaphrynus melanostictus*, *Fejervarya cancrivora*, and *Polypedates leucomystax*, and reptile species, such as *Calotes versicolor, Boiga dendrophila, Eutropis multifasciata, Malayopython reticulatus* and *Varanus salvator.* All these species are present in at least three study sites, with *V. salvator* being present in all five studies.

Table 3. Checklist of herpetofauna species from mangrove forests of Peninsular Malaysia

Family	Species name	Mangrove forest: Klang Island Mangrove Forest Reserve (Norhayati et al. 2009)	Pulau Singa Besar, Langkawi (Lim et al. 2010)	Universiti Malaysia Terengganu Campus (Badli-Sham et al. 2019)	Delta Tumpat (Talib et al. 2020)	Sungai Kerteh, Kemaman (This study)
Amphibians						
Bufonidae	*Ingerophrynus parvus*					
	Duttaphrynus melanostictus		+	+	+	+
	Phrynoidis asper					+
Microhylidae	*Kaloula pulchra*			+	+	
	Microhyla heymonsi			+		
Dicroglossidae	*Fejervarya cancrivora*		+		+	+
	Fejervarya limnocharis			+		+
	Limnonectes blythii		+			
	Limnonectes hascheanus		+			
	Limnonectes macrognathus		+			
	Occidozyga laevis		+			
Ichthyophiidae	*Ichthyophis* sp.		+			
Ranidae	*Hylarana erythraea*		+			
	Hylarana raniceps		+			
Rhacophoridae	*Polypedates leucomystax*		+	+		+
Reptiles						
Agamidae	*Acanthosaura crucigera*		+			
	Aphaniotis fusca		+			
	Bronchocela cristatella		+			
	Calotes versicolor			+	+	+
	Leiolepis belliana			+	+	+
	Leiolepis triploida				+	
Colubridae	*Ahaetulla nasuta*			+		
	Boiga cyanea		+			
	Boiga dendrophila	+	+	+		
	Chrysopelea ornata			+		
	Coelognathus radiatus			+		
	Dendrelaphis pictus			+	+	
Elapidae	*Calliophis maculiceps*		+			
	Naja kaouthia		+	+		
	Ophiophagus hannah		+			
Emydidae	*Trachemys scripta*			+		
Gekkonidae	*Cyrtodactylus pulchellus*		+			
	Gehyra mutilata			+		
	Gekko gecko		+	+		
	Gekko monarchus					
	Hemidactylus frenatus			+		+
	Hemidactylus platyurus			+		
Geomydidae	*Cuora amboinensis*			+		
	Siebenrockiella crassicollis			+		
Homalopsidae	*Cerberus rynchops*		+			+
	Enhydris enhydris			+		
	Hypsiscopus plumbea			+		+
	Homalopsis buccata			+		
Hydrophiidae	*Hydrophis caerulescens*		+			
Scincidae	*Dasia olivacea*		+	+		
	Emoia atrocostata	+	+			
	Eutropis multifasciata		+	+		+
	Eutropis longicaudata			+	+	
	Subdoluseps bowringii			+		+
Pythonidae	*Ahaetulla prasina*		+			
	Malayopython reticulatus		+	+	+	
Varanidae	*Varanus salvator*	+	+	+	+	+
Viperidae	*Trimeresurus purpureomaculatus*		+			

Note: +: species present

Discussion

For the class of Amphibia, five species were recorded, which was lower than the class of Reptilia with eight species. A total of 19 individuals were recorded for amphibians compared to 34 individuals recorded for reptiles which could be attributed to the water salinity of the study site (Kearney et al. 2014; Hopkins and Brodie 2015; Hsu et al. 2018). Mangrove forests have brackish water that is more saline than freshwater as it is the area where sea water combines with freshwater (Kodikara et al. 2018). The brackish water in this mangrove area has a salinity of 22.14-27.33 ppt (Siti et al. 2022). Meanwhile, freshwater salinity is about 0.5 ppt, and seawater salinity is around 34-36 ppt (Nasreen 2022). A crucial feature of amphibians' biology, especially frogs, is how quickly water is lost from its body, which limits the periods and locations where it can be active (McCann et al. 2014). For amphibians that are osmotically sensitive towards salinity of the water, thriving in a saline environment would be difficult (Hopkins and Brodie 2015), hence why the abundance and species richness of amphibians here was lower than that of reptiles. Certain amphibian species that are able to adapt to saline conditions, such as *Fejervarya cancrivora* (family Dicroglossidae) was evidently able to thrive in the mangrove forest of Sungai Kerteh as this species recorded the highest abundance. This also resulted in Dicroglossidae being the most dominant family, as *F. cancrivora* belongs to this family. According to Shao et al. (2015), *F. cancrivora* lives abundantly in coastal lowland areas and mangrove swamps of Southeast Asia. This species can survive in brackish water that is up to 18% salinity, while the majority of amphibians cannot (Wijethunga et al. 2016; Li et al. 2022). This adaptability is due to three physiological pathways: (i) elevation of concentrations of salinity ions, especially sodium and chloride, in its blood plasma (Gordon et al. 1961); (ii) increase of Na^+/K^+-ATPase expression, allowing them to more efficiently maintain osmotic homeostasis (Bernobo et al. 2013; Wu et al. 2014); (iii) accumulation of organic osmolyte-urea in tissues, such as plasma and muscle via up-regulating hepatic urea synthesis (Wright et al. 2004). It is also possible that certain amphibian species could adapt to the saline habitat to escape the pressure of predators that are intolerant of salinity (Moreira et al. 2015). For reptiles, *Leiolepis belliana* (family Agamidae) was the most abundant, with 14 individuals recorded and this can be attributed to the fact that *L. belliana* thrives on open plains (Lei et al. 2021) like Sungai Kerteh. *Leiolepis belliana* is also listed as a protected species under the Malaysia Wildlife Conservation Act 2010. Compared to the osmotically sensitive amphibians with highly permeable skin (Hopkins and Brodie 2015), reptiles can withstand saline conditions due to their scaly skin (Rutland et al. 2019). To survive in brackish environments, some reptiles implement various behavioral mechanisms, such as movements between saline and freshwater areas, frequent retreats to freshwater sources higher upstream, and reduced feeding and drinking that would result in ingestion of higher salinity water (Harden et al. 2015; Bower et al. 2016).

The Shannon Diversity Index values for amphibians, reptiles and herpetofauna were referred to as the classification scheme for the Shannon Diversity Index following Dimalen and Rojo (2018). Diversity of amphibians (H': 1.26) and reptiles (H': 1.70) at Sungai Kerteh were defined as very low. However, the diversity of herpetofauna (H': 2.20) was considered as low. According to the classification scheme, H' value that is lower than 1.99 is considered very low diversity and a value between 2.00-2.49 is considered low diversity. These can be attributed to the short sampling period with a small area sampled as well as the saline conditions of the study site which all contributed to the low species richness, species abundance, species evenness and ultimately low species diversity. From the diversity t-test using Shannon and Simpson diversity indices value, there was no significant difference ($p>0.05$) between the diversity of amphibians and reptiles in the mangrove forest of Sungai Kerteh. The location of the study site, which was at the mangrove forest of Sungai Kerteh is an area of brackish water. Thus, the salinity of the water was higher than freshwater, which is similar to other estuarine in Peninsular Malaysia (Cheng-Ann et al. 2012; Jalal et al. 2012). The highly saline environment makes it difficult for amphibians with highly permeable skin to thrive there (Hopkins and Brodie 2015), hence inhibiting dispersion and limiting diversity. This limited diversity and abundance of amphibians could also affect the abundance and diversity of reptiles as reptiles are also predators of amphibians and could drastically decline in population size when in shortage of food (Nowak et al. 2015). Snakes, for example, are not able to survive with limited food (Shine and Koenig 2001) and the prey items carried by larger snakes were significantly more numerous and diverse than those carried by smaller snakes (Wolfe et al. 2018).

The Rank Abundance Curve (RAC) of amphibians showed a higher steepness compared to reptiles, suggesting that amphibians had a lower evenness and higher dominance compared to reptiles. *Fejervarya cancrivora* dominated the amphibian species in the study area as *F. cancrivora* is the only amphibian species that can withstand saline water as high as 28%, allowing it to thrive in this area better than other amphibians (Wright et al. 2004; Hopkins and Brodie 2015). Reptiles, on the other hand, are more evenly distributed as reptiles are not as osmotically sensitive towards salinity as amphibians are. *Leiolepis belliana* dominated this area, possibly due to suitable sandy and open fields as a habitat (Lei et al. 2021) as well as being a protected species which allows it to thrive well in this area. Rarefaction curves plotted for both amphibians and reptiles also include the 95% confidence interval in order to observe whether the species richness differs significantly or not. The species richness of amphibians and reptiles was considered significantly different as 95% confidence intervals were not overlapped with each other. This means that the higher species richness of reptiles compared to amphibians were not due to chance only and can be attributed to other factors such as better adaptability of species to the saline conditions compared to amphibians that cannot tolerate saline environment as well due to their highly permeable skin and eggs (Hopkins and Brodie 2015).

Species Accumulation Curve (SAC) of a population gives the expected number of observed species as a function of sampling effort. The slopes of the curve will be able to indicate the completeness of the sampling and whether the study will benefit from additional sampling efforts (Deng et al. 2015). SAC curves plotted for amphibians and reptiles all resulted in curves that have not yet reached an asymptote. This indicates that the study would benefit more from extra sampling effort. With a complete sampling, the gradient of the curves plotted would reach asymptote and start levelling off to indicate that all species in the area have been recorded. Any additional sampling beyond the asymptote will not add more species and will not change the relative abundance distribution (Gotelli and Chao 2013). An increase in sampling effort, such as a longer period of sampling, a larger area covered, more surveyors and more methods of surveying (e.g., Acoustic Encounter Survey, pitfall trap and collapsible trap) can all contribute to more species able to be recorded as the evasive nature of fast and cryptic herpetofauna requires extensive sampling with multiple sampling methods to sample all species present in the community (Boynton et al. 2021). Estimation of species richness tends to require high sampling efforts because species richness is very dependent on rare species, which are only able to be recorded in small abundance in accumulated samplings (Schneck and Melo 2010). A study by Hutchens and DePerno (2009) found that the Visual Encounter Survey method was only able to capture the most common species. This means that the species under the category of Near Threatened (NT), Vulnerable (VU), Endangered (EN), and Critically Endangered (CR) according to the IUCN Red List of Threatened Species may be harder to be recorded due to their scarce populations which require an extended period of sampling compared to species that are listed under Least Concerned (LC) category which has bigger and more stable populations. The VES method is always preferred since it requires little equipment and technology, is simple to learn, and is inexpensive (Fragoso et al. 2016).

A recent study on the herpetofauna in mangrove forests was conducted by Talib et al. (2020) at Delta Tumpat, Kelantan, for 36 days. The number of species recorded did not differ much from this study, with 11 species of herpetofauna (three species of amphibians; eight species of reptiles) documented at Delta Tumpat. For this study had only three days of sampling, a total number of 13 species of herpetofauna (5 species of amphibians; 8 species of reptiles) were recorded. This indicates that the SAC outcome must be defined carefully. For example, more samplings itself may not immediately equate to more species as it depends on other factors such as sampling intensity and manpower during the sampling as well as sampling area (Szaro and King 1990). The number of individuals recorded from this study was only 53 individuals, and this could be attributed to the short sampling sessions (3 days) and limited manpower (5 researchers). This could lead to imperfect detection of species richness, species abundance, and species evenness, as an inability to correctly determine these factors have been a problem in wildlife surveys (Kellner and Swihart 2014). When a species is falsely recorded as absent when in fact, it is present in the sampling area, this will cause a problem as it exaggerates the rarity of the undetected species or suppresses estimates off its abundance (Mackenzie et al. 2006). Other than that, the low detection of species diversity, species abundance and species richness can hamper conservation efforts as the location may be excluded when conservation efforts are performed due to false negative recording of the species.

In conclusion, a total of 53 herpetofauna individuals were recorded belonging to 13 species (5 amphibian species and eight reptile species) in Sungai Kerteh, Kemaman, Terengganu. *Fejervarya cancrivora* was the most abundant amphibian species as it is the only species that can withstand the saline environment of the mangrove forest. *Leiolepis belliana* is the most abundant reptile species as Sungai Kerteh has open and sandy plains, which allows *L. belliana* to thrive in the mangrove forest. The family Dicroglossidae and Agamidae were the most dominant family representing 68.42% of amphibians and 52.94% of reptiles recorded, respectively. Diversity of amphibians (H': 1.26) and reptiles (H': 1.70) were considered very low ($H<1.99$), meanwhile, collectively, the diversity of herpetofauna (H': 2.20) was considered as low (H': 2.00-2.49). More species can be recorded with more sampling efforts. Amphibians were more dominant, with lower evenness compared to the reptiles. There was a significant difference between the species richness of amphibians and reptiles. However, there was no significant difference between the diversity of amphibians and reptiles ($p>0.05$).

Finding from this study on the diversity of herpetofauna of the mangrove forest of Sungai Kerteh is vital in providing the first checklist of herpetofauna species in Sungai Kerteh that can give insights about the existing herpetofauna species and possible endangered or rare species at mangrove forest of Sungai Kerteh. This checklist will be helpful to be baseline information for further research of herpetofauna in the mangrove forest. Information obtained will be beneficial for effective management by stakeholders, especially for the herpetofauna conservation and preservation of the mangrove ecosystem. However, further future research with more sampling efforts is required to thoroughly determine the diversity of herpetofauna in the mangrove forest of Sungai Kerteh, which will help contribute even more to the conservation efforts of the herpetofauna in this area. Preservation of Sungai Kerteh is important as few protected species are present here, such as *Leiolepis belliana*, *Calotes versicolor*, *Varanus salvator* and *Cerberus rynchops*. Hence it is important for the habitat of these species to be preserved in order for the population to continue persisting, as habitat degradation has limited the existence of these species elsewhere, especially *L. belliana* as one of only two species under the genus *Leiolepis* in Malaysia.

ACKNOWLEDGEMENTS

We would like to thank the Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, for providing logistic and technical support. Special thanks to Malaysian Nature Society (MNS) Kerteh for the accommodation and field work assistance. We are grateful to Muhd Fatihah Syafiq for helping us with the species identification. We also would like to express our special thanks of gratitude to Siti Mariam Muhammad Nor, Maisarah Jaafar, Nurul Shahida Redzuan, Wan Bayani Wan Omar Muhammad and Nik Shibli Nik Jaafar, who gave us the opportunity to do this project together with them.

REFERENCES

Abrantes KG, Johnson R, Connolly RM, Sheaves M. 2015. Importance of mangrove carbon for aquatic food webs in wet dry tropical estuaries. Estuar Coast Shelf Sci 38: 383-399. DOI: 10.1007/sl2237-014-9817-2.

Akinrotimi OA, Edun OM, Williams IJE. 2015. The roles of brackish water aquaculture in fish supply and food security in some coastal communities of Rivers State, Nigeria. Intl J of Agric Sci Food Technol 1 (1): 16-19. DOI: 10.17352/2455-815X.000005.

AmphibiaWeb. 2019. https://amphibiaweb.org. University of California, Berkeley, CA, USA.

Badli-Sham BH, Ibrahim NSM, Goh SX, Noh HS, Shaife FA, Daud NM, Razak FABA, Rosli R, Razak AAA, Mohammad FNF, Kamaruzzaman MF, Mohamad S, Dzu K, Shariffudin A, Sawawi SNM, Ahmad A. 2019. Herpetofauna of Universiti Malaysia Terengganu campus: Sustaining biodiversity in campus green area. J Sustain Sci Manag 14 (1): 11-28.

Bernabo I, Bonacci A, Coscarelli F, Tripepi M, Brunelli E. 2013. Effects of salinity stress on *Bufo balearicus* and *Bufo bufo* tadpoles: Tolerance, morphological gill alterations and Na+/K+-ATPase localization. Aquat Toxicol 132-133: 119-133. DOI: 10.1016/j.aquatox.2013.01.019.

Bower DS, Scheltinga DM, Clulow S, Clulow J, Franklin CE, Georges A. 2016. Salinity tolerances of two Australian freshwater turtles, *Chelodina expansa* and *Emydura macquarii* (Testudinata: Chelidae). Conserv Physiol 4 (1): cow042. DOI: 10.1093/conphys/cow042.

Boynton MK, Toenies M, Cornelius N, Rich LN. 2021. Comparing camera traps and visual encounter surveys for monitoring small animals. Calif Fish Wildl 107 (2): 99-117. DOI: 10.51492/cfwj.107.9.

Cheng-Ann C, Shabdin ML, Norliana MR. 2012. Spatial distribution of tropical estuarine nematode communities in Sarawak, Malaysia (Borneo). Raffles Bull Zool 60: 173-181. DOI: 10.5281/zenodo.5347196.

Colwell RKA, Chao NJ, Gotelli SY, Lin CX, Mao RL, Chazdon RL, Longino JT. 2012. Models and estimators linking individual-based and sample-based rarefaction, extrapolation, and comparison of assemblages. J Plant Ecol 5: 3-21. DOI: 10.1093/jpe/rtr044.

Cortés-Gómez A, Ruiz CA, Valencia-Aguilar A, Ladle RJ. 2015. Ecological functions of neotropical amphibians and reptiles: A review. Univ Sci 20: 229-245. DOI: 10.11144/Javeriana.SC20-2.efna.

Das I. 2021. A Naturalists' Guide to the Snakes of South-East Asia (3rd Ed.). John Beaufoy Publishing, Oxford.

Deng C, Daley T, Smith AD. 2015. Applications of species accumulation curves in large-scale biological data analysis. Quant Biol 3 (3): 135-144. DOI: 10.1007%2Fs40484-015-0049-7.

Dimalen FK, Rojo MJA. 2018. Floral diversity of a mangrove forest in Cotabato City, Philippines. J Biodivers Environ Sci 13 (6): 117-123.

Dzung TL, Ngam TL, Hai NT, Yen TD. 2020. Biodiversity and composition of the herpetofauna from the Tien Hai Wetland Nature Reserve, North Vietnam. J Adv Biotechnol Exp Ther 3 (2): 116-121. DOI: 10.5455/jabet.2020.d115.

Fragoso JMV, Levi T, Oliveira LFB, Luzar JB, Overman H, Read JM. 2016. Line transect surveys underdetect terrestrial mammals: Implications for the sustainability of subsistence hunting. Plos One 11 (4): e0152659. DOI: 10.1371/ journal.pone.0152659.

Gordon MS, Schmidt-Nielsen K, Kelly HM. 1961. Osmotic regulation in the Crab-eating frog (*Rana cancrivora*). J Exp Biol 38 (3): 659-678. DOI: 10.1242/jeb.38.3.659.

Gotelli NJ, Chao A. 2013. Measuring and estimating species richness, species diversity, and biotic similarity from sampling data. In: Levin SA (eds). Encyclopedia of Biodiversity. Second Edition. Volume 5. Academic Press, Waltham, Massachusetts, USA.

Grismer L, Quah E. 2019. An updated and annotated checklist of the lizards of Peninsular Malaysia, Singapore, and their adjacent archipelagos. Zootaxa 4545 (2): 230. DOI: 10.11646/zootaxa.4545.2.4.

Hammond SA, Nelson CJ, Helbing CC. 2015. Environmental influences on the epigenomes of herpetofauna and fish. Biochem Cell Biol 94 (2): 95-100. DOI: 10.1139/bcb-2015-0111.

Harden LA, Midway SR, Williard AS. 2015. The blood biochemistry of overwintering diamondback terrapins (*Malaclemys terrapin*). J Exp Mar Biol Ecol 466: 34-41. DOI: 10.1016/j.jembe.2015.01.017.

Hopkins GR, Brodie Jr ED. 2015. Occurrence of amphibians in saline habitats: A review and evolutionary perspective. Herpetol Monogr 29 (1): 1-27. DOI: 10.1655/HERPMONOGRAPHS-D-14-00006.

Hutchens S, DePerno C. 2009. Measuring species diversity to determine land-use effects on reptile and amphibian assemblages. Amphib-Reptil 30: 81-88. DOI: 10.1163/156853809787392739.

Igulu MM, Nagelkerken I, Dorenbosch M, Grol MGG, Harborne AR, Kimirei IA, Mumby PJ, Olds AD, Mgaya YD. 2014. Mangrove habitat use by juvenile reef fish: Meta-analysis reveals that tidal regime matters more than biogeographic region. Plos One 9 (12): e114715. DOI: 10.1371/journal.pone.0114715.

Jaafar I, Awang Z, Shahrudin S, Shahrul AMS, Ibrahim NH, Hurzaid A, Rahim NDA, Min MA, Ismail A. 2012. Checklist of the herpetofauna of Bukit Peranginan Forest Reserve, Kedah, Malaysia. Sains Malays 41 (6): 691-696.

Jalal KCA, Ahmad ZM, Akbar JB, Kamaruzzaman YB, Shahbudin S. 2012. Diversity and community composition of fishes in tropical estuary Pahang Malaysia. Pak J Zool 44: 181-187.

Kearney BD, Pell RJ, Byrne PG, Reina RD. 2014. Anuran larval developmental plasticity and survival in response to variable salinity of ecologically relevant timing and magnitude. J Exp Zool Ecol Genet Physiol 321: 541-549. DOI: 10.1002/jez.1887.

Kellner KF, Swihart RK. 2014. Accounting for imperfect detection in ecology: A quantitative review. Plos One 9 (10): e111436. DOI: 10.1371/journal.pone.0111436.

Kloskowski J, Nieoczym M, Stryjevki R. 2020. Between-habitat distributions of pond tadpoles and their insect predators in response to fish presence. Hydrobiol 847: 1343-1356. DOI: 10.1007/s10750-020-04190-5.

Kodikara KAS, Jayatissa LP, Huxham M, Dahdouh-Guebas F. 2018. The effects of salinity on growth and survival of mangrove seedlings changes with age. Acta Bot Bras 32 (1): 37-46. DOI: 10.1590/0102-33062017abb0100.

Lee SY, Primavera JH, Dahdouh-Guebas F, Mckee K, Bosirem JO, Cannicci S, Diele K, Fromard F, Koedam N, Marchand C, Mendelssohn I, Mukherjee N, Record S. 2014. Ecological role and services of tropical mangrove ecosystems: A reassessment. Glob Ecol Biogeogr 23 (7): 726-743. DOI: 10.1111/geb.12155.

Lei J, Yusof NS, Wu NC, Zhang Z, Booth DT. 2021. The burrowing ecology of a tropical lizard (*Leiolepis belliana*). Herpetol 77 (1): 37-44. DOI: 10.1655/0018-0831-77.1.37.

Li J, Wang X, Lan T, Lu Y, Hong M, Ding L, Wang L. 2022. CDK5/NFAT5-Regulated transporters involved in osmoregulation in *Fejervarya cancrivora*. Biology 11: 858. DOI: 10.3390/ biology11060858.

MacKenzie DI, Nichols JD, Royle JA, Bailey LL, Hines JE. 2006. Occupancy Estimation and Modeling; Inferring Patterns and Dynamics of Species Occurrence. Elsevier, San Diego, California.

McCann S, Greenlees MJ, Newell D, Shine R. 2014. Rapid acclimation to cold allows the cane toad to invade montane areas within its Australian range. Funct Ecol 28: 1166-1174. DOI: 10.1111/1365-2435.12255.

Moreira LFB, Knauth DS, Maltchik L. 2015. Intermittently closed estuaries and tadpole communities: Influence of artificial breaching. Estuar Coasts 38 (3): 979-987. DOI: 10.1007/s12237-014-9852-z.

Munisamy B, Kamaruddin KN, Kulaimi NAM, Mohamed KA, Ithnin H, Rovie-Ryan JJ, Topani R, Manickam S. 2020. A revised and updated checklist of herpetofauna of Tasek Bera Ramsar Site, Pahang, Malaysia. J Wildl Parks 35: 93-103.

Muro-Torres VM, Soto-Jiménez MF, Green L, Quintero J, Amezcua F. 2019. Food web structure of a subtropical coastal lagoon. Aquat Ecol 53: 407-430. DOI: 10.1007/s10452-019-09698-0.

MyBis. 2022. Malaysia Biodiversity Information System. www.mybis.gov.my (Accessed 17 October 2022).

Nasreen. 2022. Ocean salinity. Intl J Mod Tr Sci Technol 8 (1): 296-302.

Nazir KNK, Mohd YZ. 2007. Sustainable forest management in Peninsular Malaysia. In: Chua LSL, Kirton LG, Saw LG (eds). Status of Biological Diversity in Malaysia and Threat Assessment of Plant Species in Malaysia. Forest Research Institute Malaysia, Kepong.

Norhayati A. 2017. Frogs and Toads of Malaysia: Malaysia Biodiversity Information System (MyBIS). UKM, Bangi, Malaysia.

Norhayati A, Chan KO, Daicus B, Samat A, Grismer LL, Mohd IA. 2010. Potential biosites of significant importance in Langkawi Geopark: Terrestrial vertebrate fauna. Plan Malays 9 (1): 103-120. DOI: 10.21837/pmjournal. v1. i1.93.

Nowak EM, Schuett GW, Theimer TC, Sisk TD, Nishikawa KC. 2015. Does short-term provisioning of resources to prey result in behavioral shifts by rattlesnakes? J Wildl Manag 79: 357-372. DOI: 10.1002/JWMG.847.

Nur AMI, Azhari M, Shukor MN, Aisah MN, Ahmad A, Norhayati A, Grismer LL, Nor ANA, Norshaqinah A. 2017. Species composition of amphibians and reptiles in Tembat Forest Reserve, Hulu Terengganu, Terengganu, Peninsular Malaysia. Malays Appl Biol 46: 119-129.

Omar H, Misman MA, Linggok V. 2018. Characterizing and monitoring of mangroves in Malaysia using Landsat-based spatial-spectral variability. IOP Conf Ser Earth Environ Sci 169 (1): 012037. DOI: 10.1088/1755-1315/169/1/012037.

Rong L, Hui Y, Fuqing B, Tingli X, Xinchuang C, Xinsheng C. 2020. Application of species cumulative curve in the investigation of swimming organisms in the fishway of Cao'e river. IOP Conf Ser: Earth Environ Sci 568: 012034. DOI: 10.1088/1755-1315/568/1/012034.

Rutland CS, Cigler P, Kubale V. 2019. Reptilian skin and its special histological structures. In: Rutland CS, Cigler P, Kubale V (eds). Veterinary Anatomy and Physiology. Books on Demand, London.

Schneck F, Melo AS. 2010. Reliable sample sizes for estimating similarity among macroinvertebrate assemblages in tropical streams. Intl J Limnol 46: 93-100. DOI: 10.1051/limn/2010013.

Shaari H, Mohd-Nasir Q, Pan HJ, Mohamed CAR, Yusoof AH, Wan Khalik WMA, Naim W, Setiawan, RY, Anthony EJ. 2020. Sedimentation and sediment geochemistry in a tropical mangrove channel meander, Sungai Kerteh, Peninsular Malaysia. Prog Earth Planet Sci 7 (45): 1-11. DOI: 10.1186/s40645-020-00362-y.

Shao Y, Wang LJ, Zhong L. 2015. Transcriptomes reveal the genetic mechanisms underlying ionic regulatory adaptations to salt in the crab-eating frog. Sci Rep 5: 17551. DOI: 10.1038/srep17551.

Shine R, Koenig J. 2001. Snakes in the garden: An analysis of reptiles "rescued" by community-based wildlife carers. Biol Conserv 102: 271-283. DOI: 10.1016/S0006-3207(01)00102-1.

Siti MMN, Jaafar M, Nik JNMS, Redzuan NS, Wan BWO, Deraman MY, Azli SNSN, Shehrom NA, Mahyudin A, Bahari NA, Zukafli NN, Jaafar NF, Ma'ad SNS, Zamri MIM, Amirudin A, Abdullah NA, Zakaria N. 2022. Dataset of physico-chemical water parameters, phytoplankton, flora, fauna in mangrove ecosystem at Sungai Kertih, Terengganu, Malaysia. Data Br 42: 108096. DOI: 10.1016/j.dib.2022.108096.

Sukri NS, Jothivel J, Ghazi RM, Shafiee, Ismail NS, Yaacob SH, Kedri FK, Zakaria M. 2017. Determination of heavy metals in water samples from Sungai Kerteh and Sungai Paka, Terengganu, Malaysia. J Trop Resour Sustain Sci 5 (2): 74-78. DOI: 10.47253/jtrss. v5i2.597.

Szaro RC, King RM. 1990. Sampling intensity and species richness: Effects on delineating southwestern riparian plant communities. For Ecol Manag 33: 335-349. DOI: 0.1016/0378-1127(90)90202-M.

Talib AAA, Hambali K, Ngadi E, Haiqal MS. 2020. A preliminary study at Delta Tumpat Mangrove Forest. J Wildl Parks 35: 27-37.

Uetz P, Stylianou A. 2018. The original descriptions of reptiles and their subspecies. Zootaxa 4375: 257-264. DOI: 10.11646/zootaxa.4375.2.5.

Warui MW, Manohar S, Obade P. 2020. Current status, utilization, succession and zonation of mangrove ecosystem along Mida Creek, Coast Province, Kenya. Bonorowo Wetl 10: 32-43. DOI: 10.13057/bonorowo/w10010.

Weiss S, Xu ZZ, Peddada S, Amir A, Bittinger K, Gonzalez A. 2017. Normalization and microbial differential abundance strategies depend upon data characteristics. Microbiome 5: 27. DOI: 10.1186/s40168-017-0237-y.

Wijethunga U, Greenlees M, Shine R. 2016. Living up to its name? The effect of salinity on development, growth, and phenotype of the "marine" toad (*Rhinella marina*). J Comp Physiol B 186: 205-213. DOI: 10.1007/s00360-015-0944-2.

Willes AD. 2019. Rarefaction, alpha diversity, and statistics. Front Microb 10: 2407. DOI: 10.3389/fmicb.2019.02407.

Wolfe AK, Bateman PW, Fleming PA. 2018. Does urbanization influence the diet of a large snake? Curr Zool 64 (3): 311-318. DOI: 10.1093/cz/zox039.

Wright P, Anderson P, Wong S, Fick N, Wong WP, Ip YK. 2004. The crab-eating frog, *Rana cancrivora*, up-regulates hepatic carbamoyl phosphate synthetase I activity and tissue osmolyte levels in response to increased salinity. J Exp Zool Part A Comp Exp Biol 301 (7): 559-68. DOI: 10.1002/jez.a.54.

Wu CS, Yang WK, Lee TH, Gomez-Mestre I, Kam YC. 2014. Salinity acclimation enhances salinity tolerance in tadpoles living in brackish water through increased Na^+, K^+-ATPase expression. J Exp Zool Ecol Genet Physiol 321 (1): 57-64. DOI: 10.1002/jez.1837.