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Activity budgets and dietary investigations of *Varanus salvator* (Reptilia: Varanidae) in Karamjal ecotourism spot of Bangladesh Sundarbans mangrove forest

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Tropical mangrove forest ecosystem of Sundarbans is considered as the most potential habitat for *Varanus salvator* in Bangladesh. The study was conducted to understand the general ecology and behavior of *V. salvator*, to assess its activity patterns and feeding ecology in and around Karamjal ecotourism spot of Bangladesh Sundarbans. The activities of water monitor were more frequently seen during 0900 – 1200 hrs, and 1530 – 1700 hrs of the day. The proportion of time spent on different behavioral states by the water monitors varied significantly between the wet and dry seasons. It was found that adult water monitors spent a highest proportion of time in foraging activity during the rainy or wet season, whereas during winter they spent most of the time basking. During this study, their diet was mostly crabs, although they also showed their character as scavengers. Since *V. salvator* is an ectothermic species, the influence of environmental variables upon its activities in different habitats either in summer or in winter, should not be ignored.

Key words: activity; diet; habitat; Sundarbans; *Varanus salvator*; water monitor.

The diverse ecosystems of Bangladesh are the home of three different monitor lizard species, among them Asian water monitor (*Varanus salvator* Laurenti, 1768) is the largest (Khan, 2008; Hasan *et al.*, 2014). Popularly the species is also known as ring lizard, as it has yellowish rings arranged in rows upon blackish upper parts of the body (Fig. 1). Water monitors are native to South and Southeast Asia. In Bangladesh they are distributed mostly in coastal areas and mangrove swamps of Sundarbans; rare in Northeast, Southeast forests, Manikganj and Keraniganj (Narayanganj). Its habitat is declining due to anthropogenic factors and development activities, and its population is also deteriorating day-by-day at an alarming rate. Nationally the species is considered Vulnerable (IUCN Bangladesh, 2015). Water monitors are hardly ever found far from water and can cover long distances swimming. This ability has allowed them to colonize many remote islands.

In wild ecosystems, time is an important limited resource for all animals, its partitioning might be influenced by sociality, and therefore, may constrain sociality of free-ranging individuals (Pollard & Blumstein, 2008). Proportion of time

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Figure 1: (A) *Varanus salvator* and its altered habitat found in the backyard of Karamjal Ecotourism Center. (B) An overview of Sundarbans Mangrove forest from Pasur River during heavy tide of monsoon month.

spend in different activities has significant effects on the adaptive ecology of wildlife species (MARZLUFF *et al.*, 2001). Availability of food and environmental variables like temperature play a significant role in many aspects of ectotherm physiology, behavior and ecology of wild animals (SMITH, 1932; BOGERT, 1949; HUEY & STEVENSON, 1979; BENNETT, 1980; WINNE & KECK, 2004; POLO *et al.*, 2005). Thus, for the entire cold-blooded lizards, activity patterns and food preference during the active period may reflect changing environmental conditions, especially temperature (WIKRAMAYAKE & GREEN, 1989; VITT *et al.*, 1996; PIANKA & VITT, 2003; RAHMAN *et al.*, 2016). Animals invest time in the acquisition of information about forage resources within their environmental setting, thus affecting the proportion of time allocated to other activities (FORTIN *et al.*, 2004). It is essential to know how water monitors interact with their environment and invest energy, as well as time, for survival purposes by exploring their activity budgets.

We conducted an ethological study of free-living water monitors in a semi natural environment of Karamjal ecotourism spot of Sundarbans mangrove forest. For developing a better conservation and management action plan, an understanding of behavioral patterns and feeding ecology of any animal is undoubtedly essential. It is noteworthy to mention that behavior is what animals do to interact with, react to, and regulate their habitat. Behavior is generally the animal's "first line of defense" in response to environmental change (MENCH & MASON, 1997). Hence, careful research of behavior provides with a great deal of information concerning animals' requirements, preferences and dislikes, and internal insight which will help us to implement any animal conservation and management program.

MATERIAL AND METHODS

Study sites

For the present study, field work was carried out from October - December 2014 and from June - December 2016 at Karamjal ecotourism spot and adjacent areas (22° 25'43.19" N, 89°35'24.96" E) (Fig. 2). The sites are situated under Chadpai range of Sundarban Forest Department, Bagherhat, Bangladesh. The Crocodile & Deer Breeding Center is the main attraction of Karamjal. The jungle is surrounded by a number of county villages (Herbaria, Laodove, Baniashanta and Koilashgang). Sunderbans is a very humid area, due to its proximity to the Bay of Bengal, and it is usually very hot during the summer, when the mercury can soar up to 40°C. On the other hand, winters in the area are quite cold, with temperatures droping to around 9.2°C. Sunderbans receives heavy rainfall, from mid-June to mid-September. The habitat types of the study area are categorized as (1) mangroves, dominated by *Heritiera fomes*, *Excoecaria agallocha*, and *Sonneratia apetala*; (2) grasslands, typically with *Imperata cylindrica*, *Acrostichum aureum*, *Myriostachya wightiana*; (3) mudflats, including sandy tidal flats and beaches; (4) transitional zones between these three habitats, usually with few trees, sometimes with reeds; and (5) deep water, including rivers and estuaries, covering most of the sanctuary (KHAN, 2005). Recent hydrological connectivity of the aquatic ecosystems in the Sundarbans Delta, makes them highly sensitive to a broad range of anthropogenic activities (BAUTISTA & RAHMAN, 2015).

Figure 2: Bangladesh map showing the study area Karamjal of Sundarbans mangrove forest (Google Maps, 2017).

A variety of methods were employed to conduct this research. The Visual Encounter Survey method (HEYER *et al.*, 1995) was followed for observing and counting the study lizards. These surveys generally comprised walking through a forest trail or specific transect line to check for sheltering animals. The number of observed animals and sighting time was then recorded in a data sheet.

The activity patterns of water monitors were studied by focal sampling method in which data was recorded continuously during a certain period. Focal sampling means observing one individual for a specified amount of time and recording all instances of its behavior (ALTMANN, 1974; SLATER, 1978; MARTIN & BATESON, 1986).

Ideally, the choice of focal individual is determined prior to the observation session (ALTMANN, 1974). The observation was done daily in every 1 week of each month from morning to evening. During this time, all the activities that the focal animal performs were recorded, while the activities of any other active animal were not recorded at the same time. When a focal individual became not visible, we started searching for another active animal, and after finding it we started to record all its behavioral activities. To avoid influencing their behavior, the animals were followed on foot and observed from hidden points. The activities of water monitors were recorded in six distinct categories as feeding (any activity of an animal that is directed toward the procurement of nutrients), foraging (visits different potential food sources in search of food by walking, swimming or by climbing), resting (when an individual becomes inactive and does not move much), basking (that is basically sunbathing or thermoregulatory behavior, occurring especially during the cold season to heat-up the body, conflicting (when an individual competes or engages in clash with another individual of the same or different species for food, mate or territory), and others (combination of some miscellaneous minor activities like hiding, escaping and courtship that were seen or observed rarely during field study). Proportion of time spent in different activities or behavior was calculated by the equation: Tf = (nf × 100) ÷ N (GUPTA & KUMAR, 1994). Where, Tf = time spent on a specific behavior as percentage (%) of total active period; nf = amount of time spent for showing a specific behavior; and N = total amount of time spent for all behavior.

Besides field observation and interview with local people, stomach content samples were also taken from the field-captured *V. salvator* to examine its diet in this study. Field-captured *V. salvator* were stomach-flushed to collect the dietary items (MAYES *et al.*, 2005). We inserted a plastic tube (approximately 1 cm in diameter and 1 m in length) down the esophagus past the glottis until the distal end of the stomach was reached. A hand pump was used to pump approximately 500-600 ml of water through the tube into the stomach. Vomited stomach contents flushed from individuals were collected in a bowl-shaped utensil. Water was pumped into each individual 2 to 3 times before the plastic tubing was removed. The collected stomach contents were then stored in 70% ethanol. Then, stored stomach contents were later dried for a specific period and identified the prey group. The proportion in the diet represented by each prey group was calculated by using the previsous equation Tf = (nf x 100) / N (GUPTA & KUMAR, 1994), where Tf = proportion of a specific prey group as % of total stomach content; nf = number of a specific prey group; and N = total prey group recorded from the stomach.

The activities of each focal water monitor were observed with the aid of NIKON 10 × 50 binoculars. Temperatures were recorded with a mercury thermometer, and photographs of the vegetation types and lizards were taken with a NIKON D3200 camera and a Tamron 70-300 mm lens.

Data analysis

Data regarding the activity patterns of *V. salvator* were tested for normality using the Chi-square ($\chi 2$) test, and satisfied the normality assumptions. Based on the chi-square statistic and the degrees of freedom, we determined the *P*-values. All statistical analyses were performed using SPSS release 16.0 (SPSS Inc., 2007).

RESULTS

During 10 months of fieldwork a total of 211 *V. salvator* were observed for a period of 4105 minutes from morning to evening, of which 142 individuals were recorded from 0700 – 1200 hrs and 69 individuals were recorded from 1200 – 1700 hrs.

Monthly activity patterns

Except conflicting all of the other behavioral activities of *V. salvator* varied significantly in different months (χ^2 - Post Hoc test, $P < 0.05$; Table 1). Throughout the study period, water monitors spent most of their time in foraging activities in different locations. The highest proportion of foraging activities was recorded in August (24.15 ± 2.92) and the lowest in November (3.01 ± 1.06). The highest proportion of time spent feeding was recorded in July (25.94 ± 2.63) and the lowest in November (3.77 ± 1.01). For resting, the lizards spent the highest proportion of time in June (24.48 ± 1.96), and they have not shown any resting activity in December. On the other hand, the highest proportion of basking activity was recorded in November (60.33 ± 3.30) and the lowest in June (0.17 ± 0.14). Conflicting was the highest in August (24.13 ± 1.47) and the lowest in both June and October (6.89 ± 0.61 and 6.89 ± 0.75, respectively). Behaviors that were rarely observed during fieldwork (i.e., other activities: hiding, escaping, courtship), comprised a higher proportion of time budgets during June and September (25.00 ± 1.34 and 25.00 ± 0.77, respectively), and a lower proportion during December (4.16 ±

Table 1: The mean (± SE) proportion of time (%) spent on different activities by *Varanus salvator* for different months of the study period.

Month	Foraging	Feeding	Resting	Basking	Conflicting	Other
June	18.11 ± 2.20	21.22 ± 2.28	24.48 ± 1.96	0.17 ± 0.14	6.89 ± 0.61	25.00 ± 1.34
July	21.50 ± 1.76	25.94 ± 2.63	21.08 ± 1.42	0.33 ± 0.18	20.68 ± 1.14	14.58 ± 0.89
August	24.15 ± 2.92	17.45 ± 1.41	16.33 ± 1.10	0.33 ± 0.18	24.13 ± 1.47	16.66 ± 0.67
September	19.62 ± 4.04	14.15 ± 1.72	12.24 ± 1.33	0.5 ± 0.20	17.24 ± 1.04	25.00 ± 0.77
October	8.30 ± 1.47	11.80 ± 1.83	24.45 ± 1.33	3.33 ± 0.59	6.89 ± 0.75	8.33 ± 0.40
November	3.01 ±1.06	3.77 ± 1.01	1.36 ± 0.20	60.33 ±3 .30	10.34 ± 0.99	6.25 ± 0.59
December	5.28 ± 1.44	5.66 ± 1.42	0.00 ± 0.00	35.00 ± 2.17	13.79 ± 1.03	4.16 ± 0.61
χ^2	185.59	105.74	271.66	2194.69	20.14	44.62
P	0.0001	0.0001	0.0001	0.0001	0.9128	0.0419

Table 2: The mean (± SE) proportion of time (%) spent on different activities by *Varanus salvator* for the wet and dry season.

Activity	Wet season	Dry season	$\chi^2 = \Sigma((o-e)^2/e)$	*P*
Foraging	39.63 ± 1.58	16.70 ± 1.17	145.57	0.0001
Feeding	30.00 ± 1.58	17.08 ± 1.40	57.25	0.0001
Resting	19.58 ± 1.17	14.42 ± 2.67	13.01	0.0233
Basking	0.28 ± 0.11	44.95 ± 5.12	1224.41	0.0001
Conflicting	3.58 ± 0.58	3.41 ± 0.53	0.1251	0.9997
Other	6.99 ± 0.55	3.41 ± 0.32	19.57	0.0015

0.61). A comparative analysis of proportion of time spent on different activities in different months by *V. salvator* is represented in Table 1.

Seasonal activity patterns

The proportion of time spent on different behavioral states by the water monitors varied significantly during both wet and dry seasons (χ^2- Post Hoc test, $P < 0.05$; Table 2). The proportion of time spent in foraging by water monitors was higher in the wet season than in the dry season (Table 2). Like foraging behavior, feeding, resting, conflicting and others activity were also higher in the wet season (Table 2). Only basking activity was recorded higher in proportion during the dry season than in the wet season (Table 2). Although most of the activities differed significantly between the wet season and dry season ($P < 0.05$), there were no significant differences in the proportion of time spent in conflicting between both seasons ($\chi^2 = 0.1251$, $P = 0.7236$).

Diet of **Varanus salvator**

In the territory of Sundarbans mangrove forest, we found *V. salvator* as an extreme carnivore as well as scavenger, and they consume a diversity of food items, mostly found in and around the forest floor and water's edges. The diet of water monitors consisted mainly of crabs (both freshwater and marine), which comprised 13% of the number of identified prey items (Table 3). The rest of the diet covered many other prey groups (Table 3).

DISCUSSION

Water monitors are active from sunrise to sunshine, and the general activity level remains highest during 1200 – 1500 hrs (GAULKE & HORN, 2004). However, TRAEHOLT (1997) revealed that a prominent level of activity starts at early morning (0600-0800 hrs) during the hot and dry season (February, April, August), when they do not spend time basking before the activity period. However, in our observations the study species was more active between 1100 and 1300 hrs. As an ectothermic animal, *V. salvator* obtains heat from environmental sources, and its activity is highly correlated with ambient temperature (GAULKE & HORN, 2004). In this study, most of the activities of *V. salvator* took place when temperatures were between 29°C and 31°C. During winter months

Table 3: Food items consumed by *Varanus salvator* during entire study period in Karamjal eco-tourism spot of Bangladesh Sundarbans mangrove forest.

Sl. No.	Prey group	Prey class	Frequency	Proportion (%)	Data source[a]
1	Ants	Insecta	15	10	DO, SC
2	Cricket	Insecta	4	3	SC
3	Butterfly	Insecta	3	2	DO
4	Centipedes	Chilopoda	1	1	SC
5	Spider	Arachnida	7	5	SC
6	Small Fishes	Actinopterygii	7	5	DO
7	Mudskipper	Actinopterygii	6	4	DO
8	Carps	Actinopterygii	1	1	IS
9	Climbing perch	Actinopterygii	1	1	IS
10	Shrimps	Malacostraca	1	1	DO
11	Prawn	Malacostraca	3	2	DO, SC
12	Crabs	Malacostraca	18	13	DO
13	Snails	Gastropoda	12	8	DO, SC
14	Frog	Amphibia	14	10	DO
15	Toad	Amphibia	7	5	DO
16	Snakes	Reptilia	1	1	IS
17	Snake's eggs	Reptilia	2	1	IS
18	House geckos	Reptilia	1	1	SC
19	Lizards	Reptilia	1	1	DO
20	Crocodile eggs	Reptilia	1	1	IS
21	Bird eggs	Aves	5	3	DO
22	Birds	Aves	3	2	IS
23	Chicken	Aves	5	3	IS
24	Duck	Aves	7	5	IS
25	Mouse	Mammalia	1	1	SC
26	Food scraps from households	Waste	12	8	DO, SC
27	Carcass	Dead animal	2	1	DO
28	Polythene	Plastic	1	1	DO
Total			142	100	

[a]DO = Direct observation, SC = Stomach content, IS = Interview survey

(November and December), when the temperature drops to around 12°C, activities started later and ended earlier than in summer.

In this study, the foraging behavior of *V. salvator* included the combination of walking, swimming and climbing activities. The foraging behavior of *V. salvator* comprises slow, forward progression with progressive swaying of the head from side to side and regular tongue flicking to detect the presence of prey. MAYES *et al.* (2005) described the same foraging activity for *V. mertensi* in both terrestrial and aquatic ecosystems. During the study period, the highest foraging activity was recorded in August because of the suitable environmental conditions and temperature. In August, the average temperature was 26°C. Many of the areas inhabited by *V. salvator* are subject to extreme seasonal change (GAULKE & HORN, 2004). The animals appeared to be more active during the warmer and wetter part of the year, and less active in the dry winter. Monitor lizards also exhibited reduced movement activity under lower ambient temperatures (GREEN & KING, 1978).

Feeding activity of *V. salvator* was mostly seen in the first half of the day and in the afternoon. Temperature was lower during whole November and December compared to other months of the study period, and the lowest feeding activity was also recorded during that time. The feeding activity of *V. salvator* depends on food abundance, local temperature and the size of the animal (TRAEHOLT, 1997). We also observed that during winter months the temperature in the study area and the availability of food was relatively low, and we did not carry out any experiment to find out the relationship between seasonal variation in feeding activity and body size of the animal. Asian water monitors, *V. salvator*, are carnivores, and have a wide range of preys, which vary with respect to the habitat (GAULKE & HORN, 2004). They are known to eat fish, frogs, rodents, birds, crabs, snakes, turtles, young crocodiles and crocodile eggs (WHITAKER, 1981; SPRACKLAND, 1992). In a study by KULABTONG & MAHAPROM (2015), they recorded 15 prey items as part of the water monitors' diet. But in our study, we have found almost 28 food items, including several of the food items recorded by the mentioned authors. LOSOS & GREENE (1988) stated that seasonal and geographical variations of temperature have some effect on the diet of the monitor lizard, which generally agrees with our findings. Monitor lizards are scavengers (UYEDA, 2009; RAHMAN *et al.*, 2015) and like many other monitor lizard species, Asian water monitors also scavenge to fulfill their dietary needs (GAULKE & HORN, 2004; FITZSIMONS & THOMAS, 2016). We also recorded the scavenging activity in *V. salvator* several times, and we observed an adult water monitor eating a piece of polythene bag from an open garbage site near the ecotourism office kitchen. The lizard may have mistaken the polythene for a natural food item found in the surrounding area.

Water monitors spent considerable proportion of time resting in order to relax, sleep or for recovering strength. In this study, the proportion of time spent in resting behavior by *V. salvator* was found higher during the wet season than the dry season. It may be that the study animals were more active proportionately during the wet season of the year and to recover the strength they spent considerable proportion of time resting.

Like other reptiles, most Varanids behaviorally adjust their core body temperature for recovering strength. During winter, most of the Monitor lizards maintain their body temperature by basking, and that is the reason why animals in activity were scarcely observed during the winter months. Varanids bask in sunlight to elevate core body temperature within a narrow-preferred temperature range (BARTHOLOMEW & TUCKER, 1964; CHRISTIAN & BEDFORD, 1996; CHRISTIAN & WEAVERS, 1996). It is well known that during the night, monitor lizards' body temperatures drop below ambient, and that in the following day they must raise it by basking before commencing foraging and other activities (ABAYARATNA & MAHAULPATHA, 2006). When their body temperature increases extremely, they move to the shade. Therefore, thermoregulation actively influences the behavior and habitat selection of *V. salvator*.

Conflicting is another type of behavior showed by the water monitors that we observed during field study. In the wild habitat, *V. salvator* are almost solitary. Much of the daytime is spent in constant movement, searching for food. Monitor lizards are more likely to interact with one another during the peak breeding season, when males compete for mates (AUFFENBERG, 1981). Ritual combat in *V. salvator* has been noticed several times both in the wild and captivity (HORNE *et al.*, 1994; GAULKE & HORN, 2004). Nonetheless, in this study conflicting behavior appeared for the competition of food only. The actual clash generally arises with the jungle crow and domestic dogs. We encountered the same conflicting behavior in the case of *V. bengalensis* (RAHMAN *et al.*, 2015).

Other types of activity performed by *V. salvator* in this study, are the fusion of some miscellaneous activities like hiding, escaping and courtship, which were rarely observed during fieldwork. As *V. salvator* is an aquatic species, sometimes during the active period and data collection they remained submerged under water. In the same way, they sometimes hide or camouflaged themselves in the bushy areas or in burrows for different purposes.

As mentioned above, the activity patterns of water monitors are significantly influenced by environmental variables. Seasonal climatic conditions also play major roles in the case of their activity patterns. Like other semi-aquatic lizard, monitor lizards also show similar geographic and seasonal variations in activities (LOSOS & GREENE, 1988). During summer months, in different habitats our study species was more active during the first and last half of the day (0900 – 1200 hrs and from 1530 – 1700 hrs), because during that time ambient temperature was more suitable for their activity patterns, but they were less active during 1300-1530 hrs, as at this time the temperature was too high for them to forage. Hence, during hot midday sometimes their activities were recorded from shady and bushy areas of the habitats. Nevertheless, in a report by GAULKE & HORN (2004), they mentioned that water monitors' general activities were more important between 1200 – 1500 hrs of the day. IBRAHIM (2000) also noted that there is a significant variation in the activity level of monitor lizard within a 12-hour period.

In winter months, water monitors were less active throughout the day during the study periods. There were significant differences between summer and winter months' activity patterns of water monitor in different habitats. During this time, they were often found basking near the river and canal edges and sometimes upon a fallen tree trunk to regulate their body temperature. In winter months *V. salvator* were more active during 1300 – 1530 hrs of the day and were less active between 0900 – 1200 hrs and from 1530 – 1700 hrs of the day. However, data from different countries reveal that water monitors activities remain with a peak throughout the year during mid-half of the day (GAULKE & HORN, 2004). Nevertheless, our study discloses that just in winter months water monitors remain more active during mid-half of the day. Since water monitors are ectothermic animals and they have physiological constrains regarding thermoregulation, the influences of environmental variables upon their activities in different habitats either in summer or in winter should not be ignored.

Our field observations suggest that for feeding purposes *V. salvator* remains active in a variety of habitats of Sundarbans, from floodplains, marshy lands, farmlands and scrublands to forests floor, and prefers to live in lowlands and swamps near riverbanks or the edge of water bodies. However, due to anthropogenic factors and development activities, its habitat is shrinking, and its population is also decreasing day-by-day in an alarming rate. Monitor lizards have the status of protected species by Schedule-I of Wildlife (Conservation and Security) Act 2012 of Bangladesh (IUCN Bangladesh, 2015), but most of the rural people are not aware of that. Therefore, together with illegal trade, rural people kill monitor lizards just based on some myths and misconceptions and children often play the key role in killing them (RAHMAN *et al.*, 2017). Although all species of monitor lizards found in Bangladesh are non-venomous, people kill them just because they think monitor lizards are venomous and a threat to people. To ensure their existence in the human-dominated ecosystems of Bangladesh there is an urgent need to raise consciousness among the local people regarding these species including water monitors.

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Bioethical considerations

Data were collected following the appropriate direction from the Bangladesh forest department. While the study was conducted, no animals were harmed or injured intentionally or unintentionally. We paid close attention to the code, conduct and legislation for the care and use of animals for research purposes during the study.

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