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**ECOLOGICAL ADAPTATION OF MONITOR LIZARDS (REPTILIA:
VARANIDAE) IN THE ALTERED HABITATS AND THEIR
CONSERVATION IN THE TROPICAL ECOSYSTEMS OF BANGLADESH**

Specialty 03.02.04 – Zoology

Abstract to fulfill the requirements of the degree of
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The dissertation can be found in the library and on the website of Kazan (Volga Region) Federal University (<http://kpfu.ru>).

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General description of the work

Relevance of the Study: Human economic activities have dramatically increased the rates of species and population extinction (Vitousek et al., 1997). In these conditions, issues like the protection of natural ecosystems and the conservation of the biota that inhabits it will become even more difficult. Intensive anthropogenic transformation of natural landscapes in virtually all regions of the globe, population growth and global environmental pollution makes the relationships between humans and biodiversity more complicated day by day. This provision is fully applicable to the People's Republic of Bangladesh, located in one of the densely populated regions of South Asia, facing today the complexity of the socio-economic and environmental issues. In this situation, the unique animal diversity of the country which is facing great threats from different direction demands extra care and protection for their existence in our surrounding ecosystems.

Until today no systemic and broad scale study was carried out addressing the ecology and behavior of reptiles of Bangladesh, mainly focusing the representatives of monitor lizards (Reptilia: Varanidae). Monitor lizards are medium to large sized lizards, attracting attention, many of which require strict protection. Anthropocentric pressures, whether directly or indirectly, are considered the primary threats to biodiversity loss across Bangladesh with animal numbers decreasing from environmental change. However, some species, including monitor lizards, are more flexible in their behavior which allows them to adapt to human altered ecosystems. These issues have not been studied before and current study made it possible to expand our knowledge about the various aspects of the ecology of monitor lizards in the conditions of anthropogenic pressure. The results are important for changing the public attitude towards monitor lizards and other reptiles, for understanding the importance of the monitor lizards in the ecosystems of Bangladesh and their status in our surrounding ecosystems. To date, there is an insignificant number of works devoted to the issues of ecological adaptation of the monitor lizards, therefore the conducted research expands our knowledge about the ecological features of the representatives of the family Varanidae.

Goals and Objectives: The overall goals of this study were to examine and provide background information on the adaptive ecology of monitor lizards and other aspects related to their conservation in diverse types of altered ecosystems of tropical Bangladesh. The specific objectives were as follows –

1. Ecology and behavior - to study ecological and behavioral adaptations of monitor lizards in anthropogenic ecosystems and to assess the adaptation mechanisms in various changing habitats.
2. Habitat ecology - to investigate the habitat status and habitat preference ecology of the monitor lizards inhabiting the territory of Bangladesh.

3. Comparative ecology - to conduct comparative characteristics of diet, daily activity, behavior and other aspects of the ecology of the three species of monitor lizards (*Varanus bengalensis*, *V. flavescens* and *V. Salvator*).
4. Public attitudes - to investigate the human perceptions toward monitor lizards.
5. Conservation issues - to evaluate and prepare conservation actions for the protection of monitor lizard populations in the territory of Bangladesh.

Materials and research methods

The research was carried out in the different human-dominated ecosystems of tropical Bangladesh from 2014 to 2018. A variety of methods were employed to conduct this research. The adaptive ecology and activity patterns of monitor lizards were examined in both humid-summer (March to May), wet (June-September) and dry seasons (October to May). Observation and counting of monitor lizards in the study areas were carried out using Visual Encounter Survey (VES). The daily and seasonal activities of the study species were measured using focal sampling method. The microhabitat characteristics of study lizards and associated microclimatic variables were measured using field sampling in different sheltering habitats. Conservation related issues and public attitudes toward monitor lizards were carried out using interview survey method. In addition, qualitative data was collected through focus group discussion with local people.

Visual Encounter Survey (Heyer *et al.*, 1994) was followed for observing and counting the study monitor lizards. These surveys generally comprised walking through a forest trail or specific transect line to check for sheltering animals. Whenever we encountered a monitor lizard, instantly the species name, sighting time, number of observed individuals and size class (either juvenile or adult) were recorded in a data sheet. In the same time, we also recorded data on temperature, humidity and precipitation in the locations of encounter.

The activity patterns of monitor lizards were studied using 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 and Bateson, 1986). Focal sampling was carried out at several fixed sites in each of the study areas (Savar, Chalan Beel and Sundarbans).

Besides field observation and interview with local people, stomach content samples were also taken from the field-captured monitor lizards to examine its diet in this study. Field-captured monitor lizards were stomach-flushed to collect the dietary items (Mayes *et al.*, 2005).

Public attitudes toward monitor lizards and their conservation related issues were carried out using interview survey method. In addition, qualitative data was collected through focus group discussion with local people and experts.

For the conservation of monitor lizards, we emphasized on awareness buildup program among the local people. In this regard, we arranged open discussion and popular lectures using multimedia projector regarding the beneficial role and importance of monitor lizards. Besides these, we also collect experts' opinion to formulate recommendations concerning the conservation of monitor lizards.

The activities of monitor lizards were observed with the aid of NIKON 10 × 50 binoculars. Temperatures were recorded by using mercury thermometer and photograph of the vegetation types and lizards were taken by using NIKON D3200 with a lens of Tamron 70-300 mm.

Scientific Novelty of the study: For the first time in the tropical ecosystems of Bangladesh, studies were carried out on the features of behavioral and adaptative ecology of three species of monitor lizards: the Bengal (*Varanus bengalensis*), the yellow monitor (*Varanus flavescens*), the water monitor (*Varanus salvator*). Currently, a number of known works dedicated to representatives of the family Varanidae. Some of the notable works on monitor lizard's species are: Komodo Monitor *Varanus komodoensis* (Auffenberg, 1981), Grey's Monitor *Varanus olivaceous* (Auffenberg, 1988), Mertens's water monitor *V. mertensi* (Mayes *et al.*, 2006), Water monitor *Varanus salvator* (Uyeda, 2015) and the Bengal monitor *Varanus bengalensis* (Auffenberg, 1994; Dey, 2016). All these previous works contain materials on diet and dietary behavior, the regimen of thermoregulation, and the reproductive cycle of these species under various conditions. The results of this research work are devoted to diet, daily and seasonal activity, habitat preferences, the distinctiveness of developing new ecological niches, and the issues regarding the conservation of *V. bengalensis*, *V. flavescens* and *V. salvator* inhabit the human-dominated ecosystems of tropical Bangladesh. The most complete literary materials were collected through different media, and analysis of data on the distribution patterns, population densities, ethology and conservation status of the monitor lizards on the territory of Bangladesh and adjacent countries of southern Asia was carried out. New information on the diet, daily and seasonal activity patterns and relative habitat preferences of the monitor lizards was obtained in the conditions of active anthropogenic influence on natural ecosystems of selected study areas. The influence of anthropogenic and environmental factors on the behavior and spatial distribution of monitor lizards were also investigated and analyzed.

For the first time, a study has been carried out regarding the sympatric association of the three species of monitor lizards in the territory of Bangladesh, where, the populations of the study species overlap. Regional characteristics of the patterns of activity, species specific dietary behavior, foraging strategy, daily activity in various types of habitat had been also taken into account to carry out this study. Seasonal changes in diet and activity of the representatives of three study species of monitor lizards were investigated as well. Identified potential threats to the monitor lizard populations and public attitudes toward the study species allowed the preparation of

recommendations for the conservation of monitor lizards in human-dominated ecosystems of the tropical Bangladesh.

Practical significance of this work: Data on the ecology of the monitor lizards and assessment of their level of adaptation in different types of habitats of tropical Bangladesh can serve as a basis for further study of the ecology of reptiles in Bangladesh and contribute to the herpetological research.

It is difficult to protect wildlife in conditions of further growth of economic activity and human influence on natural ecosystems, and for this specific data on animal populations and their role in changing ecosystems of the entire region is needed. The solution of these problems is especially important for regions with a high degree of anthropogenic transformation of natural landscapes and high population density, which is typical for the Republic of Bangladesh.

New information on the ecology, adaptation assessment, public attitudes and recommended strategies for the conservation of *V. bengalensis*, *V. flavescens* and *V. salvator* is the first board scale field level study results obtained by carrying out research in the human-dominated ecosystems of Bangladesh. These materials were used in the development of nature conservation courses, disciplines of zoology and biogeography, taught at the Department of Bioecology, Hygiene and Public Health of Kazan Federal University. The study results can also be recommended for students of biology at the universities in Bangladesh.

Fundamentals issues and results of the research to be defended:

1. Anthropogenic transformation of natural landscapes of Bangladesh has led to changes in the distribution, as well as the features of the ecology and behavior of the representatives of the family of Varanidae.
2. Factors influencing the population size and distribution of monitor lizards are human activities and a complex of physical and geographical conditions of a specific area: seasonal temperature variations, water quality, prey abundance, predator pressure and some other natural phenomena (high and low tide, etc.).
3. *V. bengalensis*, *V. flavescens* and *V. salvator*, found in the tropical ecosystems of Bangladesh, are now actively adapting to the anthropogenic transformation of natural habitats and exhibit the features of synanthropization.
4. In the natural and seminatural ecosystems to avoid the intense competition among themselves the three species of monitor lizard inhabit different ecological niches.

Reliability and approbation of the research results: The research results were presented and discussed at the International Scientific and Practical Conference "Complex Problems of Technosphere Safety" (Voronezh, 2015); International Scientific and Practical Conference "Modern Trends in Scientific Activity" (Moscow, 2015); Russian scientific and practical conference "XXVII Reading in honor of ecologist and zoologist, Professor Viktor Alekseevich Popov" (Kazan, 2016); Russian

scientific and practical conference "XXIX Reading in honor of ecologist and zoologist, Professor Viktor Alekseevich Popov" (Kazan, 2018); and VI International Ornithological Conference "Modern problems of ornithology in Siberia and Central Asia" (Irkutsk, 2018).

Publications: On the topic of this dissertation a total of 15 articles have been published in different national and international peer-reviewed journals and conferences. Among these, 3 papers published in leading peer-reviewed journals included in the list of VAK (Higher Attestation Commission of the Russian Federation). 4 articles published in the journals included in the *SCOPUS* database and 1 paper accepted for publication in *Wed of Science* indexed journal.

Personal contribution of the author: The author himself has done the full research work in the territory of tropical Bangladesh. Field surveys, the planning and execution of all activities related to the collection of data and sociological surveys were also carried out by author himself.

Structure and formation of the dissertation: The structure of this study was formed in accordance with the objectives and tasks set before. The dissertation consists of introduction, 7 chapters, conclusions, list of references and appendices. The total volume of the dissertation consists of 145 pages, it contains 34 figures, 17 tables and 5 appendices. The list of references includes 215 sources, of which 4 are in Russian.

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MAIN CONTENT OF THE WORK

In the introduction section of the study, the relevance of the chosen topic of the dissertation is described, the practical significance of the study is characterized, goals and objectives are formulated, the subject and object of research are selected. Fundamental issues and results of the study is selected for defense.

The first chapter of the dissertation describes the general characteristics of the family Varanidae, their local and global distribution and status, diversity, features of biology and ecology.

Section 1.1 describes general information about monitor lizards, including their morphological features, their origin and distribution. The monitor lizards (Reptilia: Varanidae) are the largest of the extant lizards and show a uniformity of structure not seen in the other groups. Controversy exists regarding the total number of monitor lizard species. One of the comprehensive lists of monitor lizards found in the website

of Reptile Database where, a total of 79 species of monitor lizards are currently enlisted.

Monitor lizards are adapted to a variety of habitats, ranging from mangrove swamps to dense forests to savannas to arid deserts. Some species are aquatic, some semi-aquatic and others terrestrial, while others are saxicolous or semi-arboreal or truly arboreal. Monitor lizards are widely distributed throughout the world. Today they are found throughout most of Africa, southern Asia-including Arabia, Iran, India, Indochina, and Indonesia- New Guinea, and Australia.

Section 1.2 deals with the global distribution and conservation status of monitor lizards that inhabit ecosystems of Bangladesh. Among the three species of monitor lizards, the most common is the Bengal monitor lizard (*V. bengalensis*). The area covers a vast territory, and the boundary of distribution extends from southeastern Iran through the south of Central Asia. Globally *V. bengalensis* has been assessed as Least Concern. The yellow monitor or golden monitor, *V. flavescens*, is a species of monitor lizard found in Asia. In southern Asia, their presence has been reported in the floodplains of Indus, Ganges, and Brahmaputra rivers of Northern India, Bangladesh, Nepal, Myanmar and Pakistan. The monitor has been categorized as Lower Risk/Least Concern in IUCN Red Data List assessed by World Conservation Monitoring Centre. Water monitor (*V. salvator*) is extremely widespread throughout southern and Southeast Asia *V. salvator* has been assessed as Least Concern (IUCN, 2017).

Section 1.3 shows the distribution and status of monitor lizards in Bangladesh. The Bengal monitor lizard (*V. bengalensis*) is widely distributed throughout Bangladesh. Nationally the species is categorized as near threatened. The yellow monitor lizard (*V. flavescens*) is also thought to be found throughout Bangladesh but is mainly found in swampy areas. Nationally the species is categorized as near threatened. Usually, water monitor lizards (*Varanus salvator*) are found in the southern coastal areas of Bangladesh. As its habitat is shrinking due to anthropogenic factors and development activities, and its population is also decreasing day by day. That's why in Bangladesh *V. salvator* has been categorized as Vulnerable (IUCN Bangladesh, 2015).

In section 1.4 adaptation of monitor lizards to different environmental conditions and habitat is presented. Ecologically, monitor lizards show a wide variety of adaptations. Various forms of anthropogenic factors directly or indirectly contribute to the reduction of species throughout the country (Khan, 2008; Khan et al., 2016). However, monitor lizards, are more tolerant and flexible in their behavior, which allow them to adapt to a wide range of ecosystems, including human-dominated ecosystems.

In section 1.5 the seasonal activity of monitor lizards is presented based on literature review. Like other lizards, monitor lizards also show seasonal dependence on temperature and precipitation for their activities. In warm tropical regions, these monitor lizards are active in May – August, the remaining months they usually hibernate under various sheltering ground (Pianka et al., 2004).

Section 1.6 focuses on the conservation initiatives in Bangladesh for the protection of monitor lizards. Not only in Bangladesh but also the global populations of monitor lizard are facing formidable threats created by human that testing their ability to survive and reproduce. They are forced to either adapt to changing life with humans or face extinction. Bangladesh vast biodiversity supports three Varanid species, which get legal protection by the Ordinance of the Government of the People's Republic of Bangladesh (Khan, 2008; IUCN Bangladesh 2015). But conservation organizations give very little attention to protect monitor lizards.

The second chapter describes the physiographic characteristics of Bangladesh and the study areas.

Section 2.1 represents the geographic allocation, seasonal climate, topography and ecosystem composition of Bangladesh.

Geographically the country is located between 20°34'-26°33' North latitudes and 88°01'-92°41' East longitudes. Bangladesh is bordered on the west, north, and east with India and, in the southeast with Myanmar. Bangladesh has a tropical monsoon climate characterized by wide seasonal variations in rainfall, elevated temperatures, and high humidity. Bangladesh can be divided into three main physiographic divisions – Tertiary hills, Pleistocene terraces and recent plains. The Tertiary hills are situated in Greater Chittagong and Chittagong Hill Tracts, and Sylhet areas. The diverse forest ecosystems of the country are biodiversity rich. The forests of Bangladesh have been classified into four ecological categories 1) mixed-evergreen forest, 2) deciduous forest, 3) freshwater swamp forest and 4) mangrove forest.

Section 2.2 discusses about the study area Savar region including a location map, physiography and biodiversity. The vast and diverse ecosystems of the Savar region comprise hundreds of wildlife species of national and international importance. Of the three-study species of monitor lizards, two species inhabit Savar, namely *V. bengalensis* and *V. flavescens*.

Section 2.3 describes the study area of Chalan Beel. The Chalan *beel* is the largest and most important watershed in northern part of Bangladesh. The *beel* is a Bengali term used for relatively large surface, static waterbody that accumulates surface run-off water through an internal drainage channel. The Chalan beel and its adjacent areas are enriched with biodiversity. Two species of monitor lizards *V. bengalensis* and *V. flavescens* inhabit this region.

Section 2.4 represents the study area Sundarbans, the world's largest mangrove forests. Sundarbans is intersected by a complex network of tidal waterways, mudflats and small islands of salt-tolerant mangrove forests. The Sundarbans forest is about 10,000 sq. km across India and Bangladesh, of which 60% lies in Bangladesh. The three wildlife sanctuaries of Sundarbans cover an area of 317,950 ha and are considered core breeding areas for several endangered species. A total of 1,397 km² of the three wildlife sanctuaries (Sundarbans East, Sundarbans South and Sundarbans West) of the

Bangladesh Sundarbans form a UNESCO World Heritage Site. The Sundarbans provides a unique ecosystem and a rich wildlife habitat. Sundarbans is the home of the Bengal tiger. The study of the species *Varanus salvator* is also found mainly in Sundarbans.

The third chapter is devoted to the materials and methods that we used to conduct this study.

Section 3.1 presents fieldwork. The study was conducted in various anthropogenic ecosystems of tropical Bangladesh from 2014 to 2018. In addition to this, we used data on activity patterns of *V. bengalensis* conducted in the Jahangirnagar University campus as part of my master's thesis work from 2010 to 2011. A variety of methods were employed to conduct this research.

Section 3.2 describes the focal sampling method which is used to assess the activity patterns of monitor lizards in which data were recorded continuously for 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 and Bateson, 1986). The activities of monitor lizard were recorded in six distinct categories: foraging, feeding, resting, basking, conflicting and others (combination of some miscellaneous minor activities).

Section 3.3 deals with the methods used to analyze the diet of monitor lizards. Besides field observation and interview with local people, stomach content samples were also taken from the field-captured monitor lizards to examine its diet in this study.

Section 3.4 describes the field sampling method used to assesses the relative habitat uses of monitor lizards. For habitat study we surveyed almost all types of habitat found in the study area which includes natural and semi natural forest, homestead forest, agricultural land, large and small water bodies, slow moving canal and river. Habitat characteristics were also recorded collecting data regarding soil type, vegetation structure, weather condition, water and soil temperature and type.

Section 3.5 describes the social survey method which is used to assesses the attitudes of local people towards monitor lizards. Public attitudes, belief in myths, and knowledge of monitor lizards are measured by a set of questionnaires where a total of 9 questions were asked. In addition, qualitative data was collected through focus group discussion with local people and experts. For the conservation of monitor lizards, we emphasized on awareness buildup program among the local people. Besides these, we also collect experts' opinion to formulate recommendations concerning the conservation of monitor lizards.

The fourth chapter deals with the results of activity patterns, food and feeding behavior of monitor lizards.

Section 4.1 is devoted to the time budget and activity patterns of monitor lizards. The active time of *V. bengalensis* and *V. salvator* varied significantly during this study.

However, for *V. flavescens*, active time were not varied significantly. Most of the *V. bengalensis* (68.71%, n = 292), *V. flavescens* (50.54%, n = 235) and *V. salvator* (47.60%, n = 139) were seen active first half of the day. Whereas, *V. bengalensis* (14.12%, n = 60) were less observed during mid half of the day but *V. flavescens* (22.37%, n = 104) and *V. salvator* (15.75%, n = 46) were less seen during last half of the day (figure 1).

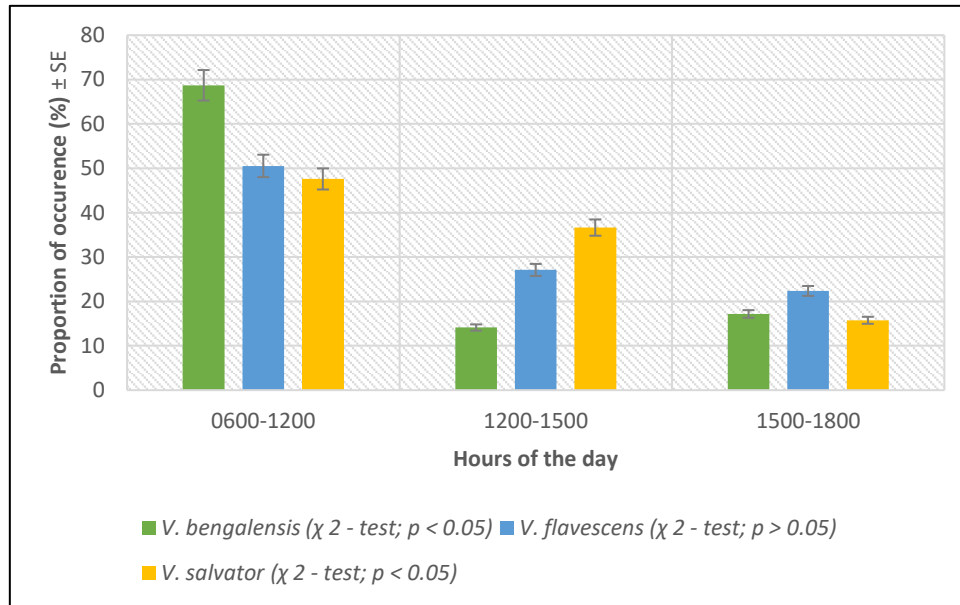


Figure 1 Proportion of sightings of monitor lizards in different half of the day throughout the study period.

Table 1 The mean (\pm SE) proportion of time (%) spent on different activities by *V. bengalensis*, *V. flavescens* and *V. salvator* for the humid summer, wet and dry season.

Activity	Species Name	Humid summer	Wet season	Dry season	χ^2	P-Value
Foraging	<i>V. bengalensis</i>	45.00 \pm 2.18	36.36 \pm 1.78	21.01 \pm 1.50	105.53	0.0001
	<i>V. flavescens</i>	46.32 \pm 2.63	41.50 \pm 1.72	23.08 \pm 1.26	106.18	0.0001
	<i>V. salvator</i>	36.97 \pm 1.74	39.63 \pm 1.58	16.70 \pm 1.17	146.22	0.0001
Feeding	<i>V. bengalensis</i>	28.13 \pm 1.70	29.51 \pm 1.95	16.63 \pm 1.51	61.83	0.0001
	<i>V. flavescens</i>	25.76 \pm 1.62	28.78 \pm 1.82	10.08 \pm 1.03	139.24	0.0001
	<i>V. salvator</i>	32.11 \pm 1.74	29.95 \pm 1.58	17.08 \pm 1.41	67.35	0.0001
Resting	<i>V. bengalensis</i>	16.44 \pm 0.91	22.08 \pm 1.76	14.18 \pm 2.67	35.20	0.0001
	<i>V. flavescens</i>	16.09 \pm 1.22	19.65 \pm 1.55	2.02 \pm 0.56	200.04	0.0001
	<i>V. salvator</i>	17.19 \pm 1.55	19.54 \pm 1.17	14.43 \pm 2.67	13.50	0.0012
Basking	<i>V. bengalensis</i>	2.00 \pm 0.32	0.32 \pm 0.16	41.72 \pm 4.55	1574.63	0.0001
	<i>V. flavescens</i>	2.31 \pm 0.53	0.34 \pm 0.19	53.54 \pm 4.62	1918.45	0.0001
	<i>V. salvator</i>	3.07 \pm 0.83	0.29 \pm 0.14	44.95 \pm 4.66	1578.24	0.0001
Conflicting	<i>V. bengalensis</i>	4.00 \pm 0.53	4.18 \pm 0.84	2.82 \pm 0.55	4.73	0.0939
	<i>V. flavescens</i>	3.68 \pm 0.78	3.10 \pm 0.78	2.91 \pm 0.79	1.09	0.5798
	<i>V. salvator</i>	2.81 \pm 0.63	3.59 \pm 0.85	3.42 \pm 0.71	1.66	0.4360
Other	<i>V. bengalensis</i>	4.43 \pm 0.54	7.55 \pm 0.66	3.64 \pm 0.77	28.90	0.0001
	<i>V. flavescens</i>	5.78 \pm 0.91	6.62 \pm 1.12	8.36 \pm 1.30	6.03	0.0490
	<i>V. salvator</i>	8.86 \pm 1.18	7.00 \pm 0.55	3.42 \pm 0.33	30.48	0.0001

Section 4.2 shows the monthly and seasonal activity of monitor lizards. The activity patterns of monitor lizards differed among months and seasons. Overall,

monitor lizards were most active in July. Activity was clearly different among different months for both *V. bengalensis*, *V. flavescens* and *V. salvator*. Monitor lizards were most active during the wet season or monsoon season. The behavior of *V. bengalensis*, *V. flavescens* and *V. Salvator*, in general, differed in different periods of the year. During the dry season, basking in the sun for all three types of monitor lizards was almost completely absent. However, significant changes over time for individual behavioral patterns (Test χ^2 ; $P < 0.05$) were observed during the humid summer period, relative to the dry season of the year (Table 1).

Section 4.3 describes the factors affecting the activity patterns of monitor lizards. For monitor lizards, the manifestation of certain behavioral acts depends not only on the diurnal or seasonal fluctuation of temperature and humidity, but also on several other environmental factors. In addition to temperature, abundance of prey, predation pressure, water quality and tidal effect also play significant role in determining the activities of monitor lizards.

Section 4.4 is devoted to the diet of the monitor lizard. Monitor lizards are used to a different group of prey items to fulfill their dietary needs. During this study, ants were the most predominant prey items (15.18%) consumed by *V. bengalensis* while for *V. flavescens*, beetles were the most frequently eaten prey group (10.10%). Whereas, the diet of *V. salvator* consisted mainly of crabs (both freshwater and marine), which comprised 12.68% of the number of identified prey items. Besides natural prey items monitor lizards in the anthropogenic landscapes of Bangladesh largely depend on anthropogenic food sources to fulfill their dietary needs.

Section 4.5 describes the behavioral responses of monitor lizards to anthropogenic disturbances. Research has shown that among the three species of monitor lizards, relatively *V. bengalensis* are behaviorally well adapted to the human-dominated landscapes of Bangladesh.

The fifth chapter describes the habitat of monitor lizards in the territory of tropical Bangladesh.

Section 5.1 deals with the potential habitat types used by monitor lizards in Bangladesh. In the human-dominated ecosystems of Bangladesh Bengal monitors are adapted to diverse types of habitat. Highest proportion of *V. bengalensis* (22.24%, $n = 103$) used garden floor as their preferred habitat (figure 2). The highest proportion of *V. flavescens* (24.52%, $n = 114$) were found in and around the aquatic ecosystems of *beel* and the lowest proportion (2.80%, $n = 13$) were seen in irrigated areas (figure 3). During entire study period, forest floor of Sundarbans mangrove forest was the most preferred habitat for *V. salvator* and maximum proportion of individuals (23.60%, $n = 69$) were found there (figure 4).

Section 5.2 shows the influence of various factors on the habitat use patterns of monitor lizards. Not only natural factors, but also anthropogenic factors play a significant role in choosing the habitat of the monitor lizards. In summer time they

prefer to live in shady places but during winter mostly they remain inactive. Since, monitor lizards are poikilothermic animals, the influence of environmental variables and other natural phenomena upon its activities in different habitats either in summer or in winter, should not be ignored.

Section 5.3 describes the relative habitat preference ecology of three species of monitor lizards living in Bangladesh. Monitor lizards are sympatric species with certain competitive relationships, but in the anthropogenic landscapes of Bangladesh, ecological niches have been formed which reduce the degree of competition. This study also reveals that, *V. bengalensis*, *V. flavescens* and *V. salvator*, found in the tropical ecosystems of Bangladesh, are now actively adapting to the anthropogenic transformation of natural landscapes and exhibit the features of synanthropization.

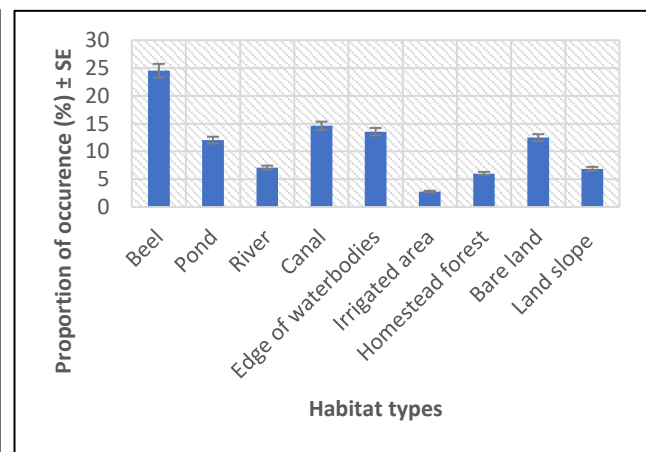
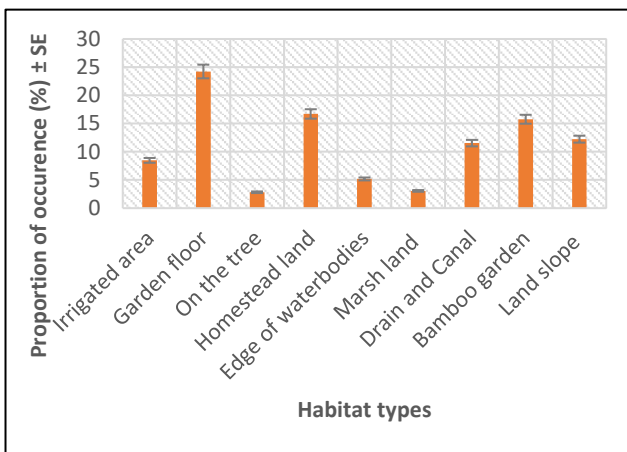


Figure 2 Relative habitat preferences of *V. bengalensis* throughout the study period.

Figure 3 Relative habitat preferences of *V. flavescens* throughout the study period.

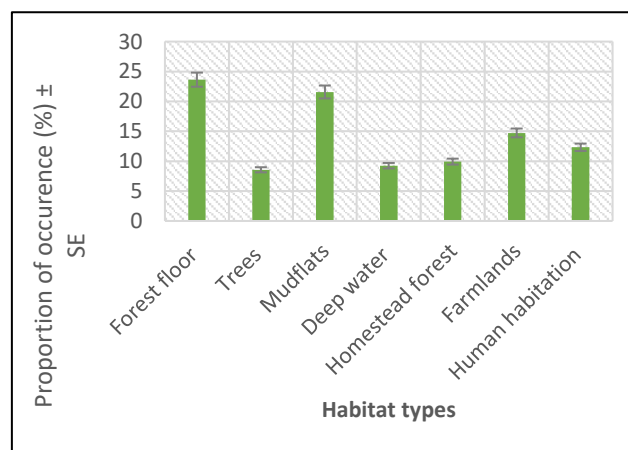


Figure 4 Relative habitat preferences of *V. salvator* throughout the study period.

Chapter six examines the public attitudes toward monitor lizard populations of Bangladesh. The success of adaptation and the protection of monitor lizards in the anthropogenic landscapes of Bangladesh depends on the kindness of the people and the

awareness of the local people regarding the features of the biology and ecology of the monitor lizards.

In **section 6.1** local people's species level identification knowledge is assessed. Based on the participants opinion it was found that *Varanus bengalensis* is mostly known (58 ± 2.20), and *Varanus salvator* is the least known (22 ± 3.48) species among the three species of monitor lizards found in Bangladesh.

Section 6.2 exposes the public opinion about monitors. Several questions have been asked to local peoples to know their attitudes toward monitor lizards. During this study, the highest proportion of participants (77 ± 0.50) mentioned that monitor lizards are snakes and a small proportion of participants (23 ± 0.50) mentioned that they are not snake they are lizard. It was also found that among all participants, major proportion (63 ± 1.53) believe that monitor lizards are venomous, and they can attack and bite people.

Participants opinion regarding the ecological importance of monitor lizards was very positive. Most of them (71 ± 1.27) believed that monitor lizards play significant role in our ecosystems, and only a small proportion (29 ± 1.27) of the participants responded negatively.

Regarding the conservation and protection issues of monitor lizards nationally, most of the participants (56 ± 1.35) agreed that there are no alternatives of awareness building if we are to conserve them in our surrounding ecosystems.

Section 6.3 reveals public knowledge on Bangladesh Wildlife (Conservation and Security) Act 2012. The interview result reveals that only a very few proportion ($8.00 \pm 0.40\%$) of interviewed local people knew (i.e. knew the basic features) about the existence of Bangladesh Wildlife (Conservation and Security) Act 2012 and surprisingly, most ($64.00 \pm 1.15\%$) of the local people did not even know the existence of the such act.

Chapter seven deals with potential threats to the monitor lizards and their conservation scenario in Bangladesh.

Section 7.1 describes the main threats to monitor lizards in Bangladesh. Monitor lizards are facing several threats that test their ability to survive and reproduce in the human-dominated ecosystems of Bangladesh. Based on expert opinions following is the list of threats that responsible for the population decline of monitor lizards throughout the country: habitat loss and fragmentation, lack of awareness of the local community regarding the importance of monitor lizards, limitations of the *law* and *lack* of implementation, excessive use of pesticides and other pesticides, pollution of the habitat, expansion of agricultural land, development of human settlements, the growth of cities and their infrastructure, and the impact of forest fires (Table 2).

Section 7.2 presents conservation activities in Bangladesh. Varanids occur in many protected areas across its extensive range and it is protected as a part of wildlife,

which get legal protection by the Ordinance of the Government of the People's Republic of Bangladesh. Our study revealed that though several number of conservation and management programme are running in Bangladesh to protect the wildlife of Bangladesh but monitor lizard populations always remain out of consideration in these types of conservation initiatives.

Table 1 Importance of the individual threat factors based on its level of impact (%) on the survival of monitor lizard populations by expert opinion.

Sl. No.	Identified threat factors	Impact levels			
		Level 0	Level 1	Level 2	Level 3
Direct threat					
1.	Retribution killing	0	28	32	40
2.	Illegal hunting for meat and traditional medicine	72	12	16	0
3.	Poaching for local or international commercial purpose	80	16	4	0
4.	Myth and misconceptions	0	24	32	44
5.	Domestic dog attack	44	56	0	0
6.	Accidental death	0	52	48	0
Indirect threat					
7.	Habitat loss and fragmentation	0	0	16	84
8.	Agricultural expansion	0	28	44	28
9.	Human settlement and infrastructure development	0	24	52	24
10.	Pesticides and other agrochemicals	0	32	24	44
11.	Tourism and pollution	0	32	32	36
12.	Fire	60	20	12	8
13.	Disease	76	24	0	0
14.	Lack of awareness of the local community regarding the importance of monitor lizards	0	0	24	76
15.	Limitations of the law and lack of implementation	0	0	28	72

Section 7.3 shows our taken steps and initiatives for the conservation of monitor lizards and their habitats in Bangladesh. Man is the biggest threat to the monitors living in the anthropogenically transformed landscapes of Bangladesh. In the course of this study, we set the task not only to conduct awareness buildup programs, but also to evaluate the role of various programs and projects activities for the conservation and management of wildlife in Bangladesh, carried out by the government and non-governmental organizations. However, it was matter of disappointment that all the projects were mainly natural forest or coastal area ecosystem based. Human-dominated ecosystems and animals like monitor lizards most of the cases remain out of consideration in these types of conservation initiative.

Section 7.4 provides recommendations for intensifying the conservation of monitor lizards in Bangladesh. Based on our real-life experience during fieldwork, expert

opinions and after reviewing the work and initiatives of different conservation and management organizations of Bangladesh we recommend several suggestions for the conservation of Monitor lizards.

The **conclusions** formulated the main results of the study:

1. The activity pattern of monitor lizards is divided into behavioral acts related to the foraging, feeding, resting, basking, conflicting and few other miscellaneous activities. In general, monitor lizards spent a highest proportion of time (34.91%) in foraging and lowest proportion of time (3.46%) in conflicting throughout the year. Monitor lizards spent second highest proportion of time (25.57%) in feeding and they spent 17.15% and 12.43% time in resting and basking respectively.
2. The activity and habitat use pattern of monitor lizards of Bangladesh greatly influenced by seasonal temperature variations, prey abundance, predation pressure, water quality and some other natural phenomena. Since *V. salvator* are more frequently found in the coastal areas of Bangladesh, the influence of low and high tide upon its activities in different habitats either in summer or in winter, should not be ignored.
3. Besides natural prey items monitor lizards in the anthropogenic landscapes of Bangladesh largely depend on anthropogenic food sources to fulfill their dietary needs. Both *V. bengalensis*, *V. flavescens* and *V. salvator* found in the tropical ecosystems of Bangladesh are typically synanthropic species and they have been particularly successful in settling and persisting in landscapes with relatively high human densities because of the availability of domestic fowl and scraps food materials from households. Scavenging on waste and domestic fowl depredation by monitor lizards occurs widely across Bangladesh.
4. Three species of monitor lizards are sympatric species with certain competitive relationships, but in the anthropogenic landscapes of Bangladesh, ecological niches have been formed which reduce the degree of competition. As a terrestrial animal *V. bengalensis* occurs in wide range of habitats, but more frequently found near human settlement, while semi-aquatic *V. flavescens* are well adapted to in and around freshwater marshes. However, water monitor (*V. salvator*) as their name suggests, are rarely found far from water and they have no trouble swimming long distances. This ability has allowed them to colonize many remote coastal islands like Sundarbans.
5. The food and feeding habits, foraging sites and substrate use patterns of monitor lizards varied significantly among different seasons of the year, which allows them to coexist in one territory without pronounced trophic competition. Monitor lizards are used to almost 30 different group of prey items to fulfill their dietary needs. More than 20% of the consumed food item of *V. bengalensis* are anthropogenic origin. The process of the synanthropization of monitor lizards took place in the direction from accustomed to anthropogenic environment, in

the subsequent foraging, feeding, nesting near human habitation and finally which ended up with the formation of synanthropic populations.

6. Anthropocentric pressures, whether directly or indirectly, are considered the primary threats to biodiversity loss across Bangladesh with animal numbers decreasing as a response to adverse ecological changes. However, some species, including monitor lizards, are more flexible in their behavior which allows them to adapt to human altered ecosystems. Conditions that also ensure the successful adaptation of monitor lizards in the human-dominated ecosystems of Bangladesh are the availability and accessibility of anthropogenic food, availability of scavenging sites, the presence of diverse habitats and the absence of concern from human being.
7. Though *V. bengalensis*, *V. flavescens* and *V. salvator* plays significant role in our ecosystems but still they are facing formidable threats created by people. In most parts of the country, because of the anthropogenic activities, like- habitat destruction, habitat fragmentation and alteration, over exploitation, illegal trades, excessive uses of insecticides in the farmland and unconsciousness of the people the number of monitor lizards are declining at an alarming rate.

Based on the study results, recommendations have been developed for the conservation of monitor lizards in both the natural and human-dominated landscapes of Bangladesh.

LIST OF PUBLISHED WORKS ON THE TOPIC OF DISSERTATION

Publications in leading peer-reviewed journals included in the list of VAK (Higher Attestation Commission of the Russian Federation)

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