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Checklist of herpetofauna in wetland ecosystems, Muara Angke Wildlife Reserve, Indonesia

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ABSTRAK

Urbanisasi menyebabkan kerusakan pada lingkungan alami dan mengancam kawasan konservasi seperti Suaka Margasatwa Muara Angke (SMMA). Urbanisasi berdampak negatif pada keanekaragaman jenis, termasuk peningkatan jenis asing terutama herpetofauna di SMMA yang berperan menjadi indikator kesehatan lingkungan. Penelitian ini bertujuan untuk mendata kembali keberadaan herpetofauna menggunakan metode *Visual Encounter Survey* (VES) dan *Acoustic Encounter Survey* (AES) yang dapat menunjukkan adanya perubahan signifikan dalam keberadaan jenis selama enam tahun terakhir. Hasil yang didapatkan yaitu, dari 28 jenis yang teridentifikasi sebelumnya, hanya 18 jenis ditemukan dalam penelitian terbaru. Jumlah atau keragaman jenis herpetofauna yang terdata dapat dipengaruhi oleh faktor antropogenik, seperti adanya perumahan, jalan raya, dan suhu perkotaan. Jalur yang tidak terpengaruh oleh gangguan manusia menunjukkan keragaman jenis yang lebih tinggi dibandingkan jalur yang terpengaruh seperti pada jalur *boardwalk*. Jalur dengan habitat alami yang relatif tidak terganggu mencatatkan keragaman tertinggi, sementara jalur lain seperti pada jalur sungai Angke dan tanggul mengalami penurunan.

Kata kunci: amfibi, herpetofauna, keanekaragaman, persebaran, reptil

ABSTRACT

Urbanization causes damage to the natural environment and threatens conservation areas such as Muara Angke Wildlife Reserve. Urbanization has a negative impact on species diversity, including an increase in alien species, especially herpetofauna in Muara Angke Wildlife Reserve which acts as an indicator of environmental health. This study aims to record the presence of herpetofauna using Visual Encounter Survey (VES) and Acoustic Encounter Survey (AES) methods that can show significant changes in species presence over the past six years. The results showed that, of the 28 species previously identified, only 18 species were found in the most recent study. The number or diversity of herpetofauna species recorded can be affected by anthropogenic factors, such as housing, roads, and urban temperatures. Trails unaffected by human disturbance showed higher species diversity than affected trails such as the boardwalk. Paths with relatively undisturbed natural habitats recorded the highest diversity, while other paths such as the Angke river and embankment paths decreased.

Keywords: Amphibians, herpetofauna, diversity, distribution, reptiles

INTRODUCTION

Urbanization is one of the greatest threats to the survival of animals and plants and has an indirect impact on biodiversity. Urbanization can reduce biodiversity and alter the structure of local ecosystems, ultimately affecting the natural balance and ecosystem function (Lasaiba, 2024). Significant turnover patterns can occur as species that are less tolerant to urban environments are replaced by those that are more tolerant (Larcher, 2003). Furthermore, many non-native and invasive species thrive in urban environments, evident in their extremely high densities, with various negative consequences for humans and ecosystems (Haag-Wackernagell & Moch, 2004; Shochat et al., 2010).

Species that depend on specialized habitats are particularly vulnerable to these changes, making their existence increasingly threatened in urban areas. As a result, biodiversity declines and ecosystem stability becomes less stable. One type of biodiversity impacted by urbanization is herpetofauna. Amphibians and reptiles (herpetofauna) are two of the most vulnerable vertebrate groups today, both experiencing population declines worldwide (Gibbons et al., 2000; Stuart et al., 2004) due to several factors such as urbanization, habitat loss (Mayani-Parás et al., 2019), climate change (Bickford et al., 2010), and invasive species (Petreanu, 2023). Therefore, urbanization is a crucial issue that requires attention.

Urbanization causes numerous environmental changes, often driven by human activities (Ramalho et al., 2012), which can degrade the natural habitats available to herpetofauna. Conservation areas located in urban areas, such as the Muara Angke Wildlife Reserve are inevitably impacted annually by urban pressure, both directly and indirectly (Dewantoro et al., 2015). In previous years, Muara Angke Wildlife Reserve was impacted by water hyacinth invasions, and this continues to impact the herpetofauna there. Muara Angke Wildlife Reserve is also a location impacted by invasive and introduced species caused by humans. Many residents around Muara Angke Wildlife Reserve have a tradition of releasing animals back into the wild, known as Fang Sheng. Herpetofauna are often released, but sometimes the animals are not suited to their natural habitat and are not native species, impacting or even altering the Muara Angke Wildlife Reserve ecosystem.

Muara Angke Wildlife Reserve is the smallest wildlife sanctuary in Indonesia, covering an area of 25.02 hectares, so its biocapacity is considered low. Its environment, consisting of mangrove vegetation and being a nature reserve with a wetland ecosystem, allows for the utilization of this ecosystem and vegetation by herpetofauna, especially in urban areas. Herpetofauna are part of the food chain and play a crucial role in supporting biodiversity. The presence of various herpetofauna species serves as an environmental indicator that helps measure ecosystem balance in a region (Subeno, 2018; Arroyyan et al., 2020). A specific biodiversity checklist for herpetofauna is not yet available in Muara Angke Wildlife Reserve, and the impact of urbanization pressures can lead to a reduction in herpetofauna species diversity or even an increase in non-native species in Muara Angke Wildlife Reserve. Therefore, herpetofauna data updates are needed to assess changes in population, distribution, and species diversity in the region.

METHODOLOGY

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This study was conducted for 25 days from July to September 2024 at Muara Angke Wildlife Reserve, North Jakarta. Tools used included amphibian and reptile identification books, cameras, stationery, head lamp, hand scoon, snake hook, and GPS. Herpetofauna data collection methods included Visual Encounter Survey (VES), Acoustic Encounter Survey (AES) and accidental sampling with surveys conducted in the morning (07.00-10.00 WIB) and evening (19.00-22.00 WIB). The length of the transect line was 500-1000 m with a distance of 150 m between lines. The observation location was determined purposively based on the possibility of herpetofauna presence in three transect that is Angke River, boardwalk and canal, and boundary embankment.

FIGURE 1. Map of herpetofauna observation path in Muara Angke Wildlife Reserve.

In species identification, each species was documented and identified using the identification key books "Panduan Bergambar Identifikasi Amfibi Jawa Barat" by Mirza D. Kusrini and "Panduan Bergambar Ular Jawa" by Nathan Rusli. Results that could not be identified directly were sampled and documented for further examination by more experts. Data analysis was carried out descriptively quantitatively, by comparing baseline data from BKSDA Jakarta with this research data. The distribution of herpetofauna was mapped using QGIS, and species diversity was calculated using the Shannon-Wiener index. The Shannon-Wiener diversity index was calculated based on research by Majid et al. (2025), with the formula:

$$H' = -\sum pi \ ln \ (pi)$$

Description:
pi = (ni/N)
H' = Diversity Index
ni = Number of Individuals of Species i
N = Total Number of Individuals of All Species

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The Shannon-Wiener diversity index is divided into 3 criteria, namely: H' < 1 means low diversity index, 1 ≤ H' ≤ 3 medium diversity index and if H' > 3 high diversity index.

RESULTS AND DISCUSSION

Changes in Herpetofauna List in Muara Angke Wildlife Reserve

The herpetofauna observed in Muara Angke Wildlife Reserve consists of 28 species, including 3 amphibians and 25 reptiles (Table 1). In the last six years, the presence of herpetofauna has shown changes in terms of the discovery of new species and the decline in the population of some existing species.

TABLE 1. Presence of herpetofauna in Muara Angke Wildlife Reserve

No.	Scientific Name	Species Presence			
		2018	2019	2023	2024
1	*Duttaphrynus melanosticus*	-	-	-	✓
2	*Fejervarya cancrivora*	-	✓	✓	✓
3	*Hylarana erythraea*	-	-	✓	✓
4	*Calotes versicolor*	✓	✓	✓	✓
5	*Crocodylus porosus*	✓	✓	✓	✓
6	*Draco volans*	-	✓	-	-
7	*Gehyra mutilata*	✓	-	✓	✓
8	*Gekko gecko*	✓	✓	✓	✓
9	*Hemidactylus frenatus*	✓	✓	✓	✓
10	*Hemidactylus garnotii*	✓	-	-	-
11	*Hemidactylus platyurus*	✓	✓	✓	✓
12	*Eutropis multifasciata*	✓	✓	✓	✓
13	*Subdoluseps bowringii*	-	-	-	✓
14	*Varanus salvator*	✓	✓	✓	✓
15	*Ahaetulla prasina*	✓	✓	✓	-
16	*Ahaetulla rufusoculara*	-	-	✓	✓
17	*Boiga dendrophila*	✓	-	-	-
18	*Cylindrophis ruffus*	✓	-	-	-
19	*Dendrelaphis pictus*	✓	✓	✓	✓
20	*Enhydris enhydris*	-	-	✓	✓
21	*Homalopsis buccata*	✓	-	✓	✓
22	*Lycodon capucinus*	-	-	✓	-
23	*Malayopython reticulatus*	✓	-	-	✓
24	*Naja sputatrix*	✓	-	-	-
25	*Ptyas korros*	✓	-	-	-
26	*Cuora amboinensis*	✓	-	-	✓
27	*Pelodiscus sinensis*	-	-	✓	-
28	*Siebenrockiella crassicollis*	-	-	✓	-
	Total	**18**	**11**	**18**	**18**

Description:

✓ : Found; - : Not found

*data obtained from Jakarta BKSDA (2018); collaboration BKSDA Jakarta & Yayasan Konservasi Alam Nusantara (YKAN) (2019 & 2023).

Although the Table 1 for 2018, 2023 and 2024 show no change, there are differences in species encounters between years. There are herpetofauna species that have

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been recorded consecutively, some have not been recorded since the last year, and there are species that have been newly recorded or detected. This shows that there is potential in Muara Angke Wildlife Reserve that there may be herpetofauna species that have not been recorded and is a major bridge to facilitate the movement of animals from one habitat to another.

Duttaphrynus melanostictus and *Subdoluseps bowringii* are species that were only recorded in 2024, it is suspected that these species have indeed been present in Muara Angke Wildlife Reserve but were only reported in 2024 due to the lack of monitoring of herpetofauna on the route and sampling effort during monitoring. In addition, it is possible that this species has migrated to Muara Angke Wildlife Reserve due to suitable habitat and sufficient resources. Animals often move in search of better resources. Their movements are influenced by the quality of the environment and the distribution of available resources. For example, some species tend to prefer large, resource-rich areas to small, inadequate sites, suggesting that they strategically choose locations based on environmental conditions (Potts et al., 2014).

Hylarana erythraea and *Enhydris enhydris* appeared for the first time in 2023 and were also found in 2024, indicating that both species still survive in Muara Angke Wildlife Reserve. In addition, there is the species *Fejervarya cancrivora* that can live in various habitats such as rice fields, mangroves, and tidal zones, which Muara Angke Wildlife Reserve is certainly one of the suitable places that can provide important resources for its survival. Complex habitats can increase the survival of younger individuals, thereby increasing population growth. The large number of species provides protection from predation and competition (Edeline et al., 2025).

FIGURE 2. *Ahaetulla rufusoculara* in Muara Angke Wildlife Reserve

There was one snake species in the genus *Ahaetulla* found in this study. Morphologically, it is similar to *Ahaetulla rufusoculara* but based on previous data, *Ahaetulla prasina* is native to Muara Angke Wildlife Reserve. More detailed identification is important in order to confirm whether this species is *A. rufusoculara* or not. If it is indeed *A. rufusoculara*, then conservation considerations need to be made considering that this species is quite abundant in Muara Angke Wildlife Reserve. *A. rufusoculara* is endemic to Vietnam and was discovered in 2021 as a new species of the genus *Ahaetulla* (Lam et al., 2021). Further research needs to be conducted on whether or not *A. rufusoculara* is a species whose distribution extends to Indonesia. However, it

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can also be suspected that *A. rufusoculara* is a species brought by humans or introduction and is able to compete with the native species in Muara Angke Wildlife Reserve, namely *A. prasina*. Monitoring and risk assessment as well as community education need to be carried out as initial steps in protecting the ecosystem and native species in Muara Angke Wildlife Reserve.

Calotes versicolor, *Crocodylus porosus, Dendrelaphis pictus, Varanus salvator, Eutropis multifasciata, Hemidactylus fasciatus, Hemidactylus platyurus*, and *Gekko gecko* showed consistent presence from the last 6 years, while *Homalopsis buccata*, *Fejervarya cancrivora* and *Gehyra mutilata* may have gone unrecorded due to certain factors. Such as good camouflage, avoidance behavior, lack of monitoring and environmental factors. *C. versicolor* is one of the introduced herpetofauna and has become an invasive species in Muara Angke Wildlife Reserve because it has replaced the native species, *Bronchochela jubata*, due to its high adaptation, especially in urban areas. This could indicate that the species may have a stable habitat and environmental conditions that support its existence in Muara Angke Wildlife Reserve.

There are several factors that cause animals to settle in an area such as roads and urban development (artificial barriers) that can become habitat boundaries for animals. Artificial barriers can hinder their movement in successfully crossing to other locations compared to natural barriers. Natural barriers, such as forest edges, can also restrict animal movement, although with less impact than artificial barriers (Robert & Cassady, 2004). Each animal species perceives the environment in a different way, which influences its habitat choice (habitat preference). Animals have certain behaviors on the move that are related to habitat selection, such as searching for food or nesting sites (Figure 3). This can make them unwilling to explore new areas (McClintock & Lander, 2024. A species may not recognize or utilize existing habitats due to its limited ability to explore an area (Dyck, 2012). The existence of animals usually depends on certain resources in their habitat, so some animals rarely explore new places, especially when environmental conditions change (Cox, 2010).

FIGURE 3. *Varanus salvator* nesting underground in Muara Angke Wildlife Reserve

Cuora amboinensis, Pelodiscus sinensis, and *Siebenrockiella crassicollis* are non-native species found in the study. *C. amboinensis* was found in large numbers and is thought to have settled in Muara Angke Wildlife Reserve. Based on The Reptile Database, *C. amboinensis* and *S. crassicollis* have a distribution up to Java, but the place where they live is not in accordance with their natural habitat, so it is suspected that both species are

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deliberately released animals. The three species were released but were thought to be unable to survive because Muara Angke Wildlife Reserve has brackish water or a type of water that has a lower salinity than the average salinity of normal sea water (Artiningsih & Kasmuddin, 2021) while the three species live in freshwater, so the species were only found in the year they were released. Dispersal suggests that the greater the distance an animal is from its native habitat, the less likely it is to successfully move (Kitching, 1971). Although there are many challenges for animals when moving to new habitats, some species can adapt to fragmented environments, which can help improve their survival and movement under the right conditions (Terhune et al., 2010).

Draco volans, Naja sputatrix, Ptyas korros, Boiga dendrophila, Hemydactylus garnotii, Cylindrophis ruffus, and *Lycodon capucinus* were only found once in the last 6 years, which may indicate a population decline due to anthropogenic effects or competition by superior species that do not support their existence and in subsequent years these species have not been found again. One anthropogenic effect is the presence of invasive species that enter an area. Invasive species brought by humans can disrupt the flow of nutrients and cause problems in the food chain, which in turn exacerbates the decline of native biodiversity (Clout & Russell, 2008).

According to Wagner et al. (2021), ongoing mass extinctions, due to human activities and invasive species, have reduced terrestrial vertebrate populations by one-third in the last hundred years. Although invasive species are often considered detrimental, some studies have shown that they can help restore native species (McDonald et al., 2007). In addition, habitat loss due to urbanization and land expansion leads to the destruction of natural habitats, which has severe impacts on local flora and fauna (Sponsel, 2013). Anthropogenic effects such as pollution, noise levels from human activities and artificial light can also affect animal behavior and physiology, which can have a major impact on ecosystems (Halfwerk & Jerem, 2021).

Although these herpetofauna species are currently declared lost, there is still a possibility of being found again if further monitoring and reporting is carried out. As in the species *Malayopyhon reticulatus*, which has been reported again since the last 3 years. According to Loar et al. (2025), *M. reticulatus* has high habitat flexibility, enabling it to inhabit various ecosystem types, including primary forests, secondary forests, oil palm plantations, and wetlands/swamps. This ability is supported by its semi-aquatic nature with good swimming ability and opportunistic foraging strategy, which allows this species to disperse into new areas, including anthropogenic areas such as plantations, agricultural lands, and human settlements. This may have happened because in 2024, water hyacinth in Muara Angke Wildlife Reserve was reduced so that space and food increased and animals began to arrive and stay. Of the total number of species (28 species), 18 or 64.2% of all species observed were species that had previously been recorded in Muara Angke Wildlife Reserve. Species that were not found in 2024 were due to a lack of sampling effort and for species introduced in previous years, they could not survive long in Muara Angke Wildlife Reserve and ended up becoming extinct due to their inability to adapt.

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Distribution of Herpetofauna in Muara Angke Wildlife Reserve

Based on the results of this study, 18 species were successfully re-recorded in the Muara Angke Wildlife Reserve, 16 native species (3 amphibians and 13 reptiles) and two introduced reptile species.

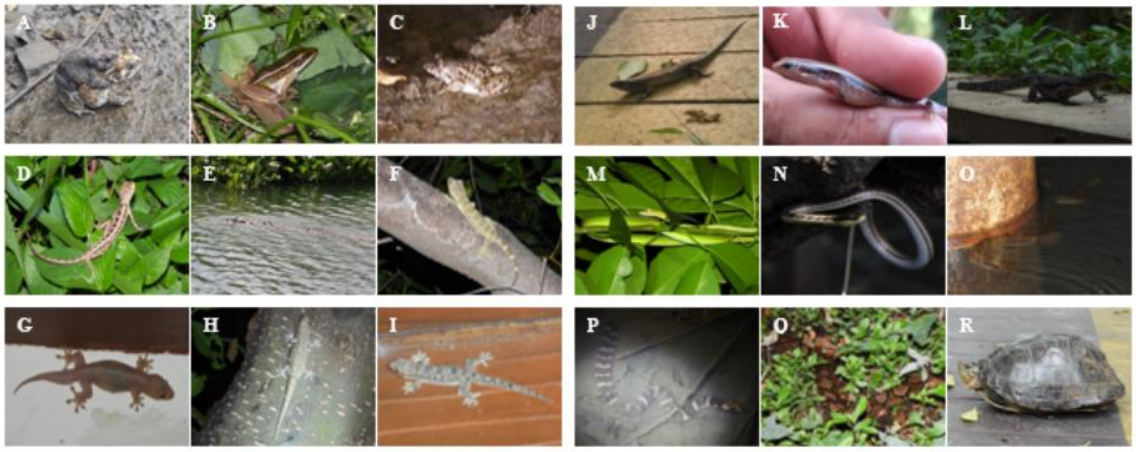

FIGURE 4. Herpetofauna found in Muara Angke Wildlife Reserve. **A.** *Duttaphrynus melanostictus*. **B.** *Fejervarya cancrivora*. **C.** *Hylarana erythraea*. **D.** *Crocodylus posorus*. **E.** *Calotes versicolor*. **F.** *Gekko gecko*. **G.** *Gehyra mutilata*. **H.** *Hemidactylus frenatus*. **I.** *Hemidactylus platyurus*. **J.** *Eutropis multifasciata*. **K.** *Subdoluseps bowringii*. **L.** *Varanus salvator*. **M.** *Ahaetulla rufusoculara*. **N.** *Dendrelaphis pictus*. **O.** *Enhydris enhydris*. **P.** *Homalopsis buccata*. **Q.** *Malayapython reticulatus*. **R.** *Cuora amboinensis*.

TABLE 2. List of herpetofauna species found in Muara Angke Wildlife Reserve (2024), with a description of the conservation status of each species.

Famili	Scientific Name	Local Name	Conservation Status		
			IUCN	CITES	Protected
Bufonidae	*Duttaphrynus melanosticus*	Kodok buduk	LC	-	No
Dicroglossidae	*Fejervarya cancrivora*	Katak sawah	LC	-	No
Ranidae	*Hylarana erythraea*	Kongkang gading	LC	-	No
Agamidae	*Calotes versicolor*	Bunglon taman	LC	-	No
Crocodylidae	*Crocodylus porosus*	Buaya muara	LC	II	Yes
Gekkonidae	*Gehyra mutilata*	Cecak gula	LC	-	No
	Gekko gecko	Tokek rumah	LC	II	No
	Hemidactylus frenatus	Cecak tembok	LC	-	No
	Hemidactylus platyurus	Cecak kayu	LC	-	No
Scincidae	*Eutropis multifasciata*	Kadal kebun	LC	-	No
	Subdoluseps bowringii	Kadal-pasir Bowring	LC	-	No
Varanidae	*Varanus salvator*	Biawak air	LC	II	No
Colubridae	*Ahaetulla rufusoculara*	Ular-pucuk mata-merah	NE	-	No
	Dendrelaphis pictus	Ular tampar	LC	-	No
Homalopsidae	*Enhydris enhydris*	Ular air pelangi	LC	-	No
	Homalopsis buccata	Ular kadut belang	LC	-	No
Pythonidae	*Malayopython reticulatus*	Ular sanca batik	LC	II	No
Testudinae	*Cuora amboinensis*	Kura-kura ambon	EN	II	No

Description:
Categories for IUCN: CR - *Critically Endangered*, EN - *Endangered*, VU - *Vulnerable*, NT - *Near Threatened*, LC - *Least Concern*, DD - *Data Deficient*, NE - *Not Evaluated*.
Categories for CITES: Appendix I (I), Appendix II (II), Appendix III (III).
Protected category: Protected (Yes). Not protected (No). Based on Ministry of Environment and Forestry Regulation No. 106/2018.

Two introduced species found in Muara Angke Wildlife Reserve are *Ahaetulla rufusoculara* and *Calotes versicolor*. In addition, there is one introduced and invasive species, namely *C. versicolor*. Most of the IUCN conservation status of herpetofauna

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species are Least Concern (LC) and Not Evaluated (NE) which means they are listed as species of no concern because these species are very widespread in their native areas, can survive in very high densities in anthropogenic habitats, and do not experience serious threats.

Species diversity and addition is also influenced by human factors such as traditions, one of which is Fang Shen. Fang Shen is a tradition of releasing living things into their habitat, this tradition is often carried out in the Muara Angke Wildlife Reserve area. Some of the herpetofauna species recorded and released in the area during this study were *Cuora amboinensis, Fejervarya cancrivora*, and *Malayopython reticulatus.*

Only one reptile was determined to have Endangered (EN) conservation status and Appendix II CITES, namely *C. amboinensis*. Based on IUCN data, threatened conservation status is due to the large numbers of this species being extracted from the wild for consumption, traditional Chinese medicine, and the pet trade (Cota et al., 2020). However, *C. amboinensis* in Muara Angke Wildlife Reserve is the result of human introduction, this species is able to adapt and live long enough to be found again. In addition, this observation also found 1 protected reptile species according to the Minister of Environment and Forestry Regulation No. 106/2018, namely *Crocodylus porosus*. Meanwhile, based on CITES, there are 5 species that are in the appendix II category, namely *Crocodylus porosus*, *Gekko gecko*, *Varanus salvator, Malayopython reticulatus, Cuora amboinensis,* which means that these species can be threatened if trade is not controlled (Jenkins, 2013) (Table 2). This proves that Muara Angke Wildlife Reserve is an important habitat for animals that are often traded, monitoring is needed to prevent excessive hunting and trade by humans.

FIGURE 5. A. Path 1 (Angke River); B. Path 3 (Boundary embankment); C. Path 2 (Left: Boardwalk; Right: Canal).

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In Muara Angke Wildlife Reserve, there are three trails that can be used to monitor wildlife, including herpetofauna. Path 1 is a river bordering a mangrove forest dominated by rattan plants, and residential housing (**FIGURE 5A**). Path 2 is a boardwalk that serves as a path between the mangrove forest and swampy waters and canals and around the information center building (**FIGURE 5C**). Path 3 is an embankment bordering a highway with bushes and trees **(FIGURE 5B**).

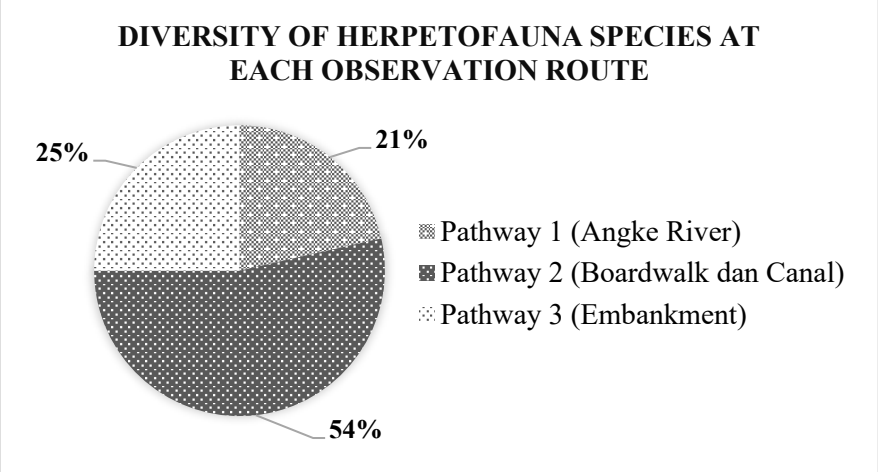

FIGURE 6. Percentage of herpetofauna species diversity in each observation route

The results of the analysis of species distribution on each observation path show that in path 1 there are as many as 6 species (21%). Path 2 found the most species, 15 species (54%) and path 3 there are 7 species (25%) (Figure 6). The difference in species distribution on each trail shows that trails that are not bordered by human disturbance such as close to housing and highways have a greater variety of herpetofauna species than trails that are directly adjacent. This proves that path 1, which is close to housing, may have experienced land cover degradation and increased noise, thus reducing species diversity. In contrast, path 2 showed the highest diversity because it has a natural habitat undisturbed by human activities, as well as exposure to artificial light and a more stable temperature. In addition, path 1 contains buildings that allow herpetofauna that can coexist with humans such as lizards to be present. Path 3, despite having trees, is still affected by its proximity to the highway, which increases noise and light pollution, reducing the number of species.

Path 2 has the most species because it is the only route with the lowest level of human disturbance and is a combination of diverse natural habitats, such as rivers, swamps, shrubs, and mangroves, which support species diversity (Tohir & Siregar, 2021). Based on research by Megantara et al. (2025), herpetofauna diversity can also be influenced by semi-natural vegetation at a broader spatial scale, while the area of water bodies affects reptile abundance at the plot scale and amphibian abundance at both the plot and landscape scales. In addition to the level of human disturbance, the distribution and reporting of herpetofauna are also largely determined by the availability of natural resources within the habitat, regardless of proximity to settlements or roads. Habitats located near settlements can still support high biodiversity if they provide sufficient food sources, safe breeding grounds, and warmth and shelter (Winchell et al., 2018).

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Noise adversely affects wildlife, including amphibians and reptiles, whose hearing range is very sensitive to low-frequency sounds, and they can be easily affected by noise in general. Reptiles are very sensitive to light as they can see different types of light better than many other animals. Light also has a big effect on reptile physiology. Light pollution can disrupt the way they search for food, their daily habits, and their ability to orient (Mancera & Phillips, 2023). In addition, herpetofauna will also face problems when temperatures increase. Species living in the tropics can be compromised by exposure above their ideal temperature range. Amphibians as ectothermic animals are particularly vulnerable to increased temperatures, which can cause significant physiological stress. In addition, temperature and rainfall patterns can also alter the type and form of plants, as well as the availability of food and shelter, all of which impact the relationship between predators and prey (Bhagarathi et al., 2024).

Human-induced changes can affect the environment and the way animals choose where to live, such as land cover change. Land cover change often increases habitat fragmentation, isolating herpetofauna populations and reducing opportunities for interaction. Some species may not be able to adapt quickly to these changes, putting them at risk of extinction (Greenwald et al., 2009). This can lead animals to select habitats that are unsuitable or unsuitable for them (Hollander et al., 2011; Schlaepfer et al., 2002).

One amphibian and two reptiles were found in all trails (Table 2). The amphibian species found in all trails was *Hylarana erythraea* while the reptile species were *Dendrelaphis pictus* and *Varanus salvator*. The three herpetofauna can live in disturbed and undisturbed habitats so they can be found in every path (Ong et al., 2022). This study found nine species that were only found in one observation path, namely *Duttaphrynus melanosticus, Fejervarya cancrivora, Crocodylus porosus, Gehyra mutilata*, *Hemidactylus platyurus, Enhydris enhydris, Homalopsis buccata, Malayopython reticulatus*, and *Cuora amboinensis* (path 1); *Calotes versicolor* and *Subdoluseps bowringii* (path 3).

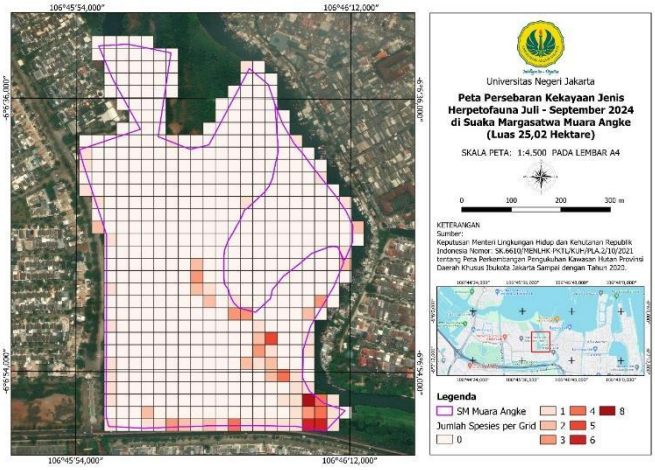

FIGURE 9. Heatmap of herpetofauna distribution in Muara Angke Wildlife Reserve

The presence of species and individuals of herpetofauna is marked in red. The darker the red color, the higher the presence of species and individuals. Many species have preferences for certain habitats, so the likelihood of a site being occupied by a

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species depends on the quality of the habitat at that site. However, habitats are not always fixed, they can change over time due to processes such as vegetation succession, human activities and environmental variation. These changes can affect species occurrence and survival rates related to occupancy dynamics, such as extinction and local colonization (McKenzie et al., 2011).

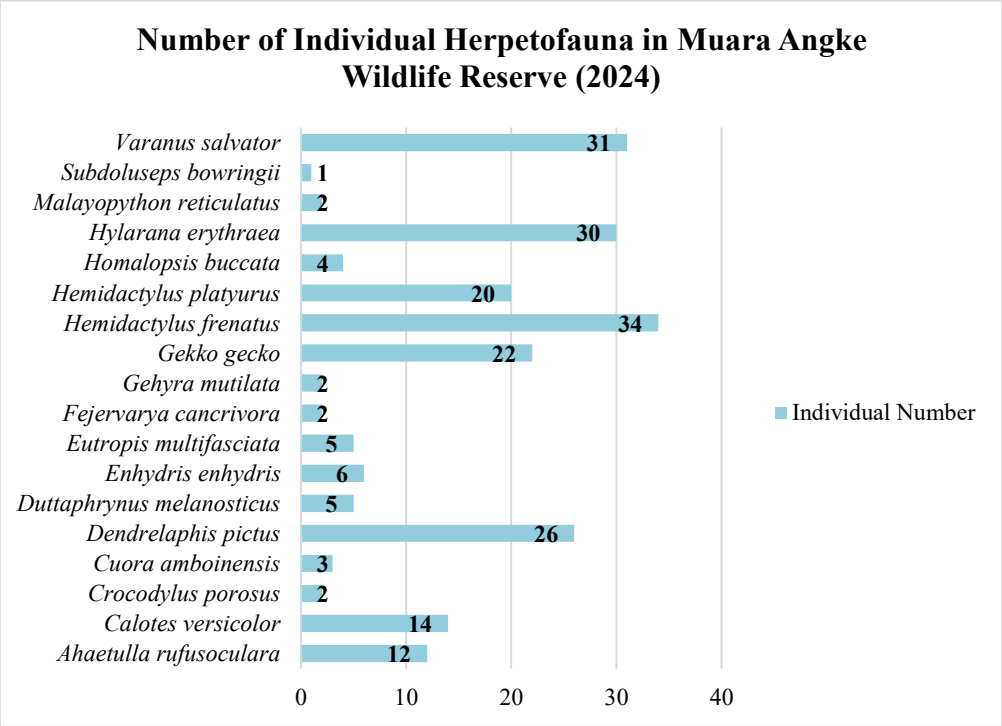

FIGURE 10. Number of Individual Herpetofauna in Muara Angke Wildlife Reserve

The distribution of herpetofauna recorded in the data shows variations in the number of individuals among the various species. Some species, such as *Hemidactylus frenatus*, *Varanus salvator*, *Hylarana erythraea*, and *Dendrelaphis pictus* show high numbers (Figure 10), reflecting their ability to adapt to various environments, including urban areas.. Based on research by Badli-sham et al. (2019), *H. frenatus* adapts to living in man-made environments and breeds in various areas, such as irrigation canals, water bodies, artificial ponds, and garbage debris, thus meeting the criteria for an urban species. *V. salvator* lives in water and has good adaptation to aquatic habitats (Briggs-Gonzalez et al. 2022), and *H. erythraea* can thrive in wetlands (Baharuddin et al. 2015), making Muara Angke Wildlife Reserve, which is a wetland ecosystem, an ideal habitat for both species. *D. pictus* is indeed commonly found in vegetated areas, urban areas, as well as rice fields, agricultural lands, and monoculture stands (Khoerunisa et al., 2021; Raharjo et al., 2015; Vogel et al., 2011). Meanwhile, species that are relatively few in number may be able to survive and adapt but not as well as species that show higher numbers. Many factors can influence species abundance, such as climate change, particularly in urban areas.

Climate change impacts herpetofauna through weather conditions, which can disrupt their reproductive processes and population numbers (Bhagarathi *et al*., 2024). In addition, land use changes such as land conversion for housing and road access, also

DOI: 10.21009/bioma.v21i1.53471

change their living environment, which impacts the diversity and distribution of these species (Tohir & Siregar, 2021). The distribution of herpetofauna is strongly influenced by factors such as climate, altitude, and land cover type, indicating that habitat quality strongly influences species diversity (Sasaki et al*.,* 2005).

Temperatures in Muara Angke Wildlife Reserve, located right in North Jakarta, are strongly influenced by urbanization and climate change, leading to the Urban Heat Island (UHI) effect. Research shows that average temperatures in the North Jakarta area can be much higher than in surrounding rural areas, with differences ranging from 1°C to 6°C (Belgaman et al., 2012). The average monthly temperature in North Jakarta is around 34.9°C, with peaks reaching 36.2°C (Maru & Ahmad, 2014). Meanwhile, the average nighttime temperature is around 28.3°C, with the highest temperature recorded at 29.0°C (Maru & Ahmad, 2014). Surface temperatures in urban areas can also reach 39.4°C, exacerbated by climate change (Lathiifunnisa et al., 2024).

Herpetofauna Diversity in Muara Angke Wildlife Reserve

The results of the herpetofauna study throughout the route identified 221 individuals, with a Shannon-Wiener diversity index of 3.01. The high herpetofauna diversity indicated by the Shannon-Wiener Index indicates that the Muara Angke Wildlife Sanctuary has many species evenly distributed throughout the community, thus increasing ecosystem stability (Dodd, 1992). The diversity index measures the variation of species within a community and reflects the level of diversity. The higher the index value in a community compared to other communities, the greater the species diversity in that community (Boontawee in Tohir et al., 2025). Habitat diversity significantly influences the diversity of fauna species. The more diverse the habitat structure, the higher the diversity of fauna species. This is due to the habitats ability to provide sufficient resources for survival and reproduction (Nasir et al., 2013). However, each route showed moderate diversity. This could be due to the location of an area and the diversity of existing habitats. Geographic location significantly influences the number of species that can live in a location (Subeno, 2018). If an area has been converted to residential land, the type of habitat dominated by that land use will significantly influence the herpetofauna species that are able to adapt to the change. Regional and habitat diversity are also important factors influencing the level of diversity. Furthermore, diversity is closely related to the number of species and individuals of each type that make up a community (Jeffries, 1997; Holvort, 1981).

Herpetofauna Species Description in Muara Angke Wildlife Reserve (2024)

Asian Common Toad, *Duttaphrynus melanostictus* (Schneider, 1799)

Snout pointed and many black bumps on its upper body. This species has a parietal groove and has a supraorbital groove connected to the supratympanic groove. The parotoid gland is elliptical. In the dull state, the toes and fingers are almost the same. The membrane on the toes exceeds half the fingers (Kusrini, 2013). Habitat in Muara Angke Wildlife Reserve: This species of frog is most commonly found in the canals around the information center and embankments.

DOI: 10.21009/bioma.v21i1.53471

Crab-eating Frog, *Fejervarya cancrivora* (Gravenhorst, 1829)

Size large, with folds or nodules that extend along the body axis. There is only one deep metatarsal nodule; the membrane always extends beyond the last subarticular nodule on the third and fifth fingers. Rough skin texture covered by elongated and thinned pustules or folds (Kusrini, 2013). Habitat in Muara Angke Wildlife Reserve: Commonly found in canal areas around information centers and embankments and tend to be near water.

Green Paddy Frog, *Hylarana erythraea* (Schlegel, 1837)

Medium-sized green frog has large, well-defined dorsalateral folds, ivory yellow in color, which are sometimes bordered by a black fringe. The head is long with a pointed snout, and the tympanum is clearly visible. The fingertips are widened and disc-shaped. The membrane reaches the base of the disk on the outer edge, on the first three toes and on the inner edge of the fifth finger. (Kusrini, 2013). Habitat in Muara Angke Wildlife Reserve: Commonly found in water hyacinth and apu-apu in brackish water on boardwalks and embankments.

Saltwater Crocodile, *Crocodylus porosus* Schneider, 1801

Head large; snout thick; a pair of ridges extending from the eye sockets to the center of the snout; scales on the back are more oval than those of other crocodiles. Juvenile crocodiles are brighter in color than adults, with black stripes, spots or blotches on a pale yellow or gray background; adults turn olive gray, with less contrast (Das, 2010). Habitat in Muara Angke Wildlife Reserve: Found in brackish waters but rarely appears.

Oriental Garden Lizard, *Calotes versicolor* (Daudin, 1802)

Body sturdy, solid; head rather large, especially in adult males; scales on the body pointing backwards and upwards; no antehumeral folds or pits in front of the shoulders. The color is variable and also fickle, the head being orange or bright red, with a black patch on the throat appearing in egg-laying males, fading to dull gray at other times; females can also be yellow, turning to dull olive gray after mating (Das, 2010). Habitat in Muara Angke Wildlife Reserve: Commonly found in lianas, shrubs, and trees on the levee path.

Tokay Gecko, *Gekko gecko* (Linnaeus, 1758)

Body robust; head large. Dorsal coloration gray-brown or bluish-gray with red or orange spots; juvenile dorsum with cream spots, sometimes merging into pale spots; bands sometimes visible on adults; tail darkly striped; venter cream, unpatterned or multicolored gray or pink-spotted; iris yellow (Das, 2010). Habitat in Muara Angke Wildlife Reserve: Often found on walls of empty houses and tree trunks on boardwalks.

Common four-clawed Gecko, *Gehyra mutilata* (Wiegmann, 1834)

Body sturdy; relatively large head; smooth skin; flattened tail, broadened at base, with sharp, slightly serrated edges; large flat scales on tail and abdomen; no claws on inner fingers. Dorsal color pale, almost translucent gray to pinkish gray, usually with pale

DOI: 10.21009/bioma.v21i1.53471

spinal area; indistinct white band along face; pale pink belly (Das, 2010). Habitat in Muara Angke Wildlife Reserve: Commonly found on the walls of the information center.

Asian House Gecko, *Hemidactylus frenatus* Duméril & Bibron, 1836

Body robust, slightly flattened; head large; 9-12 supralabials; 7-10 infralabials; tail segmented, tapering; dorsal scales smooth; no membranes on fingers and toes; sides of tail with enlarged tubercles; no skin folds along sides of body and on hind limbs. The back is gray-brown or blackish-brown, sometimes with darker markings; a light brown stripe, with lighter edges at the top, on the sides of the head, sometimes continuing down the sides of the body; the belly is cream or light cream with no pattern (Das, 2010). Habitat in Muara Angke Wildlife Reserve: Often found in bamboo and trees on embankment paths and boardwalks.

Flat-tailed House Gecko, *Hemidactylus platyurus* (Schneider, 1792)

Body slender in juveniles, robust in adults, flattened; back smooth with small granules; tail deeply concave, lateral margins serrated with pointed scales; snout rather long; supralabials 9-11; infralabials 7-8; fingers and toes half webbed. Dorsum light gray to tan, sometimes with darker variegation or elongated dark brown spots; usually dark gray postocular stripe to axilla; venter beige or light yellow unpatterned (Das, 2010). Habitat in Muara Angke Wildlife Reserve: Commonly found on the walls of the information center.

Common Sun Skink, *Eutropis multifasciata* (Kuhl, 1820)

Body robust; head firm; snout short; lower eyelid scaly. Dorsal color bronze brown, usually with yellow or red stripes along the sides; a series of white spots or stripes along the sides; breeding males with bright orange or reddish orange sides; pale dorsolateral stripes; cream on the belly (Das, 2010). Habitat in Muara Angke Wildlife Reserve: Commonly found basking near canals and boardwalks.

Bowring's Supple Skink, *Subdoluseps bowringii* (Günther, 1864)

Body slender, elongated; head barely clear of neck; lower eyelids scaly; earlobe openings rounded. Dorsal color bronze brown; flanking with dark bands, within which are formed longitudinal white and black spots, in juveniles; juvenile tail bright red, adult tail gray or brown (Das, 2010). Habitat in Muara Angke Wildlife Reserve: Found in the litter of the embankment path.

Asian water monitor, *Varanus salvator* (Laurenti, 1768)

Body robust in adults, relatively slender in juveniles; snout concave; nostrils rounded or oval, Color in juvenile individuals dark dorsally, spotted yellow or with ocelli in a transverse series; snout streaked with black, especially on the lips; venter yellow with narrow vertical V-shaped black markings extending down the sides of the venter; dorsum darkens with growth - sometimes all vestiges of the chain-like yellow pattern are lost (Das, 2010). Habitat in Muara Angke Wildlife Reserve: Commonly found basking on large tree trunks and concrete and swimming in the water in all trails.

DOI: 10.21009/bioma.v21i1.53471

Red-eyed Vine Snake, *Ahaetulla rufusoculara* Lam, Thu, Nguyen, Murphy, & Nguyen, 2021

Eyes bright red; bright green back; and a yellow or white stripe along the underside (Lam et al, 2021). Habitat in Muara Angke Wildlife Reserve: Commonly found sleeping in *Nypa fruticans, Excoecaria agalloca,* and *Leucaena leucocephala* trees.

Painted Bronzeback, *Dendrelaphis pictus* (Gmelin, 1789)

Body slender; large eyes; bronze-brown or olive-brown back; ventrolateral yellow or cream striped, black-eyed; forehead brown with a black postocular stripe covering half the temporal region that extends to the neck; blue or blue-green patch on the neck visible when threatened or hunting (Das, 2010). Habitat: Commonly found in *Sonneratia caseolaris* and *Nypa fruticans* trees.

Rainbow Mud Snake, *Enhydris enhydris* (Schneider, 1799)

Body robust, cylindrical; head small, concave and slightly distinct from the neck; snout rounded; nostrils located on the upper surface of the head; eyes small; pupils vertical; tail short, tapering; back smooth. Dorsal body color is dark brown, grayish brown or olive green with dark vertebral stripes and 2 pale brown paravertebral stripes from the upper surface of the head to the tail; venter yellowish beige, ventral with a dark spot on the edge that creates a dark stripe on the side of the body. (Das, 2010). Habitat in Muara Angke Wildlife Reserve: Commonly found in brackish water near boardwalks and canals at night.

Puff-faced Water Snake, *Homalopsis buccata* (Linnaeus, 1758)

Body robust, flattened dorsoventrally; head large and well-defined from the neck; snout square; nostrils eyes and valves directed upwards; eyes small; pupils vertically oval; tail short, with a pointed tip; back keeled. Dorsal coloration is grayish, dark brown or black (depending on population and growth stage), with a narrow yellow stripe edged with black; venter cream-colored with black spots (Das, 2010). Habitat in Muara Angke Wildlife Reserve: Commonly found in brackish water near boardwalks and canals at night.

Reticulated Python, *Malayopython reticulatus* (Schneider, 1801)

Head clear of the neck. Dorsal coloration is yellow or brown with dark markings of rhombus (resembling batik); black central stripe running from snout to nape; oblique stripe from posterior of eyes to corner of mouth; yellow venter with small brown spots (Das, 2010). Habitat in Muara Angke Wildlife Reserve: Found on the boardwalk.

Amboina Box Turtle, *Cuora amboinensis* Daudin, 1802

Carapace highly domed and smooth; vertebral keel in adults; juveniles with 2 additional keels laterally; plastron with transversely movable hinge behind pectoral and ventral scales; posterior anal notch absent on plastron. Carapace color olive, brown or almost black; plastron yellow or cream with a single black spot on each scale; face with

DOI: 10.21009/bioma.v21i1.53471

longitudinal yellow stripes (Das, 2010). Habitat in Muara Angke Wildlife Reserve: Found around the boardwalk.

Herpetofauna of Muara Angke Wildlife Reserve
Key Identification

1a. The body is not covered with scales (skinned) ..... **Class** Amphibia (2)
1b. The body is covered with scales or has a shell ..... **Class** Reptilia (4)
2a(1a) There are pustules on the back and long bumps behind the eyes ..... *Duttaphrynus melanostictus*
2b(1a) Green in color with brown and white stripes on the sides ..... *Hylarana erythraea*
2c(1a) Brown in color with dark brown stripes on the body, sometimes there are stripes on the upper body 3
3a(2c) Full membranes on hind legs ..... *Fejervarya cancrivora*
3b(2c) Non-full membranes on hind legs ..... *Fejervarya limnocharis*
4a. Has 4 legs 5
4b. Does not have legs 12
5a(4a) Shiny scales 6
5b(4a) Non-shiny scales 7
5c(4a) Has a shell 8
6a(5a) Olive green body color, generally has yellow lines on the sides, some have black lines on the sides, long snout ..... *Eutropis multifasciata*
6b(5a) Upper body color is different from the side body, reddish brown, has thick black lines on the sides, small, short snout ..... *Subdoluseps bowringii*
7a(5b) Flattened body ..... **Family** Gekkonidae (9)
7b(5b) Voluminous body 10
8a(5c) Flattened and soft shell ..... *Pelodiscus sinensis*
8b(5c) Voluminous and hard shell, has a yellow stripe on the side of the head ..... *Cuora amboinensis*
8c(5c) Shell voluminous and hard, black ..... *Siebenrockiella crassicollis*
9a(7a) Soft scales, large head, brown with red and white round motif ..... *Gekko gecko*
9b(7a) Soft scales, head size in line with body 11
10a(7b) Thick and hard scales, large body with short legs, V-shaped snout, has fangs in its teeth ..... *Crocodylus porosus*
10b(7b) Black with yellow round motifs, large, commonly called Asian water monitor ..... *Varanus salvator*
10c(7b) Green body color, has a mane ..... *Broncochela jubata*
10d(7b) Yellowish brown body color ..... *Calotes versicolor*
11a(9b) Yellowish brown with batik-like motifs sometimes seen without motifs / plain, the scale pattern on the edge of the tail is like a dense fiber, the scales on the edge of the tail are sometimes full sometimes not ..... *Hemidactylus platyurus*
11b(9b) Dark gray with black and white stripes, the scale pattern on the edge of the tail is spaced between scales, sometimes there are red spots on the fingers ..... *Hemidactylus frenatus*
11c(9b) Dark gray with black and white stripes, the scale pattern on the edge of the tail has alternating long and short scales, the long tail edge scales are spaced ..... *Hemidactylus garnotii*
11d(9b) Light brown with white spots like sugar on the body, has 5 fingers each with 4 claws, has no scales on the edge of the tail ..... *Gehyra mutilata*
12a(4b) The dominant body color is green, juvenile brown ..... **Genus** *Ahaetulla* (13)
12b(4b) Body color predominantly brown 14

DOI: 10.21009/bioma.v21i1.53471

12c(4b) Body color predominantly black.....15
13a(12a) Lighter in color on lower body, white iris, pointed snout.....*Ahaetulla prasina*
13b(12a) Yellow stripe on side of body, red iris, blunt snout..... *Ahaetulla rufusoculara*
14a(12b) Pattern on body like batik ..... *Malayopython reticulatus*
14b(12b) Brown color only on upper body, there are lines on the sides and along the body, yellowish white on the lower part of the body ..... *Dendrelaphis pictus*
14c(12c) Grayish black or brownish grayish black or brown with two lighter colored stripes on the top..... *Enhydris enhydris*
14d(12c) White or orange rings .....*Homalopsis buccata*
14e(12c) Evenly distributed brown color and bright yellow on the lower body.....
..... *Ptyas korros*
14f(12c) White spots all over the body and white necklace-like pattern on the neck
.....*Lycodon capucinus*
15a(12c) Black body color with yellow ring pattern along the body ... *Boiga dendrophila*
15b(12c) Deep black, can expand its neck to resemble a hood.....*Naja sputatrix*
15c(12c) Small in size, orange horizontal dotted lines on the upper body, black and white striped underside..... *Cylindrophis ruffus*

CONCLUSIONS

There have been changes in species presence over the past six years. There were 28 species identified in Muara Angke Wildlife Reserve, but only 18 species were found in this study. Some newly discovered species, such as *Duttaphrynus melanostictus* and *Subdoluseps bowringii*, were found in 2024 and *Draco volans, Naja sputatrix, Ptyas korros, Boiga dendrophila, Hemidactylus garnotii, Cylindrophis ruffus*, and *Lycodon capucinus* have not been recorded again in this study**.** The presence and distribution of herpetofauna suggests that anthropogenic factors, such as land cover change, light effects, and temperature, have a significant impact on species diversity in Muara Angke Wildlife Reserve. Trails that are not directly adjacent to human disturbance show higher species variation compared to trails affected by human disturbance. Path 2, which has relatively undisturbed natural habitat, recorded the highest species diversity, while paths 1 and 3 experienced decreased diversity.

AUTHOR CONTRIBUTIONS

F.D.N., M.I.N.: project conception, methodology; F.D.N.: data analyses, original manuscript draft; F.D.N., Y.M.: map results; M.I.N., Y.M.: manuscript review.

CONFLICTS OF INTEREST STATEMENT

There are no conflicts to declare.

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