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Research article

A preliminary study of the effects of enrichment on the activity and spatial distribution of captive monitor lizards in Nakhon Ratchasima Zoo, Thailand

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Abstract

The monitor lizard (Varanus salvator) has the widest distribution among all extant varanids found across South and Southeast Asia. However, behavioral studies on captive monitor lizard have not been well-documented. The objective of this research was to investigate the effects of enrichment items on the activity and spatial distribution of captive monitor lizards. The study involved three adult captive Black water monitors (Hiea dam), three adult Roughnecked monitors (Ngu-hao Chang), and two adult Dumeril's monitors (Tut-too) in outdoor enclosures. Three treatments were administered: control (no enrichment item), cone (enrichment item), and takraw (enrichment item: a rattan ball). The frequency of activity and spatial distribution of three species of monitor lizards were recorded. The results showed that the percentages of activity and spatial distribution of three species of monitor lizards were not significantly affected by the enrichment items ($P > 0.05$). However, there were significant differences only in lying behavior between the Hiea dam, Ngu-hao Chang, and Tut-too monitors ($P < 0.05$). In conclusion, the general behaviors of captive Hiea dam, Ngu-hao chang, and Tut-too monitor lizards were similar, and their spatial distribution was also similar. The behavior and spatial distribution of captive monitor lizards were not affected by the enrichment items.

Keywords: Behavior, Enrichment, Water monitors, Zoo

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INTRODUCTION

The Asian water monitor (*Varanus salvator*) has the widest distribution of all extant varanids found across South and Southeast Asia (Das, 2015; Wongtienchai et al., 2021). Globally, there are 71 species of varanid lizards, including four species in Thailand: the Asian water monitor (*Varanus salvator,* Thai name: Hiea), the Dumeril's monitor (*Varanus dumerilli,* Thai name: Tut-too), the Roughnecked monitor lizard (*Varanus rudicollis,* Thai name: Ngu-hao chang) and the Bengal monitor (*Varanus begalensis,* Thai name: Tu-kuat) (Mahaprom et al., 2015; Lauprasert and Thirakhupt, 2001).

Varanus salvator "*komaini*" is the name used by dealers for big, nearly entirely black water monitors (Thai name: Hiea dam) (Koch et al., 2007), which was described as black water dragon, a separate subspecies (*Varanus salvator komaini*), by the researcher Nutphand in 1987 (as cited in Cota et al., 2009), from the small islands and areas near the coastline in Southwestern Thailand. Nutphand distinguished this subspecies from its closest relative, *Varanus salvator*, by its shorter adult length, black coloration throughout the body (no spots or bands), and a grayish-purple tongue. The size is much smaller than *Varanus salvator* (Koch et al., 2007). The melanistic taxon *komaini* from Thailand was demonstrated to be a junior synonym of *Varanus salvator macromaculatus* in the absence of morphological differences except for the lack of a light color (Koch et al., 2013). Therefore, in the most recent taxonomic revision, black water monitor is no longer considered to be a distinct subspecies and is instead synonymized with *Varanus salvator macromaculatus* (Koch et al., 2007, as cited in Myers et al., 2011). The conservation status of studied monitor lizards has most recently been assessed for The IUCN Red List of Threatened Species. *Varanus salvator* is listed as Least Concern (Quah et al., 2021), *Varanus dumerilii* and *Varanus rudicollis* are listed as Data Deficient (Iskandar et al., 2021; Phimmachak et al., 2021).

However, globally, monitor lizards and their products are important goods in the worldwide trade in live pets and reptile leather (Koch et al., 2013; Uyeda, 2015). Promvek and Singkhajorn (2021) claimed that the water monitor is an economic animal. It can be used for economic benefits either for its meat or leather in Thailand (Boonchuay et al., 2018). However, the Wild Animal Reservation and Protection Act B.E. 2535 was established in 1992 in Thailand to protect and conserve natural populations of water monitors (Wongtienchai et al., 2020). According to the Wild Animal Conservation and Protection Act B.E. 2562 (2019), Section 8 states that "Prescription of any kinds of protected wild animals, which offer potential for economic exploitation, as breedable protected wild animals shall be made by a Notification of the Minister with the approval of the Commission" (TCIJ, 2021).

The welfare of captive reptiles has been the object of various studies (Hayes et al.,1998; Warwick et al., 2013; Bashaw et al., 2016; Pasmans et al, 2017; Hoehfurtner et al., 2021; Nagabaskaran et al., 2021), but a large part of their biological, physiological and behavioral characteristics is still not known (Scarpellini, 2018), not to mention the welfare of the reptile's requirements in captivity which are not always met, due in part to an apparent lack of awareness of their needs (Lambert et al., 2019). Enrichment has been documented to improve the welfare of mammals (Huo et al., 2021; Huo et al., 2023), birds, turtles and tortoises, but other taxa have not been well-studied (Swaisgood and

Shepherdson, 2005; Burghardt, 2013, as cited in Bashaw et al., 2016). Giving captive animals the opportunity to interact with objects in a "playful" manner is often considered a method of environmental enrichment. However, the occurrence of play in non-avian reptiles is controversial and poorly documented. According to the literature review in the behavioral study of *Varanus salvator*, Cota (2011) documented combat, pre-courtship, courtship and mating behaviors among *Varanus salvator macromaculatus* in an urban park in Bangkok, Thailand. The feeding habits of the Asian water monitor were described by Kulabtong and Maharprom in 2015 and Maharprom and Kulabtong in 2018. The study about the ecology and conservation of wild monitor lizards were conducted by Uyeda in 2015, however, including aspects of the behavior of captive monitor lizards are still rare, such as spatial distribution in an enclosure and effects of enrichment on their behaviors. Therefore, the research objective of this study was to investigate the effects of enrichment items on the percentages of activity and spatial distribution of captive monitor lizards. We hypothesized that the enrichment items could affect captive monitor lizards' behavior and spatial distribution.

MATERIALS AND METHODS

Animals and enclosures

There were three adult captive black water monitors (*Varanus salvator komaini*, one male and two females, called Hiea dam, Figure 1-a), three adult Roughnecked monitors (*Varanus rudicollis*, one male and two females, called Ngu-hao Chang, Figure 1-b) and two adult Dumeril's monitors (*Varanus dumerilli,* one male and one female, called Tut-too, Figure 1-c) in each outdoor enclosure (Hiea dam: W×L×H=3m×5m×3m; Ngu-hao chang: W×L×H=3m×4m×3m; Tut-too: W× L×H=3m×3m×3m). The 100 W Exo Terra infrared basking spot lamps were used. The enclosure consisted of wood, water, ground, stone, cage, hiding area for Tut-too (Figure 1-d), Hiea dam (Figure 1-e) and Ngu-hao chang (Figure 1-f). The study was conducted in the reptile conservation center at Nakhon Ratchasima (Korat) Zoo. The monitor lizards were fed once per week (on Thursdays). The feed included diced pork and beef according to the Korat Zoo requirements. After feeding, the enclosure was cleaned once a week when the keeper collected the feeder on next day. The ambient temperature (°C) and humidity (%) were measured during behavioral observation at 10:00 and 16:00 by an indoor digital hygrometer thermometer (ThermoPro TP-50).

Figure 1 Monitor lizards and enclosure. a=Black water monitor (Hiea dam), b=Roughnecked monitor (Ngu-hao Chang), c=Dumeril's monitor (Tut-too), d= Enclosure of Tut-too, e= Enclosure of Hiea dam, f= Enclosure of Ngu-hao Chang. (The photos were taken by Xin Huo at Korat Zoo in 2022)

Behavioral observation

The procedures of the experiment were approved by the Animal Conservation and Research Institute Zoological Park Organization of Thailand (Approval no.1108/1036). The research followed the guidelines for the ethical use of animals in applied ethology studies (Sherwin et al., 2003). One observer who had experience in behavioral studies was in charge of data collection. Cone (30 cm height, Figure 2-a) and Takraw (a rattan ball, 12.7 cm diameter, 150-160 g, Figure 2-b) were given to group monitors as enrichment items for treatment which were never used in their enclosures. The number of enrichment items was equal to the number of animals in the group. The behavioral data was collected when no enrichment item was being used as a control. The effects of enrichment on behaviors of Hiea dam, Ngu-hao chang and Tut-too were conducted during March to May 2022. Each kind of treatment (Control, Cone and Takraw) was tested two days per week (on Tuesdays and Wednesdays). The enrichment items were left overnight for two days, and there was a total of three weeks of testing for each group. Each species did not receive same treatment item at the same time. Each species received different treatment in the same week, until all treatments were tested in three weeks. The enrichment items were collected during feeding day (Thursday).

An ethogram of monitor lizards is described in Table 1 (modified from Shannon Weatherly, 2021; Kuppert, 2013). A scan sampling observation technique was used (Martin and Bateson, 1986). The data on general behaviors, total activity (active and inactive) and spatial distribution were collected every 30 minutes, with a total of 13 recordings over a 6-hour period per day (from 10:00 to 16:00).

Figure 2 Enrichment items. a=Cone (30 cm height), b = Takraw (12.7 cm diameter, 150-160 g) (The photos were taken by Xin Huo in 2022.)

Table 1 The ethogram of monitor lizards

Behavior	Description
Inactive	
Lying	Lying down on its stomach on wood, water, against the pool, ground, stone or other object, head lowered or head up without tongue flicking. Eyes may be open or closed, which included resting and basking.
Standing	All four limbs on the ground, or standing on two feet against the object
Hanging	hanging on the cage
Hiding	invisible in the enclosure
Other	Any other inactive behavior not previously described.
Active	
Lying	Lying with flicking
Walking	It is moving using all four limbs on wood or ground, with or without tongue flicking.
Climbing	It is moving using all four limbs to climb on the cage, wood, with or without tongue flicking.

Data analysis

The SPSS software (version 23.0; SPSS Inc.; Chicago, IL, USA) was used for statistical analysis. A comparison of the percentages of frequency of behavioral activity and the percentages of spatial distribution for monitor lizards were analyzed by One-way ANOVA. Means were compared using Duncan's multiple-range test and the significance was determined at $P < 0.05$.

RESULTS

Temperature and humidity

When the monitor lizards in a group were observed, the average temperature during observation between 10:00 and 16:00 were 26.72±0.95 °C and 29.08±0.99°C, respectively. The average humidity at 10:00 and 16:00 was 76.83±3.44% and 66.25±3.08 %, respectively.

Activity

Table 2 shows the percentage of general behaviors in monitor lizards when there were no enrichment items used was not significantly different between Hiea dam, Ngu-hao Chang and Tut-too, except in lying (P=0.048, df=2, F=5.95). The percentage of lying for Hiea dam was highest, but it was not significantly different from that for Ngu-hao Chang (P>0.05). The percentage of lying for Tut-too was less than that for Hiea dam (P<0.05) and for Ngu-hao chang (P>0.05). Table 3 shows that the percentage of activity for monitor lizards was not significantly different (P>0.05). monitor lizards were generally inactive during the observation. The percentage of activity in Hiea dam, Ngu-hao chang and Tut-too monitors was not significantly affected by the enrichment items (P>0.05).

Table 2 The percentages of general behaviors in monitor lizards

Behavior	Hiea dam (n=3)	Ngu-hao chang (n=3)	Tut-too (n=2)	P-value
lying	83.33±7.80^{b}	66.67±3.39^{ab}	46.15±11.54^{a}	0.048
standing against an object	1.28±1.28	2.56±2.56	17.31±17.31	ns
hanging	2.56±1.28	15.38±10.18	0.00±0.00	ns
walking	5.13±3.39	10.26±5.59	3.85±3.85	ns
climbing	2.56±2.56	2.56±1.28	0.00±0.00	ns
hiding	0.00±0.00	2.56±2.56	26.92±23.08	ns
other	2.56±2.56	0.00±0.00	5.77±5.77	ns

Values are presented as Mean ± SE.
ns means P-value >0.05 when compared with the data in the same row.
$^{a, b}$ within the same row with different superscripts means they were significantly different at P<0.05.

Table 3 Effects of enrichment items on the percentages of activity in monitor lizards

Animals	Items	Active	Inactive
Hiea dam	Control	7.69±2.22	92.31±2.22
(n=3)	Cone	2.56±2.56	97.44±2.56
	Takraw	3.85±0.00	96.15±0.00
	P-value	ns	ns
Ngu-hao chang	Control	12.82±4.62	87.18±4.62
(n=3)	Cone	8.97±1.28	91.03±1.28
	Takraw	1.28±1.28	98.72±1.28
	P-value	ns	ns
Tut-too	Control	3.85±0.00	96.15±0.00
(n=2)	Cone	1.925±1.92	98.08±1.92
	Takraw	0.00±0.00	100.00±0.00
	P-value	ns	ns

Values are presented as Mean ± SE. ns: P-value >0.05 when compared to the data in the column.

Spatial distribution

Table 4 shows that when no enrichment item is used, the percentages of spatial distribution for wood, water, ground, stone, cage and hiding in Hiea dam were significantly different (P=0.048, df=5, F=3.14). The spatial distribution in wood (50 %) was used most by Hiea dam, however, there was no statistical difference between wood (50 %), water (20.51 %) and ground (21.79 %) distribution. The stone (1.28 %) and cage (6.41 %) spaces were rarely used by the Hiea dam. The Hiea dam did not hide themselves during the observation.

The highest spatial distribution was found for wood (60.26%) in Ngu-hao chang, followed by ground, water, cage, and stone during observation. Ngu-hao chang were rarely hidden. The percentages of spatial distribution for wood, water, ground and hiding in Tut-too monitors were not significantly different (P>0.05). There were no significant differences in spatial distribution for Hiea dam, Ngu-hao chang or Tut-too (P>0.05).

Table 5 shows that the percentages of spatial distribution for wood, water, ground, stone, cage and hiding in Hiea dam were not significantly different (P>0.05). Table 6 shows that the percentages of spatial distribution in Ngu-hao chang monitor for wood, water, ground, stone and hiding were not significantly different (P>0.05). Table 7 shows that the percentages of spatial distribution in Tut-too monitor for wood, water, ground, stone, cage and hiding were not significantly different (P>0.05).

Table 4 A comparison of the percentages of spatial distribution for monitor lizards (control) in the enclosures.

Location	Hiea dam (n=3)	Ngu-hao chang (n=3)	Tut-too (n=2)	P-value
Wood	50.00±12.36 [a]	60.26±18.09 [a]	3.85±0.00	ns
Water	20.51±18.62 [a]	10.26±5.13 [b]	42.31±11.54	ns
Ground	21.79±12.23 [a]	16.67±6.41 [b]	26.92±11.54	ns
Stone	1.28±1.28 [b]	2.56±2.56 [b]	0.00±0.00	ns
Cage	6.41±4.62 [b]	8.97±7.14 [b]	0.00±0.00	ns
Hiding	0.00±0.00 [b]	1.28±1.28 [b]	26.92±23.08	ns
P-value	0.048	0.004	ns	

Values are presented as Mean ± SE. ns: P-value >0.05

[a, b] within the same column with different superscripts means they were significantly different at P<0.05.

Table 5 Effects of enrichment items on the percentages of spatial distribution for Hiea dam

Location	Control	Cone	Takraw	P-value
wood	50.00±12.36	20.51±16.81	37.18±12.23	ns
water	20.51±18.62	46.15±11.75	1.28±1.28	ns
ground	21.79±12.23	33.33±18.49	53.85±8.01	ns
stone	1.28±1.28	0.00±0.00	0.00±0.00	ns
cage	6.41±4.62	0.00±0.00	7.69±5.88	ns
hiding	0.00±0.00	0.00±0.00	0.00±0.00	ns

Values are presented as Mean ± SE. ns: P-value >0.05

Table 6 Effects of enrichment items on the percentages of spatial distribution for Ngu-hao chang

Location	Control	Cone	Takraw	P-value
wood	60.26±18.09	35.90±24.76	66.67±16.67	ns
water	10.26±5.13	10.26±8.41	32.05±16.06	ns
ground	16.67±6.41	1.28±1.28	14.10±4.62	ns
stone	2.56±2.56	0.00±0.00	0.00±0.00	ns
cage	8.97±7.14	1.28±1.28	0.00±0.00	ns
hiding	1.28±1.28	38.46±21.18	0.00±0.00	ns

Values are presented as Mean ± SE. ns: P-value >0.05

Table 7 The percentages of spatial distribution for Tut-too

Location	Control	Cone	Takraw	P-value
wood	3.85±0.00	0.00±0.00	21.15±21.15	ns
water	42.31±11.54	3.85±3.85	76.92±19.23	ns
ground	26.92±11.54	5.77±5.77	1.92±1.92	ns
stone	0.00±0.00	0.00±0.00	0.00±0.00	ns
cage	0.00±0.00	36.54±36.54	0.00±0.00	ns
hiding	26.92±23.08	53.85±46.15	0.00±0.00	ns

Values are presented as Mean ± SE. ns: P-value >0.05

DISCUSSION

The small sample size, which is a common constraint of non-model species in zoo research, may have limited our ability to detect effects (Carter et al., 2021). All lizards in this study were under the age of maturity. The effect of sex on resource use was not investigated in this study. Understanding how individuals of a particular species utilize their enclosures and the resources available to them can help to inform captive management and enclosure design, as well as aiding in assessing animal welfare (Carter et al., 2021). The behavioral research of monitor lizards provides us with a great deal of information concerning animals′ requirements, preferences and internal insight which will help to implement any animal conservation and management programs (Rahman et al., 2017).

Activity

Asian water monitor obtains heat from environmental sources and its activity level was highly correlated with ambient temperature (Gaulke and Horn, 2004). Most of the activities of Asian water monitor took place when temperatures were between 29°C and 31°C (Rahman et al., 2017). Our study was conducted during March to May 2022 in Thailand when the average temperature outdoors at 10:00 and 16:00 was 26.72°C and 29.08°C, respectively. Although the yellow monitor is most active during the monsoon season when their habitat is flooded, observers are able to view them clearly during bright and rainless days (Karki et al., 2008, as cited in Rahman and Rakhimov, 2019). However, the monitor lizards in our study were in a captive environment, so their behaviors might be different from those of a study in the wild (Wörner, 2009).

The general behavior of the monitor lizards in a group were observed between 10:00-16:00, which is the official opening hours in the zoo, and it was similar to the behavior recorded by Bashaw et al. in 2016. In our study, the monitor lizards' lying behavior included resting and basking, because resting is often used synonymously with basking. Like other reptiles, most varanids adjust their behavior to their core body temperature during activity (Rahman et al., 2015). The monitor lizards were more than 88.46% inactive during our study. Korat Zoo do not have a density problem (Carpenter, 1967; Brattstrom, 1974; Wilson, 1975; Prieto and Ryan, 1978; Warwick, 1995, as cited in Wörner, 2009) with groups of monitor lizards. The major activities of the monitor lizards in groups were similar to those of the yellow monitor which included moving, feeding, resting and basking (Rahman and Rakhimov, 2019). However, the social

behavior of monitor lizards was not seen during the data collection time. Since all varanids are solitary hunters, communication is rare (Burghardt et al., 2002). The monitor lizards usually change their habitat to find food and do not remain in any specific area (Traeholt, 1993, as cited in Mahaprom et al., 2015). When animals are held in captivity, competition for resources must be carefully monitored to ensure their health and survival (Wörner, 2009). However, the feeding schedule of captive monitor lizards in the zoo was fixed so the research did not obtain any behavioral data during feeding day.

Rosier and Langkilde (2011) provided lizards with the opportunity to exhibit natural climbing behavior which could result in improved cardiovascular health through increased exercise, as lizards that are able to climb to escape may perceive that they are less vulnerable to threats. Therefore, lizards caught in the wild which might have used this escape response to survive may be more likely to show decreased levels of stress in response to enrichment when compared to laboratory-reared individuals (Rosier and Langkilde, 2011). We also found Hiea dam and Ngu-hao chang climbed during observation. However, the Hiea dam did not perform hiding, it might because they were used to the visitors in the show area. Conversely, Ngu-hao chang and Tut-too were frequently observed to be hiding. Further research would be needed to determine whether this depends on individuals.

Spatial distribution

Understanding how individuals of a particular species utilize their enclosures and the resources available to them can help to inform captive management and enclosure design, as well as help in assessing animal welfare (Carter et al., 2021). If the behavior of captive lizards reflects that of wild animals, enclosures should be designed to allow equal opportunities to access resources, to benefit mixed age groups or to correlate with preferences as animals age (Carter et al., 2021). The provision of diverse environmental conditions undoubtedly offers significant benefits for animals to interact with their surroundings. For instance, zoos create captive environments that mimic natural habitats, incorporating elements like wood, plants, water features, outdoor spaces, nesting areas, soil substrates, and even stones. An understanding of the spatial distribution of captive reptiles in their enclosure is very important. When no enrichment items were provided, the Hiea dam and Ngu-hao chang might spend more time in wood area for their basking sites (Warwick et al., 1995) but not in water. However, Tu-too preferred to stay in water during the observation. As the yellow monitor is a semiaquatic species, they sometimes stayed submerged during active periods when they sensed any danger (Rahman and Rakhimov, 2019).

Enrichment

Enrichment items were novel items used to stimulate animal behavioral activity (Young, 2003). Burghardt (2013) suggests enrichment improves the cognitive performance of reptiles and is likely to improve their welfare. Bashaw et al. (2016) claimed that providing novel objects improves welfare in leopard geckos by increasing their propensity for exploration. However, the general activity of monitor lizards was not affected by the enrichment items during observation. Rosier and Langkilde (2011) also found that the enrichment items did not affect behaviors in the Eastern fence lizard. Small reptiles may exhibit

less behavioral response to enrichment because of their innate fear of humans or because their lower metabolic rates make active responses to enrichment more costly in terms of energy (Hosey, 2008, as cited in Bashaw et al., 2016). Although turtles interacted with objects (e.g., basketball, hose, stick) for 20.7% of the observation time (Burghardt et al., 1996), we need to consider that the relative lack of play in ectothermic reptiles is supported by the surplus resource theory of play, which considers the joint effects of parental care, metabolism, endothermy, and arousal in providing the context in which playfulness can be manifested and promoted in vertebrate evolution captivity (Burghardt et al., 1996).

Huo et al. (2023) claimed that the captive sun bear would be more interested in an edible enrichment tool compared with using other types, which could reduce the frequency of pacing. Both stabled non-stereotypic horses individually and in groups performed significantly more item-directed behaviors towards edible items (Huo et al., 2021). The enrichment items (cone and takraw: a rattan ball) used for the monitor lizards, which were made of plastic, easily to find and low cost. The size of cone and takraw used was safe because they cannot be swallowed by the adult monitor lizards. They were cleaned in water and dried before the test. There was not any scent of food and they were used as novel items without any training for the monitor lizards. Moreover, there was no interaction between monitor lizards and enrichment items during observation time in our study. Therefore, a further study would be needed to test the effects of edible enrichment items for monitor lizards.

CONCLUSIONS

The general behaviors of captive Hiea dam, Ngu-hao chang and Tut-too monitor lizards were similar. The spatial distribution of the captive monitor lizards was also similar.We conclude that the behavior and spatial distribution of captive monitor lizards were not affected by the enrichment items.

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AUTHOR CONTRIBUTIONS

Xin Huo:Conceptualization, Methodology, Project administration, Investigation, Data curation Software, Writing-original draft, Writing-Review & Editing, Supervision
Kirati Kunya: Resources
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