

**DIURNAL AND SEASONAL ACTIVITY PATTERN
OF WATER MONITOR (Varanus salvator)
IN BHITARKANIKA WILDLIFE SANCTUARY, INDIA**

**DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY,
RAJKOT IN PARTIAL FULFILMENT OF MASTER'S DEGREE
IN WILDLIFE SCIENCE (1993)**

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CERTIFICATE

This is to certify that Mr. Bivash Pandav of the Wildlife Institute of India has carried out an original piece of research work entitled "Diurnal and seasonal activity pattern of water monitor lizard (*Varanus salvator*) in Bhitarkanika Wildlife Sanctuary, India" in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University. These investigations were carried out under my supervision at the Wildlife Institute of India from November 1992 to June 1993. I also certify that this work has not been submitted for any other degree of any university.

DATE: 5/7/93

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ACKNOWLEDGEMENT

I would like to express my gratitude to all the people who made this work possible and have continued to encourage me through the last eight months.

I am grateful to the Principal Chief Conservator of Forests (wildlife), Orissa for permitting me to carry out the field work in Bhitarkanika Wildlife Sanctuary. I express my sincere thanks to Shri B.N. Nayak, Divisional Forest Officer, Mangrove Forest Division (wildlife) for the facilities in the field work, encouragement and advice. I record my sincere gratitude to Dr. C.S. Kar, Research Officer and Shri R.K. Swain, Range Forest Officer of Bhitarkanika Wildlife Sanctuary for their immense help during the field work.

I am thankful to my colleague Pranav Trivedi, who first gave me the idea to work on water monitor and helped me in many ways for successful completion of this work.

I am greatly indebted to my supervisor Shri B.C. Choudhury, Scientist-E, Wildlife Institute of India (WII), Dehradun, for his help in designing the research methodology, advice and constant encouragement during the course of this work.

Much of the credit of this work goes to Dr. S. Bhupathy, Research Biologist, WII, whose valuable suggestions during the field data collection were indispensable. He has taken a lot of pain in helping me analysing bulk of the data. His valuable comments have framed the thesis. I admire him for taking a keen interest in my work and moulding my thinking.

I am also thankful to Dr. Ajith Kumar of the Salim Ali Centre for Ornithology and Natural History (SACON) and Dr. Y.V. Jhala, WII, for helping me in statistical analysis. Dr. Ravi

Chellam and Dr. Jhala went through the drafts and offered valuable suggestions which helped me in improving the standard of the thesis.

My thanks are due to Romulus Whitaker for allowing me to avail the facilities at Madras Crocodile Bank (MCBT). Dr. R.J. Ranjit Daniels and Jayshree Ratnam of MCBT provided me with valuable literature on monitor lizards.

I record my gratitude to Dr. Eric D. Wikramanayake of the Smithsonian Institution for giving me relevant information on water monitor and for sending some key literature.

Dr. L.N. Acharjyo, Dr. S.K. Dutta and Dr. S. K. Kar were sources of constant encouragement during the field work. I thank all of them.

I acknowledge Shri Rajesh Thapa, Shri Lekh Nath Sharma, Shri Navneet Gupta and Shri V. Sukumar of the computer center of WII for their help in computer work. Thanks are due to Shomita Mukharjee, WII, for typing the tables.

I am extremely grateful to my field assistant, Dhumala who had rescued me many times from the waist deep mud in the mangrove swamps of Bhitarkanika and for all the lessons that he taught me about Nature.

Conducting field research amongst the crocodiles and king cobras in Bhitarkanika was the most exhilarating experience for me. I am eternally grateful to the crocodiles and the king cobras for allowing me this privilege.

SUMMARY

This study investigated the diurnal and seasonal activity pattern of water monitor, *Varanus salvator* in Bhitarkanika Wildlife Sanctuary, India. The study was conducted in an intensive study area of 17 sq.km selected after a pre sampling survey in the Sanctuary.

The methodology involved to record the activity pattern of water monitor was monitoring of two permanent standard paths every three hours on diurnal basis. Sightings of water monitors were recorded while walking on the standard path. Behaviour of water monitor was divided into four categories such as basking, foraging, resting and non-foraging. Microhabitat of water monitor was recorded on each sighting. Ambient and substrate temperatures and ambient relative humidity were recorded along with diurnal activity pattern of water monitors.

Results show a shift in diurnal activity pattern with season. The activity pattern of water monitor was unimodal in winter and uniform in summer. Basking was the major activity of water monitor in winter, whereas all the activities were evenly spread out in summer.

The lizards used different microhabitats for different activities. Maximum lizards were recorded active at cooler substrate temperatures (29°C).

The relation of ambient and substrate temperatures with activity was curvilinear. At low ambient temperature basking was prevalent. With increase in temperature other activities such as foraging and resting were recorded. At high ambient temperature lizards selected cooler substrates.

Ambient temperature and ambient relative humidity varied

inversely. The activity was low at high levels of humidity

It is concluded that behavioural thermoregulation plays a major role in water monitor's activity. Depending on ambient temperature water monitor selected different microhabitats and thermoregulate by behavioural means.

CHAPTER 1: INTRODUCTION

1.0 INTRODUCTION

Investigations of the inter-relationships between climate, habitat and activity pattern are of crucial importance in understanding the ecology and behaviour of many ectotherms; this is especially true in diurnal lizards (Porter *et al.* 1973; Avery 1976; Porter and Tracy 1983). Observations on activity pattern help in understanding the ecology, ecophysiology, and spatio-temporal organisation of the behaviour of an organism. It can also greatly contribute to our understanding of the adaptive significance of circadian rhythms and other cycles in the natural environment (Underwood 1990).

Being ectotherms, lizards tend to partition time and space more often than homeotherms because of their physiology and behaviour, which are closely linked to environmental conditions (Schoener 1977). The physiological adaptations and behavioural responses of lizards to ambient temperature vary considerably among taxa and span a continuum from thermoconformers to thermoregulators (Huey 1982). Thus the study of diel activity, habitat and microhabitat utilization patterns, feeding strategies and thermoregulatory behaviour of lizards helps in understanding the relationship between their thermal physiology and ecology.

The present study deals with the diurnal and seasonal activity pattern in a population of water monitor (*Varanus salvator*) inhabiting the Bhitarkanika Wildlife Sanctuary, Orissa. Apart from the Sunderbans in West Bengal, Bhitarkanika holds a fairly good population of water monitors. Among the four species of Indian monitor lizards, the distribution of water

monitor is patchy and the lizard is mainly restricted to the threatened mangrove habitat. Also, the biology of this species is poorly known in its Indian range. Reconnaissance in this Wildlife Sanctuary revealed the presence of a fairly good population of water monitor. Besides this, base line information on the distribution and general ecology of the lizard in Bhitarkanika Wildlife Sanctuary is also available (Biswas and Kar 1981). Hence, water monitor was selected for the present study.

Field work was conducted between November 1992 and April 1993 which comprised of two seasons namely winter (November - January) and summer (February - April). However, data collected during November 1992 was not included in the analysis.

1.1 REVIEW OF LITERATURE

1.1.1 Activity Pattern of Lizards:

The daily and seasonal activity pattern of reptiles are influenced by thermal biology (Porter *et al.* 1973). Limits to potential activity times are set by biophysical characteristics (i.e. temperature, moisture) of the habitat and by biological aspects of a species such as range of body temperature that is suitable for activity, thermoregulatory repertoire, species specific patterns of heat and mass flux (Bartlet and Gates 1967; Porter and Gates 1969; Tracy 1982). Time of activity may be further limited by the influence of predators (McFarland 1976), competitors (Schoener 1970, 1974, 1977; Regal 1971; Magnuson *et al.* 1979) and by the availability of food or water (Naggy 1973; Porter *et al.* 1973; Huey and Saltkin 1976; Magnuson and Beitinger 1978).

In a study on the altitudinal ecology of *Agama tuberculata*

Varanus niloticus in South Africa (Cowles 1930) and in Sudan (Cloudsley-Thompson 1966) differ markedly. They also differ for *Varanus griseus* in Iraq where it is active throughout the day in winter and shows a bimodal pattern of daily activity in summer (Corkill 1928). This species is inactive during cold winters in Iran, Egypt, Algeria and Pakistan (Anderson 1963; Haggag *et al.* 1965; Minton 1966; Vernet 1977).

Difference in activity pattern between sexes have also been observed in varanid lizards. Male lizards are known to be more active than females (Auffenberg 1979; King and Green 1979; Stanner and Mendelsohn 1987).

In regions where seasonal variation in environmental temperature is meagre, species such as *Varanus salvator* (Khan 1969) and *Varanus komodensis* (Auffenberg 1970) remain active throughout the year.

1.1.2 Water Monitor:

Water monitor is the second largest extant lizard species in the world, with largest specimen measuring two and half meters or more (Smith 1935; Daniël 1983). This large semi-aquatic lizard is commonly found in close proximity to water and it is a good swimmer (Smith 1932). Auffenberg (1981) states that a major factor determining their distribution is availability of aquatic habitat.

Water monitor is widely distributed in Southeast Asia viz. India, Sri Lanka, Indochina, Southern China, and East Indian Archipelago. In the Indian subcontinent, it is found in the coastal areas of Orissa (in the delta of river Brahmani and Baitarani); the Sunderbans of West Bengal and Bangladesh; Sri Lanka and in many of the islands of Andaman and Nicobar Islands

(Whitaker and Whitaker 1980). The available literature does not indicate the presence of this species in rest of the Indian coast and the distribution in general appears similar to that of the salt water crocodile (*Crocodilus porosus*). However, water monitor has also been reported from regions in India far from the coast. The presence of this species in Northeastern states (Assam and Meghalaya) has been reported by Anderson (1872), Smith (1935), Auffenberg (1986) and Das (1989).

Despite its wide distribution, the information available on its ecology is minimal particularly in view of the fact that this species is considered to be endangered. Available literature have largely provided information on the distribution and taxonomy (Anderson 1872; Smith 1935; Whitaker and Whitaker 1980; Auffenberg 1986; Das 1989; Gaulke 1991 a); general ecology (Auffenberg 1981, 1986); food habits (Gaulke 1991 b); nesting habits (David 1970; Biswas and Acharjyo 1977; Biswas and Kar 1981); and growth rate and social behaviour in captivity (Andrews and Gaulke 1990; Daltry 1991).

Carrion is reported to be one of the major components of the diet of water monitor (Auffenberg 1988). Gaulke (1991 b) has described water monitors as active hunters, spending a large part of the day searching for food. However, some of their raids for food are very specific e.g on the eggs of sea turtle and crocodiles (Choudhury and Bustard 1980; Deraniyagala 1931; Whitaker and Whitaker 1980). Though the spectrum of food is diverse, arthropods form a major bulk of the diet in Philippines (Gaulke 1991b). Gaulke (1991b) has also shown a variation in the diet of water monitors in different habitat types and attributed these variations to human disturbance.

Water monitor is reported to exhibit behavioural thermoregulation (Wikramanayake and Green 1989). In Sri Lanka, water monitors are mostly active in early morning and by early afternoon they retreat into cooler microclimate in the shade under bushes and on trees overhanging the river. Also, it has been observed that the afternoon activities are mostly restricted to aquatic environment, where the water presumably has a cooling effect on body temperature and enables them to regulate their body temperature and forage at the same time (Wikramanayake and Green 1989).

1.2 OBJECTIVES

The two major objectives of the study were:

- I. To record the activity pattern of water monitors on a diurnal and seasonal basis.
- II. To investigate the relationship of climatic variables with the activity pattern of water monitors.

1.3 STUDY HYPOTHESES

In order to achieve the above mentioned objectives following research hypotheses were tested:

- I. The diurnal activity pattern should change with seasons.
- II. The diurnal and seasonal activity pattern of water monitor are influenced by environmental variables such as ambient temperature and ambient humidity.
- III. Different microhabitats are used for different activities.

CHAPTER - 2 : STUDY AREA

The present study was conducted in Bhitarkanika Wildlife Sanctuary, Orissa. This sanctuary is one of the few remaining refugia for the endangered salt water crocodile and represents one of the finest remaining patches of mangrove forest along the Indian coast. The physical, floral and faunal features of the area is given below.

2.1 PHYSICAL ENVIRONS :

2.1.1 Location:

Bhitarkanika Wildlife Sanctuary is located on the east coast of India ($20^{\circ} 04'$ to $20^{\circ} 8'$ N and $86^{\circ} 45'$ to $87^{\circ} 50'$ E). The sanctuary is situated near the former port, Chandbali, which is about 50 Km from Bhadrak railway station in Balasore district, Orissa. The sanctuary encompasses a stretch of 35 Km of sea coast.

2.1.2 Boundary:

The natural boundaries of the Sanctuary are the rivers and Bay of Bengal. The sanctuary is bounded by rivers Dhamara to the north, Maipura to the south, Brahmani to the west and the Bay of Bengal in the east. The sanctuary is interspersed with numerous rivers, creeks and nullahs (Fig. 1).

2.1.3 Topography:

The total area of the sanctuary is 170 sq. km of which 115 sq. km is with mangrove cover. The deltaic mangrove swamps are subjected to regular tidal inundation and are extremely low lying. Mean elevation above mean tide level is between 1.5 to 2 metres. Higher ground extends to 3-4 metres.

2.1.4 Soil:

The study area is influenced by heavy alluvial silt brought down by the rivers and deposited in deltaic areas due to regular

tidal inundation. The ecosystem is further influenced by the high detrital content of the tidal material resulting from fallen mangrove leaves. The soil is clayey loam with sand, overlaid by rich humus layer. Some portions of the sanctuary lie on the higher ground and therefore lack mangrove cover. The soil in this area is predominantly sandy loam in nature.

2.1.5 Tidal cycle:

The mosaic of rivers, creeks, and nullahs are influenced twice daily both by high and low tides at approximately six hourly intervals. The maximum and minimum tide level varies according to lunar cycle and is also subjected to seasonal variations.

2.1.6 Climate:

The average annual rainfall of Bhitarkanika Wildlife Sanctuary is 1200 mm and the main monsoonal months are August and September. The area is prone to severe cyclonic storms twice almost every year during April to May and October to November and also, there are occasional tidal bores. In winter the temperature dips down to 10⁰C minimum and in summer the maximum temperature reaches upto 40⁰C. During the study period between November 1992 and April 1993, the lowest temperature recorded was 13⁰C in January while highest temperature recorded was 36⁰C in April (Fig. 2).

Due to the coastal environment, humidity is high throughout the year, varying between 75 and 95% (Kar 1981). During the present study the minimum humidity recorded was 35% in April while maximum was recorded in January (95%).

2.2 BIOTIC FEATURES

2.2.1 Vegetation

The vegetation of Bhitarkanika can broadly be classified into (i) mangrove formation and (ii) salt bush formation (Choudhry

1990). The salt bush formation is found along the littoral tract of 'Satvaya' and 'Gahirmatha' sea shore where the soil is sandy and is not subjected to inundation.

Mangrove formation in the sanctuary can be classified into two types: (1) vegetation of the outer estuarine bank and (2) the vegetation of the inner estuarine bank (Banerjee and Rao 1990). The outer estuarine bank vegetation is found in the river mouths of Maipura and Dhamara. Plants in the outer estuarine region are subjected to high salinity and wave action. *Avicennia marina* grows upto 10 m height with compact crown is common and characteristically forms a pioneer tree stand along the lower intertidal zone. *Sonneratia griffithii* is found at low gradient mud flats along the lower intertidal zone in mixed association with *Avicennia alba*, *Bruguiera parviflora*, *B.cylindrica* and *Aegialitis rotundifolia*. These species with increased water storage mechanism in their leaves, tolerate the highly saline conditions and are found more commonly along the central parts of the funnel shaped estuarine bank.

The inner estuarine bank is strongly dissected by several creeks, channels and their distributaries. The force of the sea surf is broken due to the presence of several creeks and vegetation is subjected to moderate salinity. These conditions make favourable habitat for many mangrove species and the flora is rich and diversified in this region. The dominant mangrove species in this region are *Avicennia officinalis*, *Sonneratia apetala*, *Excoecaria agallocha*, *Heritiera fomes*, *Phoenix paludosa*, *Kandelia kandel*, *Xylocarpus granatum*, *X. mollucensis*, *Rhizophora mucronata*, *R.appiculata*, *Aegiceras corniculatum*, *Merope angulata* and *Cerebra manghas*. A detailed account of the flora of Bhitarkanika is given

in Banerjee and Rao (1990).

2.2.2 Fauna

Kar (1981), Dani and Kar (in press) provide information on the fauna of Bhitarkanika Wildlife Sanctuary. Mangrove areas support a range of inter-connected food web which directly sustain the fisheries. Algae and detritus sustain shrimps and prawns which provide a food source for various fish species. Some of the commercially important fishes that occur in the sanctuary are *Hilsa illisha*, *Mullet* sp., *Lates calcarifer*, *Mystus gulio* and *Anchovella* sp.

The sanctuary harbours one of the largest populations of the endangered salt water crocodile (*Crocodylus porosus*) in India. Besides the water monitor, two other species namely the common (*Varanus bengalensis*) and the yellow (*V. flavescens*) monitors are also sympatric here (Biswas and Kar 1981). Other reptile species sighted during the study period were king cobra (*Ophiophagus hannah*), banded krait (*Bungarus fasciatus*), common krait (*Bungarus caeruleus*), python (*Python molurus bivittatus*), rat snake (*Ptyas mucosus*), golden tree snake (*Chrysopelia ornata*), vine snake (*Ahaetulla nasutus*). The herpetofauna also includes the garden lizard (*Calotes versicolor*), Indian flap shell turtle (*Lissemys punctata*) and snake skink (*Riopa punctata*).

Apart from the above mentioned lower vertebrates, 153 species of birds and eleven species of mammals were seen during the study period. The avifauna includes some of the rare and endangered species such as goliath heron (*Ardea goliath*), lesser adjutant stork (*Leptoptilos javanicus*) and whitebellied sea eagle (*Haliaeetus leucogaster*).

Bhitarkanika Wildlife Sanctuary is also the home for many

mammals such as the striped hyena (*Hyaena hyaena*), leopard (*Panthera pardus*), fishing cat (*Felis viverrina*), smooth Indian otter (*Lutra perspicillata*), spotted deer (*Cervus axis*) and sambar (*Cervus unicolor*).

2.3 THE INTENSIVE STUDY AREA

The study was conducted in an approximately 17 sq. km area of the sanctuary, here after referred as Intensive Study Area (ISA).

Some of the salient features of the ISA are given below.

2.3.1 Location

The intensive study area was located in the Bhitarkanika island block of the sanctuary (Fig. 3). The ISA was surrounded by Bhitarkanika river and Gokhani creek on its sides. The ISA was interspersed with five major creeks and numerous small creeks.

2.3.2 Soil

Majority of the area has clayey loam soil, overlaid by rich humus layer. Approximately 60 ha. of the ISA lie on the higher ground and therefore has a soil consisting predominantly of sandy loam.

2.3.3 Vegetation

The vegetation of the ISA resembles that of the vegetation in the inner estuarine bank as described earlier (section 2.1.1). The mangrove species occurring in this area form a two storey system, mainly top storey and middle storey while the ground flora is poor. Pure stands of *Heritiera fomes*, *Excoecaria agallocha*, *Avicennia officinalis*, *Ceriops tagal* and *Phoenix paludosa* occur in the ISA. Thorny bushes of *Caesalpinia bonduc* and *C.crista* occur in the mangrove habitat. Small bushes of *Pandanus fascicularis* are also patchily distributed in this habitat.

Sixty hectares of the ISA is covered by a sand bar and is free

of tidal inundation. Elements of moist deciduous forest occur in this non-mangrove area. Dominant plant species of this habitat are *Diospyros embryopteris*, *Strichnos nauxvomica*, *Memicylon edule*, *Micromilum integeremum*, *Maba buxifolia*, *Strebulus asper* and *Barringtonia* spp.

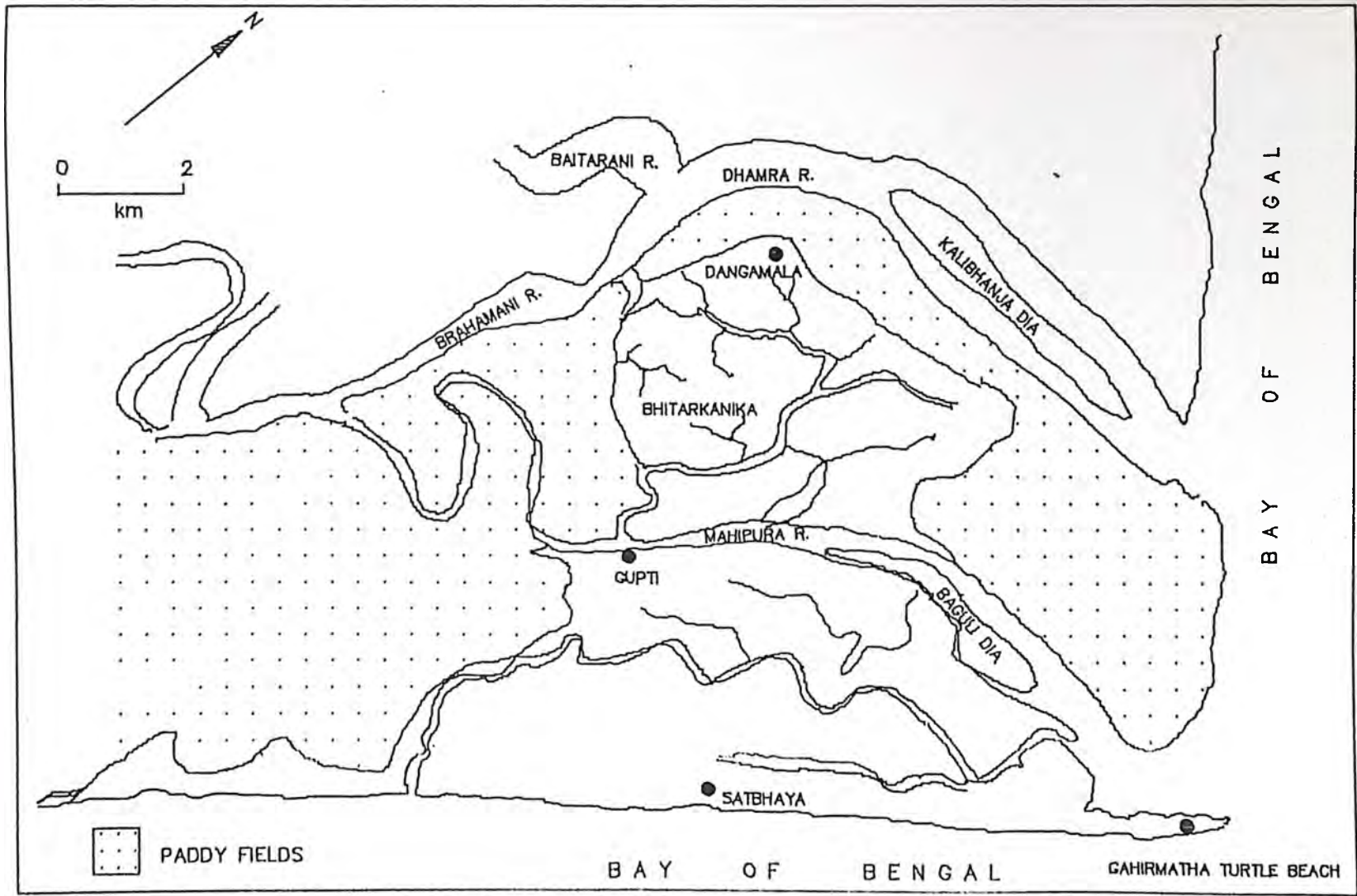
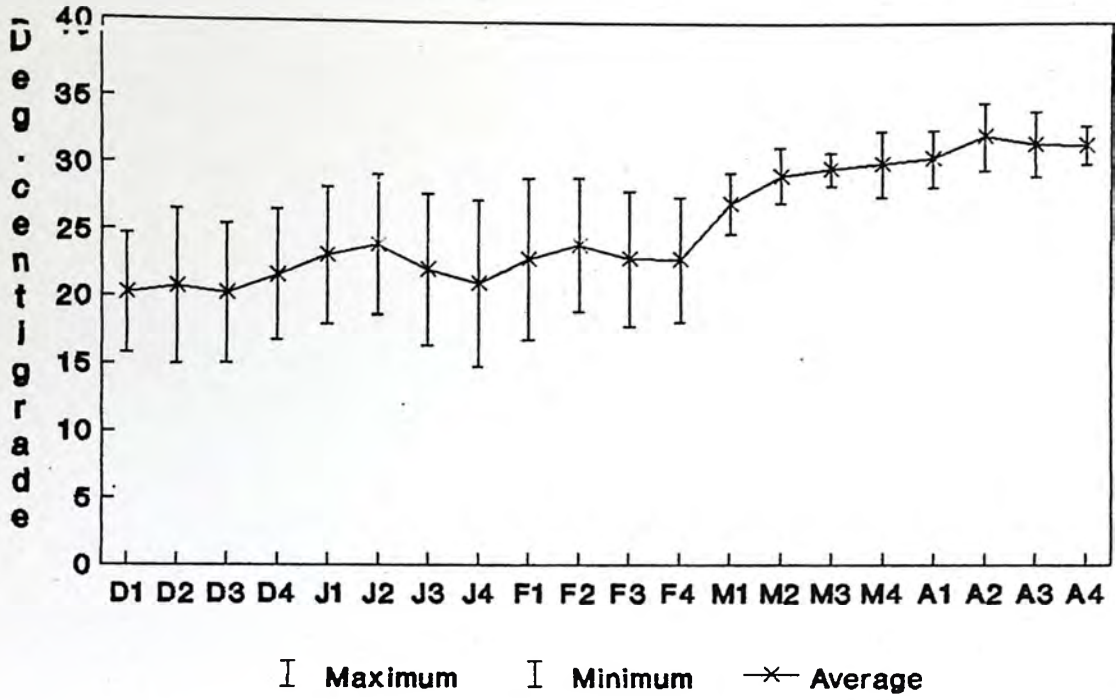


Fig. 1 General features of Bhitarkanika Wildlife Sanctuary.

Fig.2 Weekly fluctuation of temperature during the study period



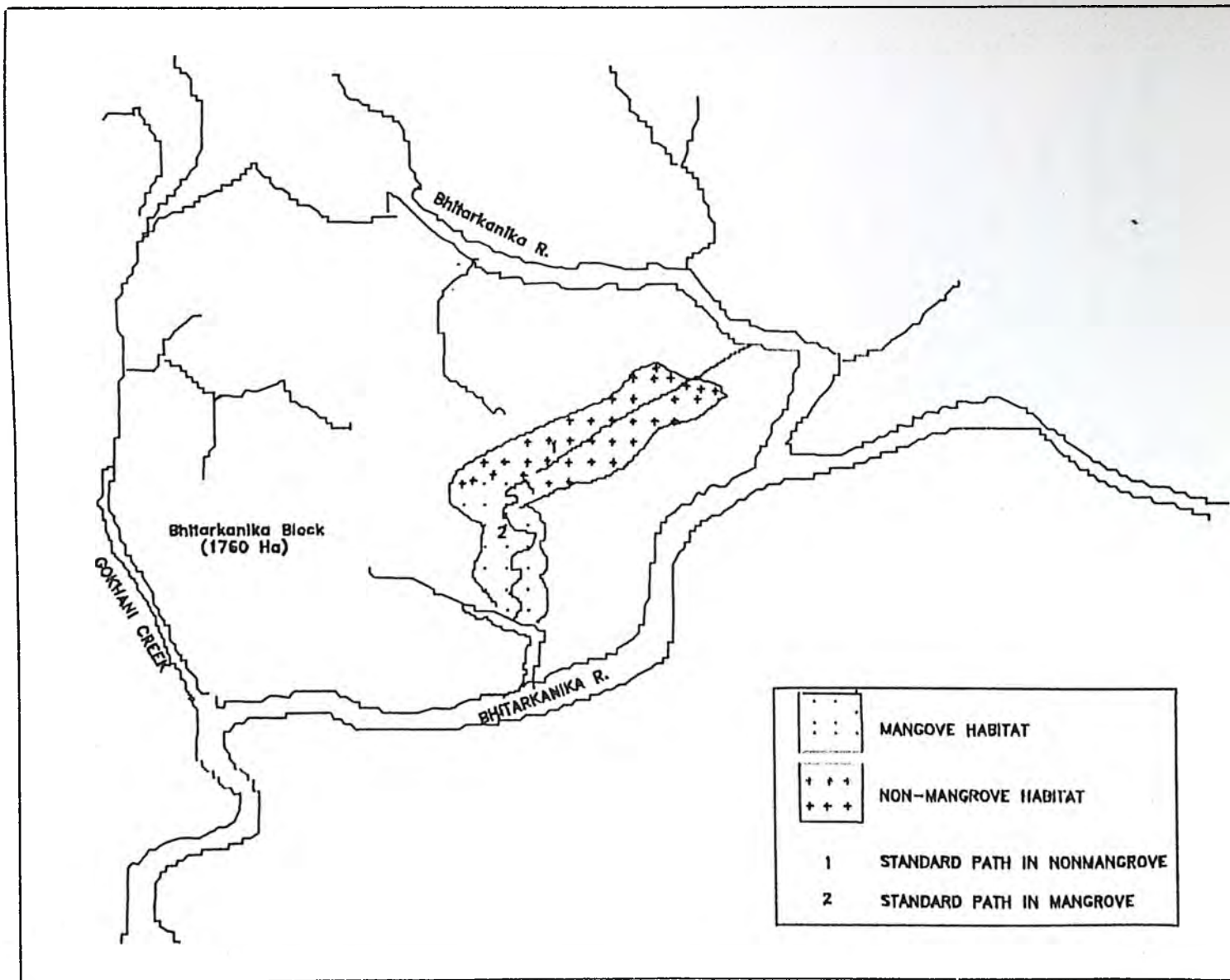


Fig. 3 MAP OF INTENSIVE STUDY AREA WITH STANDARD PATH IN BOTH THE HABITAT TYPES

CHAPTER - 3 : METHODS

Numerous methods have been employed to study the activity pattern of lizards. A few of them are radio tagging (Auffenberg 1988; King *et al.* 1989), transect count (Dryden and Wikramanayake 1991) and observing the lizards in simulated condition (Auffenberg 1981). The diel activity can be measured in indices like active or inactive to the details of proportions of time spent in different activities on seasonal as well as on a daily basis.

Temperature sensitive radio tagging of the varanids is proved to be an effective method to investigate the relation between diurnal activity and the various factors (Green and King 1978; King 1980; Stanner and Mendelssohn 1987; Auffenberg 1988; Wikramanayake and Green 1989).

Field work for the present study was conducted from November 1992 to April 1993 and the following aspects were covered.

- (I) The diurnal activity of water monitors in summer and winter.
- (II) The diurnal and seasonal variations of climatic factors which are to affect the activity of water monitors.

3.1 DIURNAL ACTIVITY OF WATER MONITORS

The methods employed to estimate diurnal activity of water monitors are similar to the methods employed by Foa *et al.* (1992) to study the activity pattern of a population of ruin lizards (*Podarcis sicula*) in Italy.

3.1.1 Field methods

Activity of water monitors were recorded by scan sampling (Altman 1974). This was achieved by walking on two standard paths, one in the mangrove and the other in the non-mangrove habitat in the ISA. The standard paths were not straight lines and were laid in such a way so as to cover the maximum number of water bodies.

This was because the distribution of water monitors was concentrated around water bodies in the ISA. The total length of the two standard paths were 2000 m and 1800 m in the mangrove and non-mangrove habitat respectively.

The term 'active' for this study is defined as all those lizards whose presence could be visually detected within the study area and these lizards were not in a burrow, tree hollow or in any kind of retreating site. Active lizards included (I) moving lizards (II) immobile lizards which were basking or resting. Activity of the lizards are further classified into four categories such as basking (monitors seeking heat in open areas or on hotter substrates), foraging (actively searching for food or feeding), resting (avoiding heat in shaded areas or on cooler substrates) and non foraging which includes walking and swimming.

The term micro habitat in the present study is defined as the lizard's immediate physical environment. The classification of micro habitat was based on soil, ground cover and water conditions. Eight types of micro habitats were recorded during the study period such as litter and sand, litter and water, water, sand and water, mud, sand, grass and tree branch.

The day light hours were divided into four three hourly time class intervals starting from 0600 to 1800 hours. The standard path in each habitat type was walked twice or thrice in a fortnight covering all time class intervals for sampling the diurnal activity of water monitors.

The following information were recorded on sighting a lizard:

- (I) Time of sighting.
- (II) Activity of the lizard when sighted.
- (III) Substrate temperature.

(IV) Ambient temperature at 1m from the ground level.

(V) Water temperature was measured whenever the lizard was found near water bodies.

(VI) The microhabitat in which the lizard was sighted.

Attempts were made to examine potential and possible retreats, such as ant or termite hills, tree hollows and burrows along the paths. However, most observations are either of active lizards or those which had emerged from the retreats but were resting or basking because often the structure of the retreats precluded a definite determination of the presence or absence of the lizards.

3.1.2 Analytical methods

Preliminary sampling was done in November 1992 and the samples after 1st December 1992 were taken for detailed analyses. Each month was divided into two halves (fortnights) described here after as a period, hence the whole study span from 1st December 1992 to April 1993 was divided into ten such periods. Periods between December and January (four periods) was considered as winter whereas, from February to April as summer (six periods).

All the observations were pooled on two hour time intervals and frequency occurrence of lizards in different activity categories were taken to describe the activity rhythm of water monitors. Similarly the winter and summer observations were taken separately to describe the seasonal activity rhythm.

Activity Index (AI) was calculated for each time class to describe the diurnal and seasonal activity pattern as well as to describe the trend in activity. The basic assumption involved here while calculating Activity Index is that the frequency of encountering of lizards on the standard paths is a function of the actual activity level existing in the population.

The activity level for time class t can be measured as Activity Index which is expressed as

$$AI = \frac{\sum S}{n} = \text{Sightings} / \text{sampling efforts}$$

where, S is the total number of lizards sighted on a sample path in a particular time class and n is the number of runs on a sample path for that particular time class.

The Activity Index thus calculated for different time class and periods were taken for further analyses to see the diurnal and seasonal pattern of activity.

Preferred temperature zone of lizard's activity was worked out by clumping frequency occurrence of lizards with different activity and with ambient and substrate temperature class. The ambient temperature and humidity records at each hour, on the day of sampling for activity pattern were taken for comparison with the Activity Index of the corresponding time classes. Mean temperature and humidity for each time class in 10 periods were calculated there after. The mean temperature and humidity for particular time class and period were correlated with activity index of that time class and period.

3.2 STATISTICAL METHODS

Due to lack of knowledge about the sampling distribution non-parametric statistics were used for the analysis. Siegel (1956) was the main text for statistical analysis.

All tests were two tailed. A significant level of 0.05 has been used through out.

Analysis was done manually as well as by computer statistical package SPSS/PC[†].

CHAPTER 4: RESULTS

4.1 ACTIVITY RHYTHM

Basking activity dominated the first two time intervals (0600-0800 and 0800-1000 hrs) of the day and was minimum during 1200-1400 hrs time class. Of all the foraging lizards a higher percentage of these (25%) were observed in the 0600-0800 hrs. Except for 0800-1000 hours, foraging in all other time classes was almost similar. Maximum percentage of resting lizards (24.3%) was observed in 1400-1600 hrs time class. Non-foraging activities were high after mid day hours. Maximum non-foraging activities took place at 1200-1400 hrs time class (Table 1).

4.1.1 Activity Rhythm in Winter.

Basking was the major activity of water monitors in winter. This activity was higher than other activities in all the time classes of the day. Basking was more pronounced in morning (0600-0800 and 0800-1000) and evening (1600-1800) hours. Most of the foraging activities in winter were during mid day and afternoon hours (1000-1200, 1200-1400 and 1400-1600) of the day. Very few lizards were observed feeding during rest of the day. Maximum non foraging lizards were recorded in 1200-1400 hrs followed by 1600-1800 hrs. Barring 1000-1200 hrs, non foraging activities were low in rest of the time classes. A notable feature in winter was the absence of resting activity (Table 2).

4.1.2 Activity Rhythm in Summer.

Most of the activities were evenly spread through out the day in summer when compared with winter (Table 3). A high proportions of lizards were found to be basking in 0600-0800 and 0800-1000 hrs time classes. This activity was low for the rest of the time classes. Higher proportions of lizards were seen foraging in almost

all time classes of the day. Maximum foraging was observed in 0600-0800 hrs. Maximum resting activity occurred in the afternoon (1400-1600) hours and was low during morning hours. Except 0600-0800 hrs non foraging activities were higher in rest of the time classes. Maximum non foraging activities were recorded during 1000-1200 hrs time class.

4.2 MICROHABITAT AND ACTIVITY

All the observations were pooled and the percentage occurrence of different activities were calculated for each microhabitat type to comprehend the relationship between microhabitat and activity. Higher percentage of basking lizards were seen in litter and sand (50.5%), tree branch (17.16%), and sand (16.67%). Most of the foraging of water monitors took place in microhabitats such as mud (33.3%), litter and sand (25.6%) and water (18.8%). Higher proportions of resting monitors were observed in microhabitats such as mud (60.5%), litter and sand (21.9%), tree branch (7.7%) and litter and water (7.7%). Maximum percentage of resting lizards were recorded in mud. Non foraging activities were maximum in litter and sand (30.5%) followed by litter and water (Table 4).

4.3 THE DIURNAL AND SEASONAL ACTIVITY PATTERN

A total of 663 lizards were encountered in both the habitat types of the ISA during the study duration (Appendix-I and II). Maximum number of lizards were recorded in period April-I, while maximum of them were seen in time class 1200-1500 hours.

Activity level was highest in 1200-1500 hrs time class; AI = 4.72 ± 0.58 (Table 5). Friedman two-way analysis of variance was performed to find out the difference in activity levels among the time classes and periods. Significant difference in activity levels among the time classes was observed ($\chi^2_r = 21.81$, $P < 0.05$). The

difference in activity levels among time classes in mangrove and non-mangrove habitat types were also tested and the results show significant difference (Mangrove - $\chi^2_r = 13.35$, $P < 0.05$; Non-mangrove - $\chi^2_r = 16.53$, $P < 0.05$).

The most active period for water monitors during the study was April-I; AI = 5.54 ± 1.33 (Table 5). Friedman two-way analysis of variance showed a significant difference in activity level among the periods ($\chi^2_r = 18.31$, $P < 0.05$). The above test was also done separately for each of the habitat types. The test showed a significant difference in activity levels among periods in the mangrove habitat ($\chi^2_r = 21.9$, $P < 0.05$). However, it was not significant in the non mangrove habitat ($\chi^2_r = 11.37$, $P > 0.05$).

4.4 ACTIVITY TREND

Mann-Whitney U test was done to find out the seasonal difference in activity levels between the mangrove and non-mangrove habitat types. The test does not show any significant difference in winter and summer activity levels between the two habitat types ($P = 0.343$ and $P = 0.294$ for winter and summer respectively). Hence, all the observations in two habitat types are pooled to describe the activity trend.

The diurnal activity pattern of water monitors and the seasonality in it for the complete study period is given in Fig. 4. The activity was unimodal in all periods of winter. In the early period of study (Dec-I), the peak was at 0900-1200 hrs time class. Activity peaks for the next three periods; Dec-II, Jan-I and Jan-II was observed at 1200-1500, 0900-1200 and 1200-1500 hrs time classes respectively. Except early part of summer (Feb-I), activity was uniform in all periods. The activity peak in Feb-I was observed at 1200-1500 hrs time class. The typical summer activity trend with

distinct bimodal pattern as in case of many other reptiles, was not observed in the present study.

4.5 CLIMATIC FACTORS AFFECTING ACTIVITY OF WATER MONITOR

Number of observations of lizards in a particular activity category in different ambient and substrate temperature classes were used to find out the preferred temperature zone.

Major activities (i.e. basking, foraging and resting) reached the peak at different ambient temperature class. A shift in activity was observed with change in temperature (Fig. 5). The lizards were seen basking in higher number between 23 to 29⁰ C ambient temperature. Maximum number of basking lizards were observed at 25⁰ C. Number of foraging lizards increased with increase in temperature. Most of the foraging lizards were seen between 25 to 31⁰ C temperature class with a peak at 31⁰ C. Peak resting was recorded at 29⁰ C.

Basking lizards were seen in a wider range of substrate temperature class (21-37⁰ C; Fig. 6). Maximum number of basking lizards were observed at substrate temperature 29-31⁰ C. Higher number of lizards were observed foraging between substrate temperature 21-33⁰ C and reached the maximum at 25-27⁰ C (Fig. 3). Narrow substrate temperature zone (27-31⁰ C) was used for resting by water monitors.

Ambient temperature, ambient relative humidity and activity index at different time classes in both the seasons were plotted. The peak of the temperature and activity levels were noted during 1200-1500 hrs time class in both winter and summer (Fig. 7a and b).

Ambient relative humidity showed inverse trend with ambient temperature (Fig 7 and 8). Relative humidity was high in morning (0600-0900) and evening (1500-1800) hours in winter as well as

summer. The lowest relative humidity was recorded in 0900-1200 and 1200-1500 hrs time classes in winter which shifted to 0900-1200 hrs time class in summer (Fig. 8 a and b). Most of the basking and foraging activities took place in relative humidity between 40 and 65%. Resting was pronounced in high humidity range and most of them were observed between relative humidity 60-80% (Fig. 9).

TABLE 1. Overall activity rhythm of water monitor from December 1992 to April 1993 in Bhitarkanika Wildlife Sanctuary.

TIME CLASS/%ACTIVITY	B	F	R	NF	N
>0600<=0800	50	25	8.4	16.6	24
>0800<=1000	48.9	8.8	14.6	27.7	137
>1000<=1200	27.3	24	5.8	42.9	154
>1200<=1400	22.9	21.1	11.4	44.6	166
>1400<=1600	25.7	16.2	24.3	33.8	148
>1600<=1800	26	11.1	18.5	44.4	27

B - Basking

R - Resting

F - foraging

NF - Non foraging

N - Total number of lizards seen

TABLE 2. Activity rhythm of water monitor in winter (December 1992 to January 1993) in Bhitarkanika Wildlife Sanctuary.

TIME CLASS/%ACTIVITY	B	F	R	NF	N
>0600<=0800	100	0	0	0	3
>0800<=1000	91	6	0	3	33
>1000<=1200	52	27.5	0	20.5	69
>1200<=1400	47.2	21.4	0	31.4	70
>1400<=1600	66	27.2	0	6.8	44
>1600<=1800	75	0	0	25	8

TABLE 3. Activity rhythm of water monitor in summer (February 1993 to April 1993) in Bhitarkanika Wildlife Sanctuary.

TIME CLASS/%ACTIVITY	B	F	R	NF	N
>0600<=0800	42.9	28.6	9.5	19	21
>0800<=1000	35.6	9.6	19.2	35.6	104
>1000<=1200	7.06	21.18	10.6	61.16	85
>1200<=1400	5.2	20.8	19.8	54.2	96
>1400<=1600	8.6	11.6	34.6	45.2	104
>1600<=1800	5.3	15.8	26.3	52.6	19

B - Basking

R - Resting

F - Foraging

NF - Non foraging

N - Total number of lizards seen in different time classes

TABLE 4. Percentage occurrence of water monitors in different microhabitats during December, 1992 to April, 1993.

ACT	LS	LW	W	SW	MVD	S	GRS	LOG	N
B	50.5	1.47	0	0.98	4.4	16.67	8.82	17.16	204
F	25.6	13.7	18.8	3.4	33.3	0.9	4.3	0	117
R	21.9	7.7	0	1.1	60.5	0	1.1	7.7	91
NF	30.5	24.6	13.3	3.1	17.2	7.0	3.5	0.8	256

ACT - Activity

LS - Litter and sand

MUD - Mud

LW - Litter and water

S - Sand

W - Water

GRS - Grass

SW - Sand and water

LOG - Tree branch

N - Total number of lizards seen

B - Basking F - Foraging R - Resting NF - Non foraging

TABLE 5. Overall Activity Index ($AI = \sum_{i=1}^k s/n$) of water monitor in each time class and period during December 1992 and April 1993.

PER\TIME	06 - 09	09 - 12	12 - 15	15 - 18	MEAN 95% CI
DEC I	1.25	6.75	5.5	1.75	3.18 ± 2.66
DEC II	1.0	4.25	6.5	1.25	3.25 ± 2.57
JAN I	1.2	4.8	3.8	1.0	2.85 ± 1.7
JAN II	1.17	2.5	3.83	2.0	2.38 ± 1.09
FEB I	0.8	2.2	5.0	0.8	2.2 ± 1.94
FEB II	2.0	3.4	3.8	1.6	2.7 ± 1.04
MAR I	2.0	3.0	3.8	2.6	2.85 ± 0.74
MAR II	2.3	4.33	5.0	3.0	3.66 ± 1.19
APR I	6.17	6.83	5.5	3.67	5.54 ± 1.33
APR II	2.75	4.75	4.5	2.5	3.03 ± 1.14
MEAN	2.06 ±	4.28 ±	4.72 ±	2.08 ±	
95% CI	0.98	0.99	0.58	0.53	

PER - Periods

95% CI - 95% confidence interval

TIME - Time classes

TABLE 6. Activity Index (AI = $\sum_i^n s/n$) of water monitor in each time class and period in the mangrove habitat from December 1992 to April 1993.

PER\TIME	06 - 09	09 - 12	12 - 15	15 - 18	MEAN 95% CI
DEC I	0.5	4.0	4.5	1.5	2.63 ± 1.90
DEC II	1.5	3.5	6.5	1.0	3.13 ± 2.45
JAN I	1.5	3.5	7.0	2.0	3.5 ± 2.43
JAN II	0.67	1.67	3.0	1.33	1.67 ± 0.96
FEB I	0.0	0.0	1.5	0.5	0.5 ± 0.68
FEB II	1.0	2.0	4.5	1.5	2.25 ± 1.52
MAR I	2.0	1.0	3.5	4.0	2.63 ± 1.35
MAR II	4.0	4.0	5.33	4.33	4.42 ± 0.68
APR I	4.33	8.0	4.33	4.67	5.33 ± 1.74
APR II	2.5	6.5	3.5	1.5	3.5 ± 2.11
MEAN	1.8 ±	3.42 ±	4.37 ±	2.23 ±	
95% CI	0.9	1.5	1.01	0.94	

PER - Periods

95% CI - 95% confidence interval

TIME - Time classes

TABLE 7. Activity Index ($AI = \sum_i^h S/n$) of water monitor in each time class and period in the non-mangrove habitat from December 1992 to April 1993.

PER\TIME	06 - 09	09 - 12	12 - 15	15 - 18	MEAN 95% CI
DEC I	2.0	9.5	6.5	2.0	5.0 ± 3.61
DEC II	0.5	5.0	6.5	1.5	3.38 ± 2.78
JAN I	1.0	5.67	1.67	1.33	2.42 ± 2.14
JAN II	1.67	3.33	4.67	2.67	3.09 ± 1.23
FEB I	1.33	3.67	7.33	1.0	3.33 ± 2.86
FEB II	2.67	4.33	3.33	1.67	3.00 ± 1.09
MAR I	2.0	4.33	4.00	1.67	3.33 ± 1.74
MAR II	0.67	4.67	4.67	1.67	2.92 ± 2.02
APR I	8.0	5.67	6.67	2.67	5.75 ± 2.21
APR II	3.0	3.0	5.5	3.5	3.75 ± 1.18
MEAN	2.28 ±	4.92 ±	5.22 ±	1.97 ±	
95% CI	1.33	1.14	1.06	0.47	

PER - Period

95% CI - 95% confidence interval

TIME - Time classes

TABLE 8. Mean body and ambient temperatures of varanids from previous studies. Tb = body or cloacal temperature. Ta = ambient temperature. N = sample size.

SPECIES	N	Tb °C	Ta °C
<i>V. salvator</i> ^a	12	29.9	29.5
<i>V. bengalensis</i> ^a	7	34.5	30.7
<i>V. eremius</i> ^b	53	37.5	28.3
<i>V. caudolineatus</i> ^b	10	37.8	33.6
<i>V. gouldii</i> ^b	67	37.5	30.0
<i>V. gouldii</i> ^c	11	35.7	22.2
<i>V. tristis</i> ^d	57	31.8	28.5
<i>V. varius</i> ^d	1	35.5	-
<i>V. komodensis</i> ^e	28	32-40	28-32

^a Data from Wikramanayake and Green (1989).

^b Data from Pianka (1986).

^c Data from King (1980).

^d Data from Stebbins and Berwick (1968).

^e Data from Auffenberg (1981), range of Ta, Tb.

Fig. 4 Diurnal activity of water monitor on seasonal basis

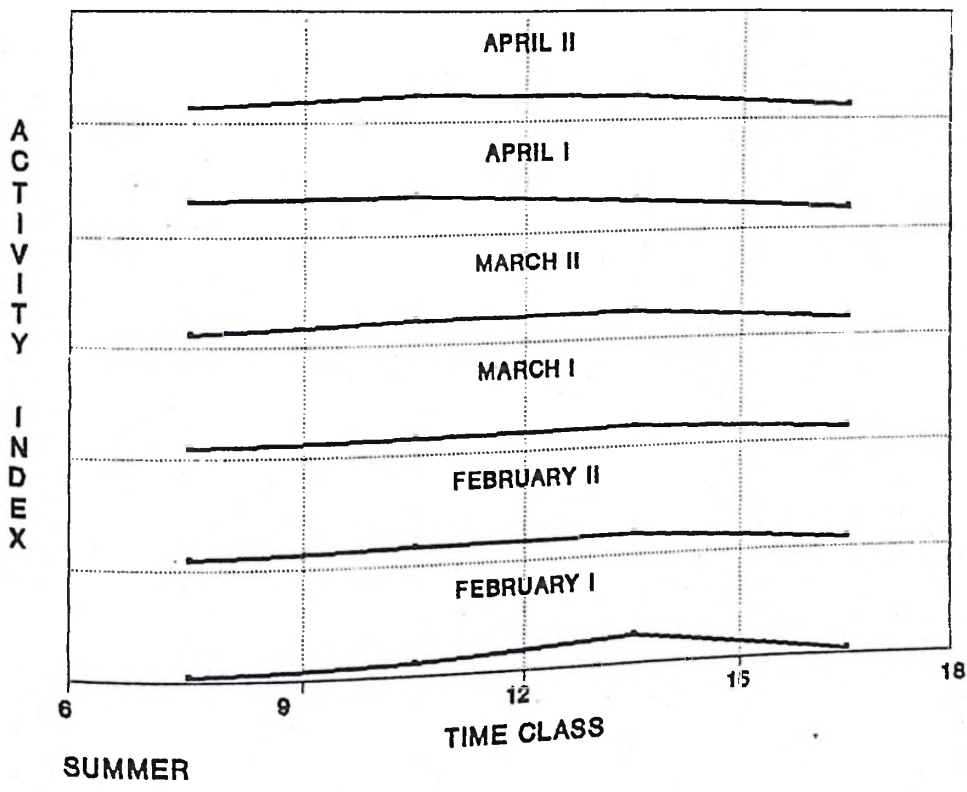
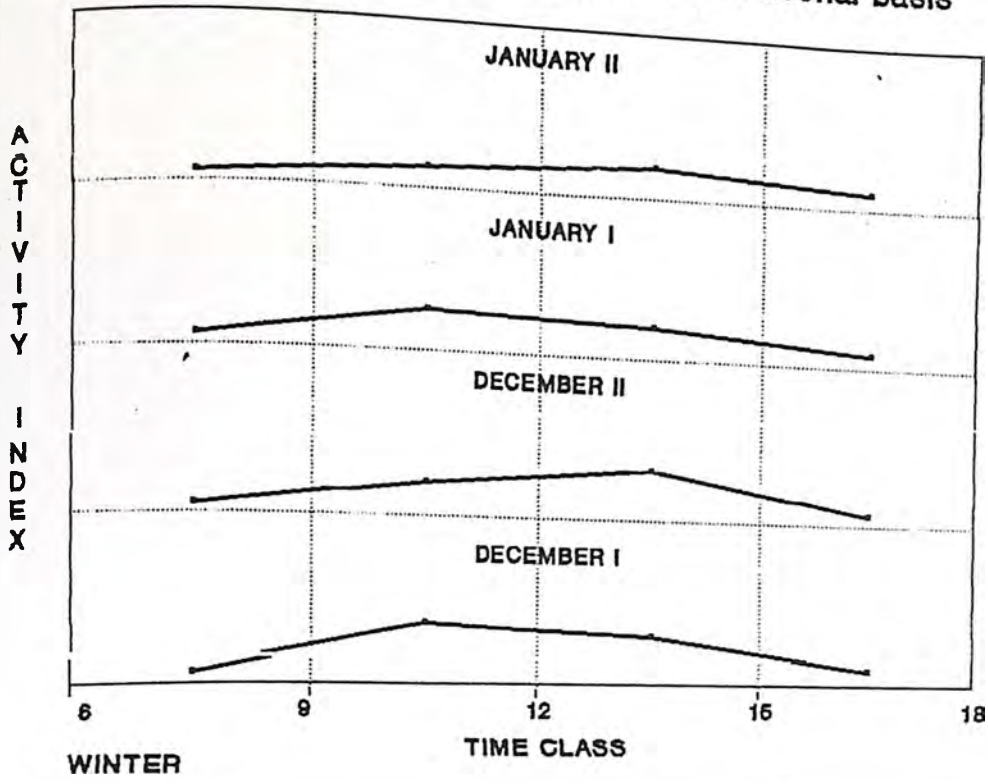


Fig. 5 Operative environmental temperature class for different activities in water monitor.

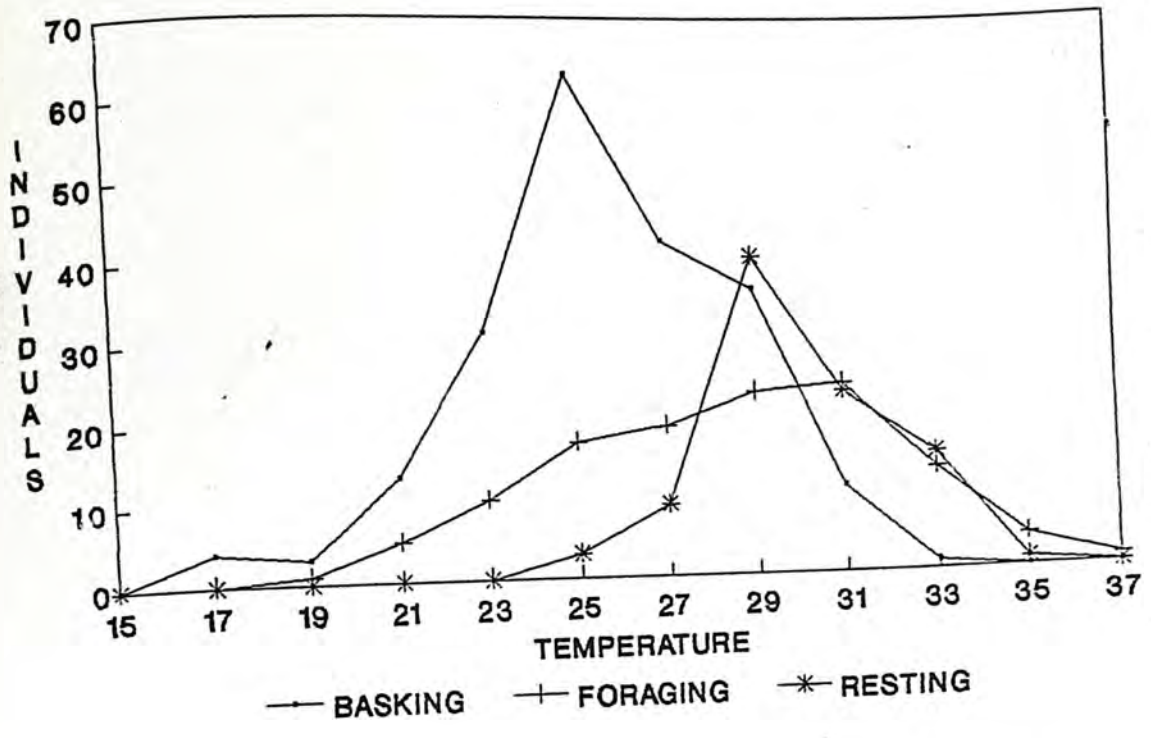


Fig. 6 Relationship between substrate temperature and activities of water monitor during the study period .

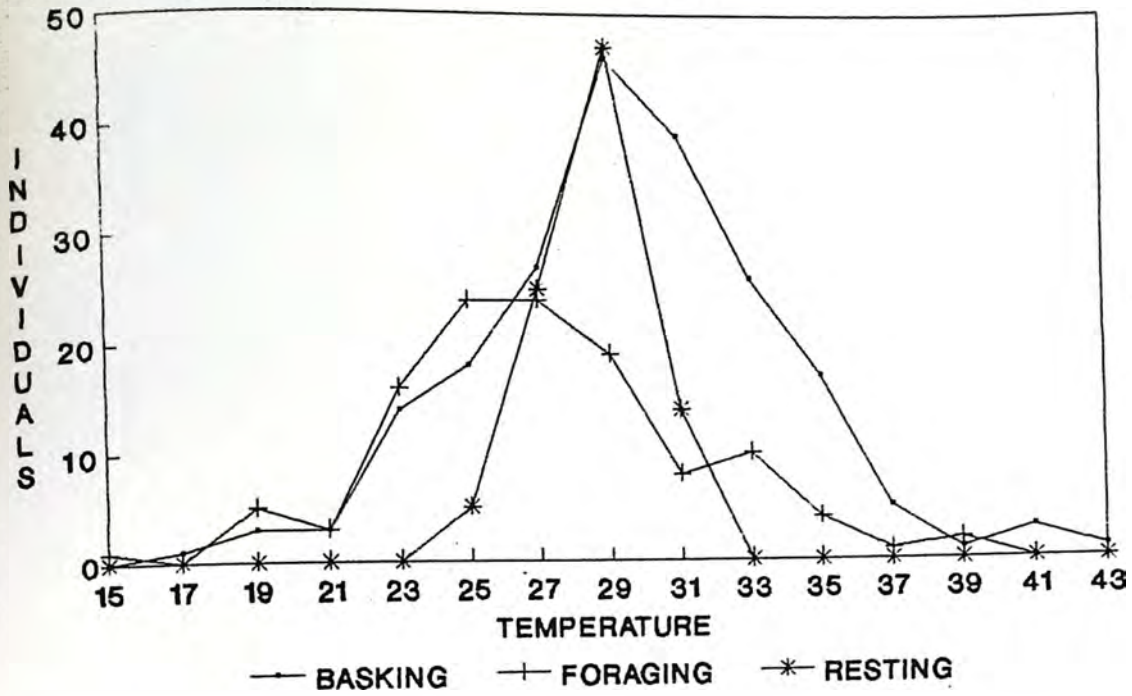


Fig. 7 Relationship of water monitor activity with ambient temperature.

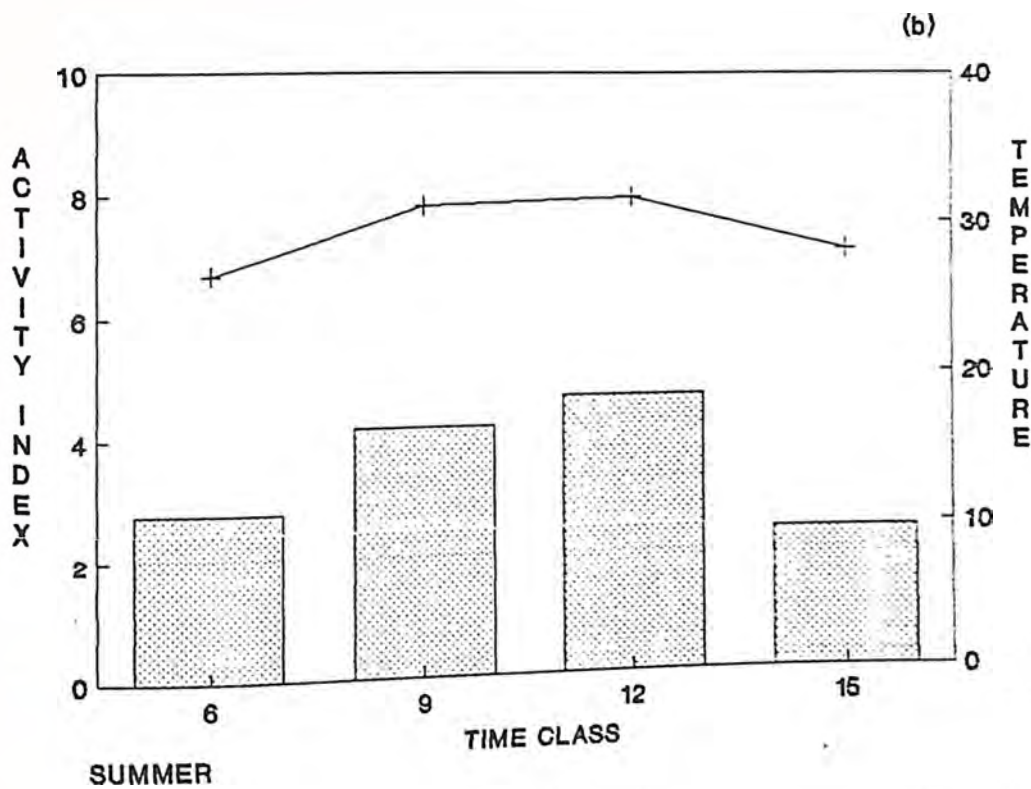
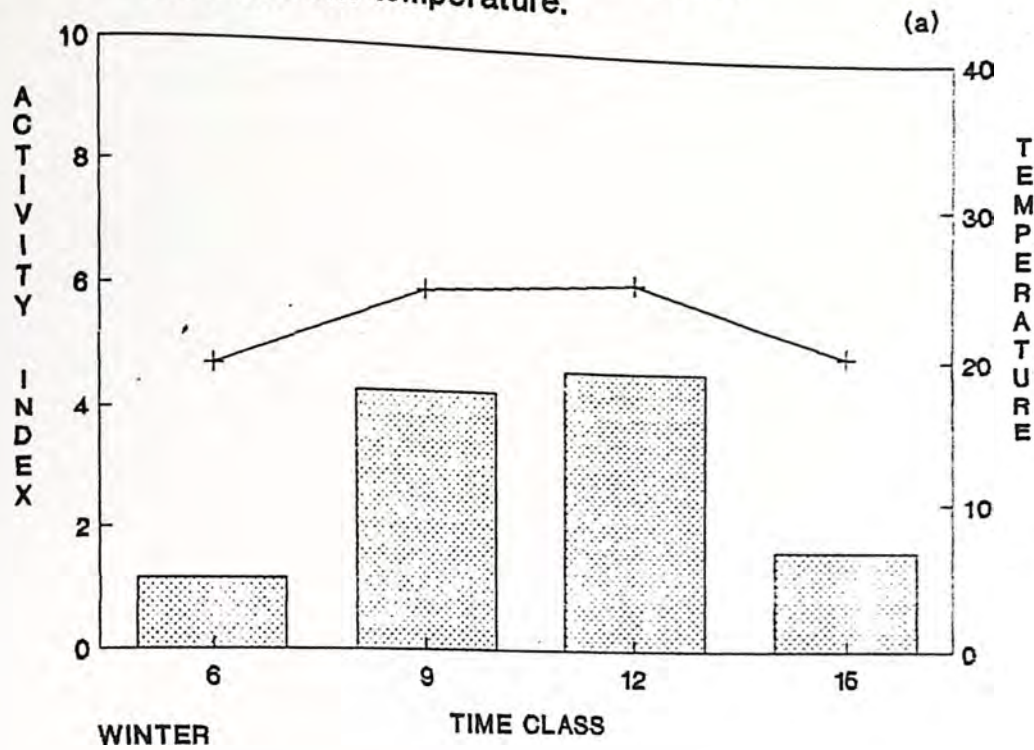


Fig. 2 Relationship of water monitor activity with relative humidity.

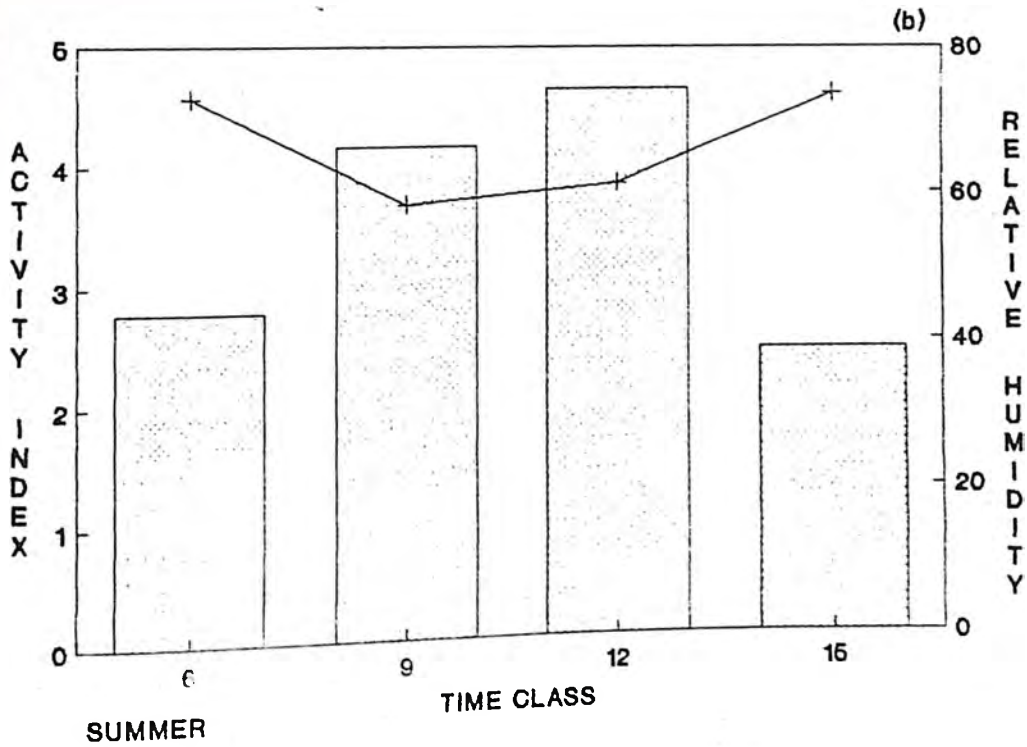
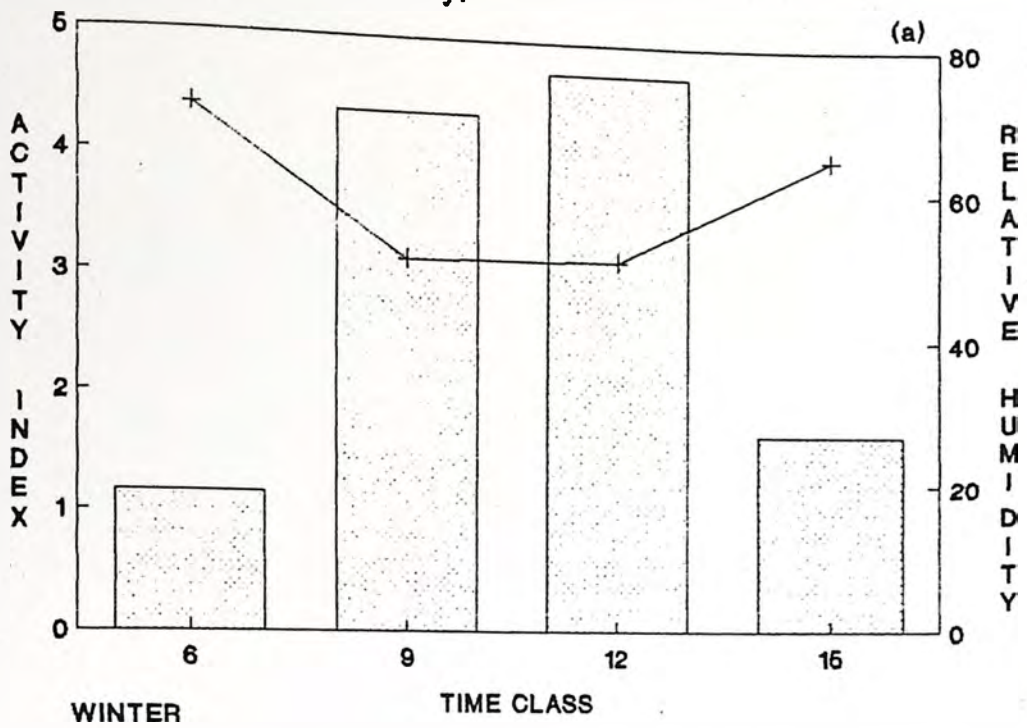


Fig. 9 Relationship between relative humidity and water monitor activity during the study period.

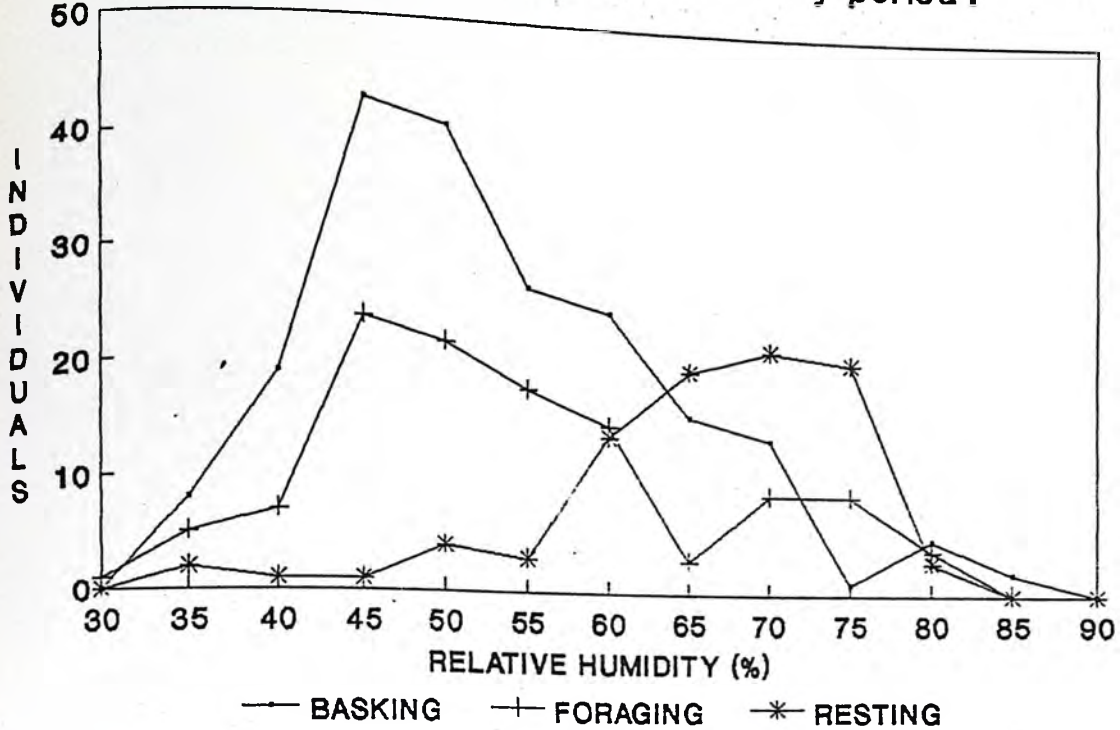
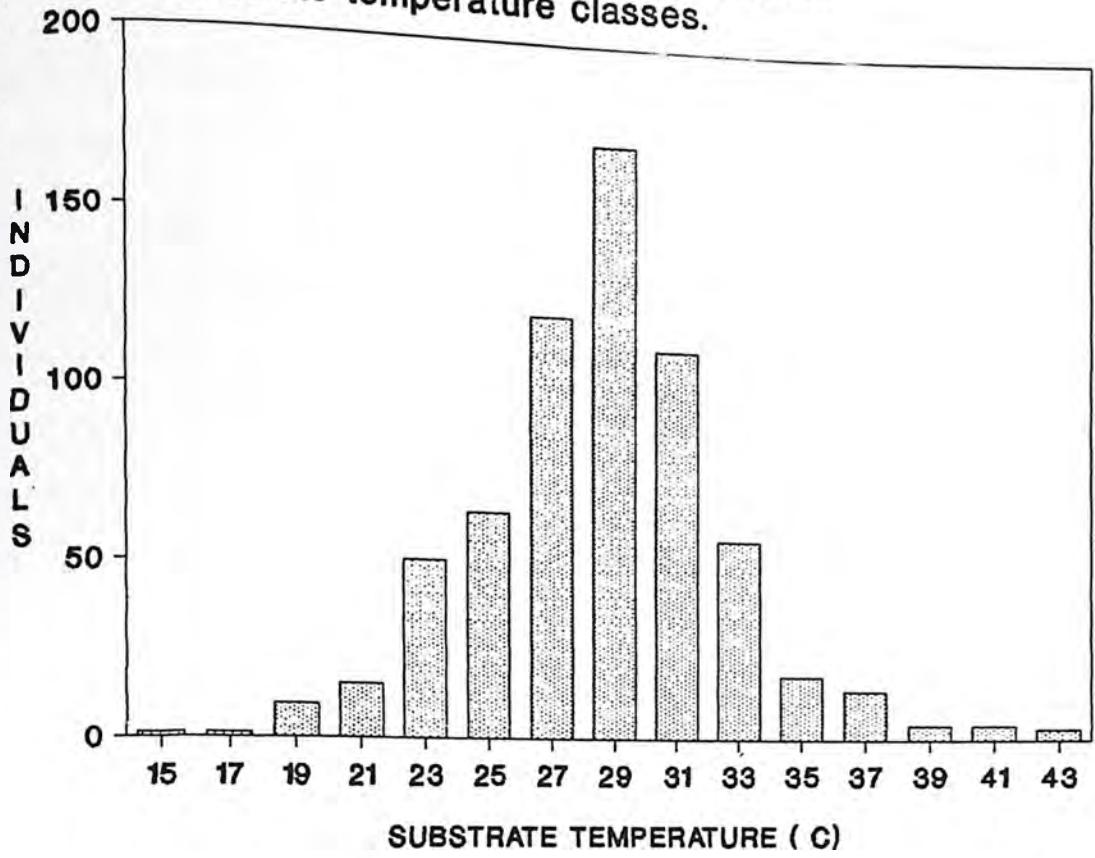


Fig. 10 Number of water monitors in different substrate temperature classes.



CHAPTER - 5 : DISCUSSION

5.1 ACTIVITY RHYTHM

Results of the activity rhythm support that the water monitor exhibits behavioural thermoregulation (discussed in section 5.4). The overall activity rhythm shows that lizards bask in the morning and afternoon hours when the ambient temperature is low. At higher ambient temperature lizards switch over to other activities. The present study augments with the findings of Wikramanayake and Green (1989) on behavioural thermoregulation in water monitor. Monitors were observed foraging in the early morning hours when carrion was available. This is supported by the fact that 80% lizards feeding were on carrion ($n = 25$) during 0600-0800 hrs time class. Water monitors were observed scavenging even after sunset and early in the morning, before sunrise. Feeding on carrion is sedentary foraging (i.e. not active foraging). Therefore, it can be expected in early morning or late evening hours since heating up of the body is not required for this. Most of the resting and non foraging monitors were observed during the warmer periods of the day as reported in *V. gouldii* (King 1980).

A difference in activity rhythm was observed between winter and summer. Basking was the major activity in winter, whereas other activities were evenly spread in summer. In winter there was decreased level of solar radiation and the temperature was low. This resulted in an increased time spent in basking with less time available for other activities.

5.2 DIURNAL AND SEASONAL ACTIVITY PATTERN

The results of the statistical tests applied to find out the difference in activity pattern shows that there is seasonal shift in diurnal activity and there is significant variation in activity

levels within the 12 hrs time class. The variation in activity levels of periods was significant for the mangrove habitat. However, this was not significant for the non-mangrove habitat. This could be attributed to one of the physiological processes of water monitors. During the period April-I and April-II monitors were sloughing their skin. In this period monitors were less mobile and many of them were seen lying under thorny bushes. The number of sightings during this period were higher in the mangrove habitat because of the presence of thorny bushes such as *Caesalpinia nuga* and *Pandanus fascicularis*. This higher number of sighting is reflected in terms of a high Activity Index in the time class 0900-1200 hrs of period April-I and II in the mangrove habitat when compared to the same in the non-mangrove habitat (Table 6 and 7). This might be the biological reason for getting a significant difference in activity level of periods in the mangrove habitat.

The observed trend of diurnal activity pattern of water monitor differs in many respects from the results of earlier works on other varanids (*V. gouldii*, King 1980; *V. komodensis*, Auffenberg 1981; *V. giganteus*, King et al. 1989). In the present case, water monitors have unimodal pattern of activity in winter which becomes uniform in summer. Whereas, the varanids studied by the above mentioned workers revealed a bimodal pattern of activity. In addition, all these species also show considerable seasonal variation in the degree and timing of bimodality. The results of this study partly agrees with the findings of Auffenberg (1988) that the overall activity pattern of Gray's monitor lizard (*V. olivaceus*) is essentially unimodal.

Pythons (*Python molurus*) in Bharatpur (Rajasthan) had a unimodal activity pattern in winter which became uniform in spring

and bimodal in summer (Bhatt 1991). The summer activity pattern of water monitor resembles the spring activity pattern of python. It is interesting to note that in semi-arid region such as Bharatpur spring is the only time when extremes of temperature are absent. Therefore, in a relatively less variable climate a uniform activity pattern would be expected. Same is the case with water monitor. Coastal habitat of water monitor experiences a less variable climate in summer permitting the monitors to be active throughout the day. Therefore, the role of temperature variability in governing the activity pattern of ectotherms becomes clear here.

5.3 MICROHABITAT AND ACTIVITY

Microhabitats play an important role in reptile's biology. By selecting appropriate microhabitat lizards maintain their body temperature (Greenberg 1976), increase their foraging efficiency and avoid predation (Pianka 1986). Studies on space and time sharing by water and common monitors in Sri Lanka (Dryden and Wikramanayake 1991) have shown that water monitor maintains its constant body temperature by selecting cooler microhabitats. The findings of the present study also show a similar result (Fig.10). Maximum number of water monitors were seen at 29°C substrate temperature.

Higher percentage of basking lizards were seen in microhabitats such as litter and sand, and sand on exposed grounds in the non-mangrove habitat. However, maximum number of basking lizards were recorded on tree branches in the mangrove habitat. The sun's rays striking the exposed ground produce heat at the soil surface. Soil and litter having good absorption capacity of heat gets heated up quickly as compared to other substrates such as mud. By basking in such microhabitats when ambient temperature is low,

the lizard absorbs heat both from the substrate and from the solar radiation and thus maintains its body temperature.

The substrate in the mangrove habitat is predominantly mud and the canopy is dense. Substrate temperature of the exposed mudflats in the mangrove habitat is usually less than the ambient temperature (Pers. Obsv.). Consequently a lizard dorsally absorbing heat from solar radiation would rapidly lose it again by ventral conduction while basking on the mudflats. Desert dragon (*Amphibolurus inermis*) was observed basking on tree branches to minimise heat loss by ventral conduction when air and substrate temperatures were low (Heatwole 1970). Again, there might be possible competition for basking sites on the mudflats by estuarine crocodile, which would result in predation on water monitor by the crocodile (Pers. Obsv). In the dense canopied mangrove forest little sunlight fall on the ground and the higher branches of the trees receive the sunlight first. This was the reason for sighting a higher number of basking lizards on tree branches in the mangrove habitat.

Most of the food searches of water monitor takes place in areas sheltering diverse fauna (Gaulke 1991 b). In the present study higher number of monitors were seen foraging in microhabitats such as mud, litter and sand, and water. The tidal mudflats of the mangrove swamp holds a diverse spectrum of food for water monitors such as crustaceans and mudskippers. Water monitors were observed feeding on crustaceans such as *Scylla serrata* and fiddler crabs in the mangrove habitat.

In the non-mangrove habitats maximum number of lizards bask on litter and sand. As soon as their body gets heated up, the lizards start foraging on litter and sand. Monitors were seen preying on

fish in pools in the non mangrove habitat during summer months. Due to higher rate of evaporation in summer the volume of water decreases in these ponds and the fishes become an easy prey for water monitors. Besides this, water presumably has a regulating effect on the body temperature of the lizard (Wikramanayake and Green 1989). The corresponding ambient temperatures ($X = 30.5 \pm 1.1^{\circ}\text{C}$, $n = 35$) were higher than water temperature ($X = 26.5 \pm 0.92^{\circ}\text{C}$) for the lizards observed in water. As the body temperature in water monitor approximates water temperature (Wikramanayake and Green 1989), being in water would enable it to maintain active body temperature.

Higher percentage of resting lizards were observed in microhabitats such as mud, tree branches and liter and sand present in close proximity to water. By selecting cooler microclimates under bushes near water and on tree branches overhanging the creeks, the lizards were shaded and were exposed to a cooling breeze. Wikramanayake and Green (1989), found that water monitor in southern Sri Lanka exploited the cooling effect of the wind to maintain a lower body temperature. Hence, selection of such microhabitats for resting in turn result in thermoregulation of the lizard.

5.4 THE CLIMATIC FACTORS AFFECTING THE ACTIVITY OF WATER MONITOR

Looking at the relation of the activity with ambient temperature it should be noted that water monitors were active during certain temperature classes (Fig.5). The ambient temperature class $23-31^{\circ}\text{C}$ was found most conducive and it can be referred as the operative environmental temperature class for activity. The relation between temperature and activity (Fig.5) is curvilinear. Such type of curvilinear relation between temperature and activity

has been reported by many other workers for snakes (Semlitsch et al. 1981; Gibbons and Semlitsch 1987).

Basking was prevalent at low ambient temperature. With increase in temperature other activities such as foraging and resting dominated. The relationship of activities with substrate temperature showed an inverse trend when compared to ambient temperature (Fig. 6). The lizards selected substrates with higher temperatures for basking. Temperature at which maximum resting lizards were observed was similar for both ambient and substrate. Maximum number of foraging lizards were observed at a cooler substrate temperature (Fig. 5 and 6).

Studies on lizard activity and temperature relations have shown that one of the two strategies is used in their thermal biology (1) maintaining similar average activity temperature through behavioural means (Parker and Pianka 1975); (2) maintaining similar diel activity patterns but tolerating temperature differences (Heatwole 1970, Pianka 1970 b). Radiotelemetric study on the thermal biology of water monitor has shown that it is stenothermic and tends to thermoregulate by behavioural means (Wikramanayake and Green 1989; Wikramanayake and Dryden, In Press). It is obvious from the present study that water monitor selects substrates with relatively higher temperature to activate it's body temperature at low ambient temperature. The body temperature of water monitor has been reported to be the lowest among active varanids (Wikramanayake and Green 1989; Table 8). Higher body temperatures have been reported for both larger (*V. komodensis*) and smaller (*V. eremius*, *V. gouldii*, *V. tristis*) varanids than water monitor. Water monitor has lower body temperature may be due to it's semi aquatic habits. Water monitor feeds mostly on fish and

crabs in the tidal mudflats, creeks and pools and is known to scavenge, frequently feeding on carrion (Gaulke 1991 b; Pers. Obsv.). The food items especially the latter hardly require any agility on the part of the monitor. In foraging for the former, fast and agile movements are restricted to the aquatic environment. Water also would serve as a heat sink and rapidly cool a lizard with higher body temperature. This would necessitate frequent shuttling between feeding grounds and basking sites, and this could be costly both in terms of time and energy. By maintaining a lower body temperature water monitor exploits cooler substrates while foraging or resting, when ambient temperature is high. Thus water monitor utilizes the first of the above mentioned two strategies and thermoregulates by behavioural means.

The trends in activity pattern observed can be explained on the basis of temperature trends upto a certain extent. As would be expected there was an increase in activity with increase in temperature as in the periods in winter (Fig.7 a). It should be noted that increase in temperature does not increase the activity, rather peak activity occurs only at the operative environmental temperature class. The activity is more dependent on the occurrence of operative environmental temperature class in time and space (Grant and Dunham 1988). In winter most of the activities occurred in mid-day. As the season progresses favourable temperature would occur earlier or latter in the day. But this was not the case in the present study. The mean environmental temperature did not exceed the operative environmental temperature and hence more or less uniform activity trend was obtained in summer.

In general, relative humidity and temperature vary inversely with each other (Fig.7 and 8). The increase in RH would in part

compensate for the decrease in activity by a temperature drop. This inverse relationship of activity with RH supports the view of Heckrotte (1962) and Shine and Lamback (1985). Humidity can significantly affect the desiccation rate of snakes (Heatwole 1976; Lillywhite 1987). But Auffenberg (1988) does not suggest any evidence of relative humidity affecting the behaviour of *V. olivaceus*. However, the variation of RH in the habitat of *V. olivaceus* (72-92%) is much less than the variation in RH in the present study (35-95%). Low humidity and high temperature during the noon hours might have forced water monitors to seek cooler microclimates. This is supported by the fact that, higher number of resting lizards were recorded in microhabitats with high humidity (Fig. 9).

5.5 BEHAVIOURAL THERMOREGULATION PLAY A MAJOR ROLE IN WATER MONITOR'S ACTIVITY

Varanid lizards have elicited considerable research in regard to thermoregulation (Johnson 1972; King 1977, 1980). Brattstrom (1968) has shown that heat retention in *V. varius* is controlled by a complex vasomotor shunting mechanism and is thus an important function in the endothermy reported in free ranging varanids (Stebbins and Barwick 1986; McNab and Auffenberg 1976). McNab and Auffenberg (1976) have shown that large size is an important factor in ameliorating temperature changes within varanids living in tropical habitats. Thus there are a number of mechanisms available at least for the larger members of the family for regulating temperature, though clearly the most important of these for most species is behaviour. Water monitor seems to be the best example of this. As mentioned earlier in section 5.4, at low ambient temperature water monitors use substrates with relatively higher

temperature. At higher ambient temperature the lizards either rest in cooler microhabitats or forage in water or in other cooler substrate (e.g. mud) and thermoregulate simultaneously. Both the mechanisms of maintaining a lower body temperature and behavioural thermoregulation have helped water monitor to exploit it's semi-aquatic habitat in the best possible way.

5.6 ECOLOGICAL ROLE AND REASONS FOR CONSERVATION

One of the major ecological roles of water monitor in terms of its activity is its scavenging habit. In the dense mangrove forest where the presence of other avian or mammalian scavengers are less, water monitor is a crucial link in the food chain.

The abundance of water monitors in Bhitarkanika suggests that this species is fairly common in the sanctuary. Water monitors in Bhitarkanika are free of any kind of human exploitation. However, their habitat is subjected to all types of anthropogenic interference and exploitation. In fact it is surrounded by the Bay of Bengal on one side and high human population on rest three sides. Enhanced protection to its coastal habitat will ensure the better survival of water monitor. If the fast depletion of its habitat is not checked, water monitors will no longer survive.

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* - Originals not seen.

APPENDIX - I. Number of water monitors encountered in each time class and period in the mangrove habitat from December 1992 to April 1993.

PER/ TIME	6-9	9-12	12-15	15-18	TOTAL
Dec-I	1	8	9	3	21
Dec-II	3	7	13	2	25
Jan-I	3	7	14	4	28
Jan-II	2	5	9	4	20
Feb-I	0	0	3	1	4
Feb-II	2	4	9	3	18
Mar-I	4	2	7	8	21
Mar-II	12	12	16	13	53
Apr-I	13	24	13	14	64
Apr-II	5	13	7	3	28
TOTAL	45	82	90	55	

APPENDIX - II. Number of water monitors encountered in each time class and period in the non-mangrove habitat from December 1992 to April 1993.

PER\ TIME	6-9	9-12	12-15	15-18	TOTAL
DEC-I	4	19	13	4	40
DEC-II	1	10	13	3	27
JAN-I	3	17	5	4	29
JAN-II	5	10	14	8	37
FEB-I	4	11	22	3	40
FEB-II	8	13	10	5	36
MAR-I	6	13	12	5	36
MAR-II	2	14	14	5	35
APR-I	24	17	20	8	69
APR-II	6	6	11	7	30
TOTAL	63	130	134	52	