

**Ecology and behaviour of the Western Ghats flying lizard
Draco dussumieri in Dandeli Wildlife Sanctuary**

A Thesis Submitted to

Manipal University

In partial fulfilment for the degree of

Master of Science
in Wildlife Biology and Conservation
2008

by

Dipti Humraskar

Post-Graduate Program in Wildlife Biology & Conservation
Centre for Wildlife Studies
and
National Centre for Biological Sciences
UAS-GKVK Campus
Bangalore – 500 065



Post-Graduate Program in Wildlife Biology and Conservation

National Centre For Biological Sciences, Post Box 6501, GKVK Campus, Hebbal, Bangalore 560 065. India

Tel: 91-80-2363 6421 - 31, Fax: 91-80-2363 6662

Email: misc@wcsindia.org Website: www.wcsindia.org

Declaration

I declare that the thesis entitled "Ecology and behaviour of the Western Ghats flying lizard *Draco dussumieri* in Dandeli Wildlife Sanctuary" comprises research work done by me under the guidance of Dr. Anindya Sinha, and co-guidance of Dr. Suhel Quader. The work is original and has not been done earlier by anyone else. Part of this work, which is related to or similar to work done by other researchers, has been cited in this thesis at appropriate places. The results presented in this thesis have not been submitted previously to this or any other university for an M.Sc. or any other degree.

Signature of the guide
(Dr Anindya Sinha)

Signature of the candidate
(Humraskar Dipti Ashok)





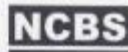
Post-Graduate Program in Wildlife Biology and Conservation

National Centre for Biological Sciences, Post Box 6501, GKVK Campus, Hebbal, Bangalore 560 065, INDIA.
Tel: 91-80-23666414, Fax: 91-80-23636662, Email: msscwildlife@ncbs.res.in Website: <http://mssc.wcsindia.org>

Certificate

I declare that the thesis entitled "Ecology and behaviour of the Western Ghats flying lizard *Draco dussumieri* in Dandeli Wildlife Sanctuary" comprises research work carried out by Humraskar Dipti Ashok at the Centre for Wildlife Studies under my guidance, and the co-guidance of Dr Suhel Quader during the period 2007-2008, for the Degree of Master of Science in Wildlife Biology and Conservation of the Manipal University. The results presented in this thesis have not been submitted previously to this or any other university for a MSc or any other degree.

Dr Anindya Sinha
National Institute of Advanced Studies
Indian Institute of Science Campus
Bangalore 560012



SUMMARY

Draco dussumieri or the Western Ghats flying lizard is an agamid lizard endemic to the Western Ghats of south India, the ecology of which remains virtually unknown. Its elaborate morphological ornamentation, including a lateral skin-membrane (patagium) and a brightly coloured gular appendage also makes this species an interesting subject for behavioural investigations. This study aimed at generating baseline ecological data on the species. In the study, I examined the time-activity budget and behavioural profile of *D. dussumieri*, with a specific focus on the diurnal and seasonal variation in behaviour between the two sexes. The study was conducted in the Dandeli Wildlife Sanctuary, Uttar Kannada District, Karnataka, over two seasons – winter (December 2007 and January 2008) and summer (March 2008 and April 2008). Data were collected on the time-activity budget and behavioural profile of the lizard using instantaneous and focal animal sampling, respectively. I used sampling *ad libitum* to record interactions between individual lizards. As thermoregulation is known to play a vital role in determining the activity levels of ectotherms, I recorded the ambient temperature and humidity throughout the study. The study reveals five common behaviours exhibited by the species – immobility, moving, gular flashing, feeding and gliding. Male and female flying lizards spent as much as 86.99% and 91.86% of their time, respectively, being immobile, although the variation in time spent immobile, by either sex, did not correspond with the variations in temperature or humidity. I found significant differences in the activity patterns of the lizards between winter and summer, and a shift from a unimodal activity peak during midday in winter to a bimodal peak during early morning and evening in summer. Males spent less time immobile than females, throughout the day, especially during summer when the breeding season began. They also exhibited higher rates of gular display, movement, feeding and gliding. In summer, the rates of

gular display by males increased in the presence of conspecific males but not in the presence of females. Gular display by females, in contrast, increased when conspecific females were present. Territoriality occurred among males only during the breeding season, while females exhibited territoriality against other females during both winter and summer.

The changes in the behaviour of the male with the advent of the breeding season and the observed differences in the behavioural profile of the two sexes across seasons, especially the display of the gular appendage in relation to the presence of conspecifics, provide novel insights into the mating system of the species.

ACKNOWLEDGEMENTS

“I am the lizard king, I can do anything” – Jim Morrison

I’m not quite the king but my study would not be possible without the immense hard work put in by several people and institutions.

I’d like to thank Dr. Ajith Kumar for his patience and for our ‘wait and hope’ motto in the last two years; we only managed because he never gave up. I’ve always had silent gratitude for my guides, Dr. Anindya Sinha and Dr. Suhel Quader who helped me conceptualize and execute this project, and I am indebted to them for their guidance and encouragement. I am extremely grateful to Dr. Geoff Hyde who sacrificed several days and sometimes even late evenings trying to make things seem and sound right. I’d also like to thank Dr. Rashid Raza, Dr. Jagdish Krishnaswamy and Devcharan Jathanna for always being just one ‘*one chai*’ away.

My study was financially supported by the Wildlife Conservation Society and the Centre for Wildlife Studies provided administrative help. The Manipal University for certifying the master’s programme and the National Centre for Biological Sciences for the academic support.

I’d like to thank the Karnataka State Forest Department for permitting me to carry out field work in the Dandeli Tiger Reserve. I would especially like to thank Mr. Manoj Kumar, IFS, Deputy Conservator of Forests, Dandeli Wildlife Sanctuary for taking keen interest in my study and providing immense logistic support. Mr. C. R. Naik, Forest Guard, and his family always provided a home away from home. Fieldwork would have

not been as comfortable without them! Bhiru Bodke, Anand and Akshay Naik for their enthusiastic assistance in field. I thank everyone at the Kulgi Nature Camp especially Sunil, Baburao, Maruti and Deepa for their hospitality while in field.

My batchmates have made my stay away from home a warm one. Especially Priya by being a great friend, Priyanka for her unlimited supply of *chai* and *gyaan*, Nandini for bringing smiles and sunshine during the most desperate times, Swapna, Kullu, Umesh, Robin, Dharmaveer and Kiran for the never ending entertainment and great company through the last two years. Sannappa, NCBS kitchen staff especially Rudra and the security staff for bearing us through these two years.

Dr. Parvish Pandya for introducing me to the wild. Anand and Dharmendra for their constant help and encouragement. Viral, Sachin and Saloni for flooding my field station with lots of food and chocolates. Viral especially for his company and encouragement while in field. Varad Giri, Sanjay Sane and Jimmy McGuire for taking interest in my study and helping me with access to literature.

And most importantly my parents and sister who have always supported and respected my choice to pursue my interests.

CONTENTS

PAGE

Summary.....	i
Acknowledgments.....	iii
Contents.....	
Introduction.....	1
Literature cited.....	5
Time-activity budget and behavioural profile of the Western Ghats flying lizard	8
<i>Draco dussumieri</i>	
Abstract.....	8
Introduction.....	9
Methods and Materials.....	
Study area	10
Study methods	11
Analysis	13
Results.....	14
Discussion.....	25
Literature cited.....	30
Appendix 1.....	33

INTRODUCTION

Flying lizards of the genus *Draco* are members of the reptilian family Agamidae and are unique in their ability to glide from one tree to another. *Draco* is a species-rich genus with more than 40 species and subspecies inhabiting the tropical rainforests of south and southeast Asia (McGuire, 2001). Smith (1935) reports the presence of at least six species from the Indian subcontinent, of which *Draco dussumieri* or the Western Ghats flying lizard is endemic to southern India and is the sole representative of the genus west of Assam in northeastern India. The recorded range of *D. dussumieri* shows a wide distribution along the Western Ghats in the states of Goa, Karnataka, Tamil Nadu and Kerala (Smith, 1935 and Daniel, 2002) and in some parts of the Eastern Ghats in the state of Andhra Pradesh (Balachandran, 2000). Within this wide distributional range, *D. dussumieri* occurs in an equally diverse range of habitats including evergreen forests, moist and dry deciduous forests as well as teak, coconut and arecanut plantations (Smith, 1935).

Flying lizards attracted attention by the virtue of their elaborate morphological ornamentation, which plays a vital role in certain specialized behaviours exhibited by them. Flying dragons, as these lizards are popularly known, possess a lateral wing-membrane (patagium) formed by the skin, which is supported by the last five to seven elongated ribs. This makes them accomplished gliders capable of covering distances as long as 20 meters (Herre, 1958). The survival and reproductive success of an animal is greatly influenced by its locomotive ability, and the flying lizards are no exception, having employed gliding as an energy-efficient mode to exploit resources including food and mates (McGuire, 2001). Mertens (1930 in Hairston, 1957), Hairston (1957) and Herre (1958) have described the gliding ability of *Draco*, which has been supported by

subsequent experiments of Colbert (1967) and Klingel (1965 in McGuire et al., 2001). This triggered further detailed studies on the morphology and physiology of the patagial membrane and the biomechanics of gliding using the patagium.

Apart from the patagium, flying lizards possess an elongated gular appendage (dewlap), which is extended and retracted at periodic intervals. Males and females are dimorphic with respect to the dewlap length and the colour pattern on the patagium. The dewlap in males is distinctively longer, as compared to that of the females, and is known to be used in territorial defence and mate attraction (Smith, 1935; Mori & Hikida, 1994). Other studies have also shown a reversed sexual size dimorphism in flying lizards, leading to an increase in the wing to body size ratio in females, attributable to a required reduced cost of gliding for gravid females (Shine et al., 1998).

The genus *Draco* represents a species complex that has undergone several taxonomic revisions since 1983. Recent genetic studies have provided a comprehensive species-level phylogenetic evaluation for the genus (McGuire, 2001). Observations on various species of flying lizards provide some insight to their natural history of the genus *Draco*. Flying lizards are diurnal and strictly arboreal with only females descending to the ground to lay eggs that are buried in a small cavity dug in the soil. Flying lizards are also known to have a mainly myrmecophagous diet, occasionally with some beetles and grubs added to it (Inger, 1983). Ecological studies on the genus have been very few. Inger (1983) investigated the utilization of the forest strata by six sympatric species of *Draco* in Borneo and observed a partitioning of the forest strata by these species on the basis of their body size. Behavioural studies, however, have only been restricted to *D. volans*

sumatranus in Borneo investigating their behavioural patterns and microhabitat use (Mori & Hikida, 1993, 1994).

Studies on *D. dussumieri* are even rarer with systematic data available only on the patagial physiology and anatomy of the species (John, 1970). Information on the behaviour of the lizard is restricted to opportunistic observations of courtship behaviour, mating of the species (John, 1962 and 1967). Difficulty in field observation of the lizards due to their highly cryptic nature has limited the ability to make systematic studies and have, therefore, confined our understanding of the species to laboratory examinations and opportunistic records. As a result of this paucity of data, the conservation status of this species remains unknown, even though it is endemic to the Western Ghats ranges. The fragmentation of rainforests in Western Ghats has, however, been reported to have negatively impacted *D. dussumieri* due to their inability to exist in small fragments (Ishwar et al., 2003).

Being the only agamid capable of gliding and exhibiting elaborate display behaviours, *D. dussumieri* nevertheless constitutes an interesting organism for ecological and behavioural studies. The goal of the current study was thus to generate baseline information on the species, with a particular focus on the time-activity budget and behavioural profile of the species. More specifically, I examined the variation in the seasonal and diurnal activity patterns displayed by the two sexes.

I conducted the study in the Dandeli-Anshi Tiger Reserve (15° 24' N and 74° 36' E), located in the Uttar Kannada District of Karnataka in southern India. The study spanned over two seasons, winter and summer (December 2007 to April 2008), which also

allowed for the documentation of the courtship and mating behaviour of the species, summer being the usual breeding season of agamids. I used instantaneous and focal animal sampling to collect data on time-activity budgets and behavioural profiles, and sampling *ad libitum* for conspecific interactions. The thesis comprises a single manuscript describing the activity-budget and behavioural profile of *D. dussumieri*, targeted for the *Journal of Herpetology*.

LITERATURE CITED

- Balachandran, S. 2000. Occurrence of Draco or flying lizard *Draco dussumieri* in Chittoor, Andhra Pradesh. Journal of Bombay Natural History Society. 97(1): 115.
- Colbert, H. E. 1967. Adaptations for gliding in the lizard *Draco*. American Museum Novitates. 2883: 1-20.
- Daniels, J. C. 2002. The Book of Indian Reptiles and Amphibians, BNHS & Oxford University Press, Mumbai.
- Hairston, N. G. 1957. Observations on the Behaviour of *Draco volans* in the Philippines. Copeia. 4: 262-265.
- Herre, A. W. 1958. On the gliding of flying lizards Genus *Draco*. Copeia. 4: 338-339.
- Inger, R. F. 1983. Morphological and ecological variation in the flying lizards (genus *Draco*). Fieldiana Zoology. 18: 1-35.
- Ishwar, N. M., Chellam, R., Kumar, A. and Rao, B. R. 2003. The response of agamid lizards to rainforest fragmentation in the Southern Western Ghats, India. Conservation and Society. 1(2): 69-86.
- John, K. O. 1962. Notes on the bionomics of the flying lizard, *Draco dussumieri* Dum. & Bib. Journal of the Bombay Natural History Society. 59: 298-301.
- John, K. O. 1967. Observations on the mating behaviour and copulation in the *Draco dussumieri* Dum. & Bib. (Reptilia: Sauria). Journal of the Bombay Natural History Society. 64: 112-115.
- John, K. O. 1970. "Territorial behaviour" in the South Indian flying lizard, *Draco dussumieri* Dum. & Bib. British Journal of Herpetology. 4: 169-172.

- McGuire, J. 2001. Phylogenetic systematics of Southeast Asian flying lizards (Iguania: Agamidae: *Draco* as inferred from mitochondrial DNA sequence data. *Biological Journal of the Linnaean Society*. 72: 203–229.
- Mori, A. and Hikida, T. 1993. Natural history observations of the flying lizard, *Draco volans sumatranus* (Agamidae, Squamata) from Sarawak, Malaysia. *Raffles Bull. Zool.* 41(1): 83-94.
- Mori, A. and Hikida, T. 1994. Field Observations on the Social Behaviour of the Flying Lizard, *Draco volans sumatranus*, in Borneo. *Copeia*. 1: 124-130.
- Shine, R., Keogh, S., Doughty, P. and Giragossyan, H. 1998. Costs of reproduction and the evolution of sexual dimorphism in a ‘flying lizard’ *Draco melanopogon* (Agamidae). *Journal of Zoology*. 246: 203-213.
- Smith, M. J. 1935. The fauna of British India Ceylon and Burma. Reptilia and Amphibia Vol II. Today and Tomorrow’s Printers and Publishers.



Photo credit: Dipti Humraskar

Picture 1: Moist deciduous forest in the intensive study area



Photo credit: Viral Mistry

Picture 2: Male *D. dussumieri* displaying the gular appendage



Photo credit: Dipti Humraskar

Picture 3: Female *D. dussumieri* displaying with partially expanded patagium

Time-Activity Budget and Behavioural Profile of the Western Ghats Flying Lizard

Draco dussumieri

ABSTRACT

I studied the time-activity budget and behavioural profile of free-ranging *Draco dussumieri* or the Western Ghats flying lizards in a moist deciduous forest using instantaneous and focal animal sampling. The data collected over 187.25 hours, reveals a time-activity budget dominated by immobility (86.99% in males and 91.86% in females) and four common behavioural events, including gular flashing, moving, feeding and gliding that occurred in bouts interspersed between the prolonged periods of immobility. The lack of a strong correlation between the mean percentage of time spent immobile by either sex and the mean ambient monthly temperature or humidity, and a corresponding absence of basking behaviour suggest the lack of active thermoregulation in these flying lizards. This is also supported by their occurrence in tropical forests, where temperatures are maintained within a tolerable range and opportunities for basking are few. The diurnal behaviour patterns, which differed between males and females, also showed significant differences across winter and summer. The males showed a unimodal activity peak during winter and a bimodal peak during summer whereas females exhibited a dispersed activity pattern, with all behaviours performed at low frequencies, for a longer period of time throughout the day in both seasons. Summer is the breeding season of flying lizards and the behavioural frequencies of both sexes increased significantly with males exhibiting higher activity rates than females. In summer, the males showed a high frequency of gular display when conspecific males were present, suggesting territoriality in males against other males, only in the breeding season.

INTRODUCTION

Elaborate morphological ornamentation in animals has attracted much attention due to their role in specialized behaviours. Flying lizards of the genus *Draco* represent one such unique group of agamids that possess accessory appendages and therefore constitute interesting systems for behavioural investigation. The ability of animals to access resources is greatly influenced by their locomotor abilities, which, in turn, relate to their survival and reproductive success. Flying lizards possess a lateral skin-membrane supported by the last five to seven ribs, which facilitate gliding (Smith, 1935). Having adapted to a strictly arboreal habit, flying lizards use gliding as an energy-efficient mode of locomotion to explore resources like food, mates and territories and to defend them. Flying lizards also possess an elongated gular appendage, which is known to be used during social displays (Smith, 1935; Mori & Hikida, 1993).

D. dussumieri, the only agamid capable of gliding and exhibiting elaborate display behaviours, is endemic to the Western Ghats biodiversity hotspot of southern India. The demography and ecology of the species remain virtually unknown, thus severely limiting our ability to investigate its complex behaviours and their function. The goal of my study, therefore, was to generate baseline information on the species, with a special focus on the time-activity budget and behavioural profile of the species. More specifically, I examined the variation in the seasonal and diurnal behavioural pattern among the two sexes of this flying lizard.

METHODS AND MATERIALS

Study Area

I carried out the study in Dandeli-Anshi Tiger Reserve (TR) (15° 24' N and 74° 36' E) located in the Uttara Kannada district of Karnataka, southern India, from December 2007 to January 2008 (winter) and March 2008 to May 2008 (summer). The Dandeli Wildlife Sanctuary (475 km²) and Anshi National Park (250 km²) together constitute the Dandeli Tiger Reserve spanning a total area of 834 km². The altitude of the area ranges from 67 m to 706 m above sea level and receives an average annual rainfall of 2284.43 mm (Karnataka Forest Department, unpubl. data). The vegetation in the region is of three main types – evergreen, moist deciduous and dry deciduous, with patches of teak plantations (Santharam, 2003).

My intensive study site was located in the Dandeli Wildlife Sanctuary and was restricted to a pre-existing forest trail (altitude - 520m asl) chosen on the basis of high encounter rates of flying lizards observed during a prior visit (Fig.1). I conducted sampling along 1.2 km of the trail and approximately on 10m on either side (restricted by the terrain and visibility of lizards). In the intensive study site, the vegetation was uniformly moist deciduous with the dominant tree species being *Tectona grandis*, *Xylia xylocarpa*, *Terminalia paniculata*, *Grewia tiliaefolia* and scattered bamboo clumps.

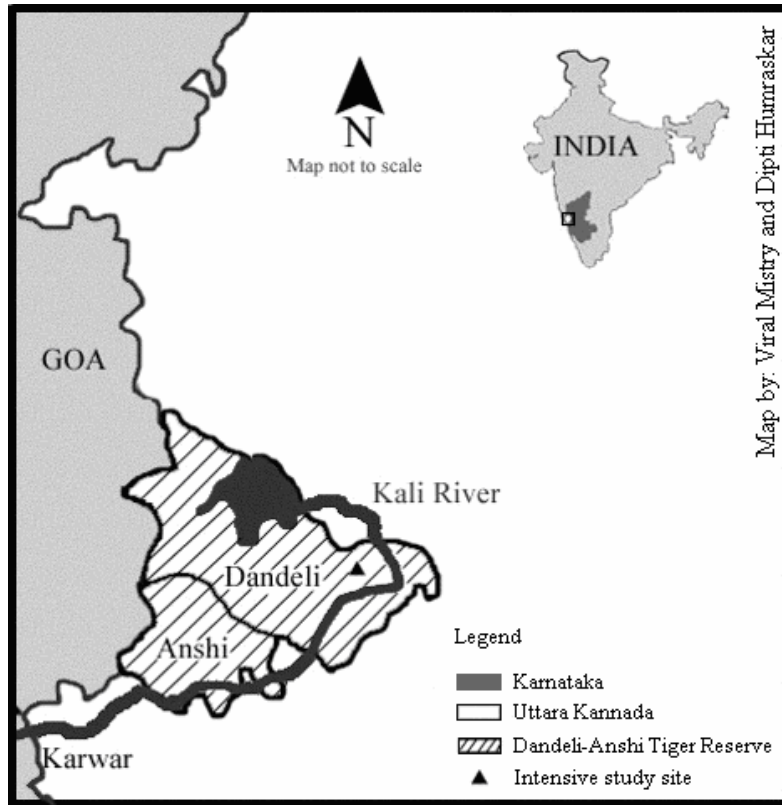


Figure 1: Map of the study area in the Dandeli Wildlife Sanctuary, Karnataka

Study methods

I collected data on time-activity budget and behavioural profiles of free-ranging unmarked flying lizards across two seasons, winter (December and January) and summer (March and April). Throughout the study period, I recorded data between 0700 to 1800 hrs. I opportunistically located individuals along the sampling route by carefully scanning the tree trunks using a pair of binoculars (Olympus 10 × 50mm). On encountering an animal I followed it and conducted structured observations on it till it disappeared from sight, after which I located another individual along the same path and continued my observations. As the sexes are dimorphic, with the gular appendage being distinctively longer in males, I could determine the sex of the individuals on almost all instances except a few when the animals remained dormant throughout the observation period.

I used instantaneous sampling on the study animals during January, March and April at 5-minute intervals to collect data on time-activity budget. I recorded data on five behaviours: immobile, moving, gular flashing, feeding and gliding (description in Appendix 1) during these samples. I recorded the ambient temperature and humidity (one foot above the ground in the shade at the site of observation) using a digital thermo-hygrometer, every 20 minutes during the observation period.

In order to determine the frequency of occurrence of short-duration behavioural events, I carried out continuous 5-minute focal animal sampling on the chosen individual alternately with the instantaneous sampling (Altmann, 1974). During each of these observation periods, I collected data on all occurrences of movement, feeding, gliding and gular flashing (see Appendix 1), exhibited by the flying lizards. These behaviours could also be considered as behavioural events as they often occurred in very short bouts throughout the day. I also recorded the presence of conspecifics around a radius of approximately 5 m of the focal individual and noted the number and sex of those individuals during these focal samples. I recorded a total of 2064 instantaneous samples on 77 individuals (49 males and 28 females) and 182.84 hours of focal animal observations on 106 individuals, 62 males and 44 females. Individuals of unknown sex were excluded from analysis.

(a)	January	March	April	Total	(b)	Winter	Summer	Total
Males	406	227	412	1045	Males	59.92	27.42	87.34
Females	340	298	381	1019	Females	64.42	31.08	95.5
Total	746	525	793	2064	Total	124.34	58.5	182.84

Table 1: (a) Number of instantaneous samples and (b) hours of focal animal observation

ANALYSIS

I used the statistical programs R (version R.2.7.0 – R Development Core Team, 2008) and SPSS Version 11.5 (SPSS Inc., Chicago, USA) to analyze the data on the diurnal and seasonal patterns in the time-activity budget and frequencies of behavioural events in female and male flying lizards. I have excluded individuals of unknown sex in the analyses comparing the two sexes.

In order to examine the diurnal activity pattern of flying lizards, I divided the sampling period of the observation day from 0700 to 1800 hours into six intervals (0700-0800 hours, 0800-1000 hours, 1000-1200 hours, 1200-1400 hours, 1400-1600 hours, and 1600-1800 hours).

The time-activity budget of an individual was calculated in terms of the percentage of time spent by the individual in various behavioural activities using the equation:

$$T_{aq} = \frac{1}{S} \sum \left[\left(\frac{n_i}{N_i} \right) * 100 \right]$$

where,

T_{aq} = percentage time spent in behaviour 'a' during 'q'th time interval

n_i = number of records of behaviour 'a' for individual 'i' in time interval 'q'

N_i = total number of instantaneous samples for individual 'i' in time interval 'q' and

S = Total number of individuals

I used the Wilcoxon signed rank test (Siegel & Castellan, 1988) to examine the difference in diurnal immobility between the two sexes individually for each month. To examine the variation in diurnal immobility among months for each sex, I used the Friedman two way analysis of variance (Siegel and Castellan 1988). I used the Spearman

rank correlation coefficient to test the effect of average monthly temperature and humidity on the behaviour of the flying lizards.

As mentioned earlier, I calculated the mean frequencies per five minutes, of moving, feeding, gliding and gular flashing using focal animal sampling. To examine the diurnal variation of these behaviours across seasons, I combined the four sampling months into two seasons, winter (December and January) and summer (March to May). Further, I classified the day into five time intervals (I = 0700-1000 hours, II = 1000-1200 hours, III = 1200-1400 hours, IV = 1400-1600 hours, V = 1600-1800 hours). For significance testing, I used the Wilcoxon signed-rank test to test the difference in diurnal activity rates of males and females across seasons. I used the Mann Whitney U test, after pooling the five time intervals into forenoon and afternoon to examine the difference between seasons for each sex.

I classified the number and sex of the conspecifics observed near the focal animal into four categories, 1M: single male, 1F: single female and >1: more than one individual irrespective of the sex and the apparent absence of conspecifics (the non-detection of conspecifics has been scored as ND) and compared the rate of gular display by the focal individual across these categories.

RESULTS

Time-activity budget

I conducted instantaneous sampling on 77 individuals (49 males and 28 females) during three months, January, March and April. The percentage time spent immobile by the males and females was 86.99% and 91.86% respectively, the highest apportionment of

their time as compared to all other behaviours recorded (Fig.2a). In contrast, the study individuals dedicated a rather negligible proportion of their time to behaviours such as moving, feeding and gular flashing (Fig. 2b).

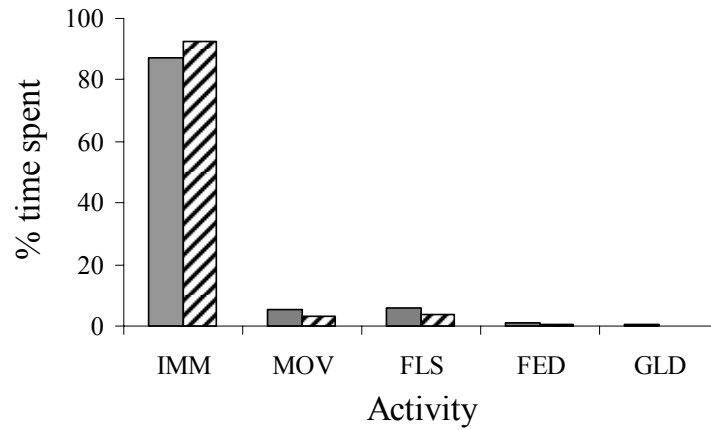


Figure 2a: Total percentage time spent immobile (IMM), moving (MOV), gular flashing (FLS), feeding (FED) and gliding (GLD) by 49 male (solid bars) and 28 female (hatched bars) lizards over the entire study period. Variances in the data have not been shown in order to account for 100% of the time-activity budget

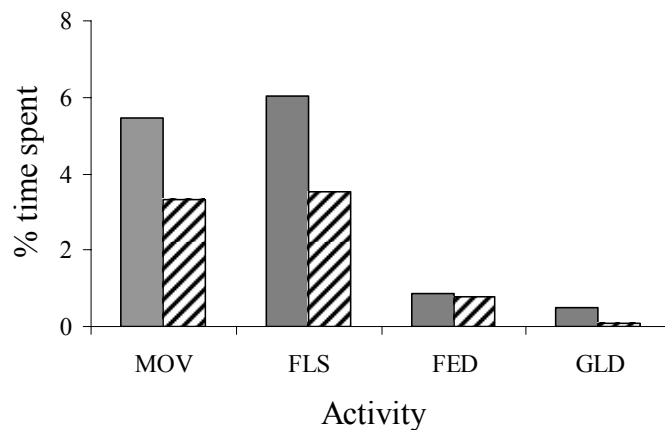
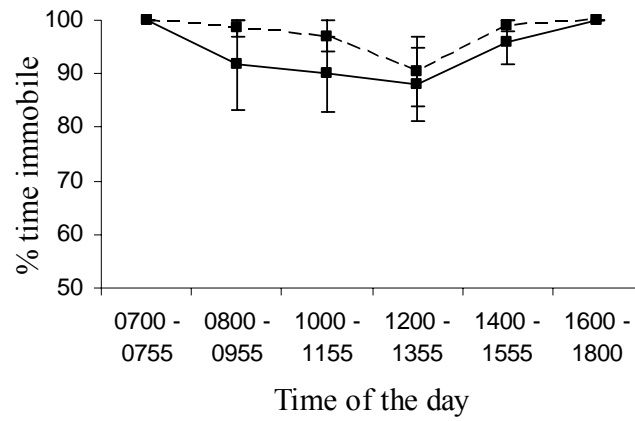


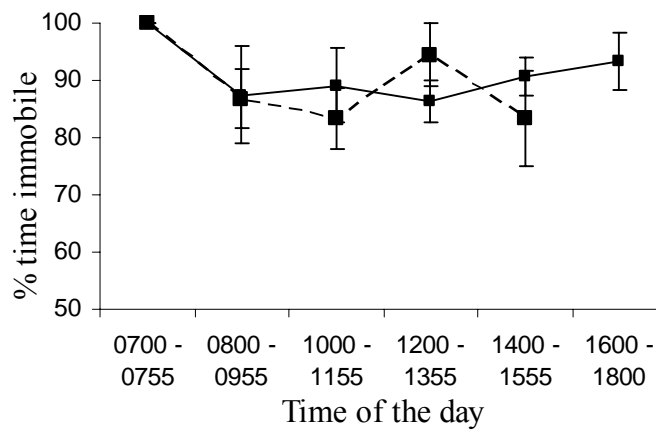
Figure 2b: Total percentage time spent in moving (MOV), gular flashing of the gular appendage (FLS), feeding (FED) and gliding (GLD) by the 49 male (solid bars) and 29 female (hatched bars) lizards over the entire study period (variances in the data have not been shown in order to account for 100% of the time-activity budget)

As flying lizards spent their maximum time being immobile, I examined the diurnal and seasonal trends in immobility in terms of its changing contribution to the time-activity budget of these individuals. The diurnal activity pattern of both males and females varied among the three months and the period of diurnal immobility showed a gradual decrease from January to April (Fig. 3). A midday (1200 to 1355 hours) decline in immobility was observed during January and March, whereas in April the inactivity was highest during this period of the day. Among months, the diurnal immobility pattern of males varied significantly through the day, with immobility being lowest in April (Friedman test: $\chi^2 = 6.348, p = 0.042$) while females showed no such significant difference (Friedman test: $\chi^2 = 3.500, p = 0.174$). Between sexes, the females exhibited a greater percentage of time spent immobile throughout the day, the difference being significant only during April (Wilcoxon signed-rank test: $Z = -2.201, p = 0.028$) but not during January ($Z = -1.826, p = 0.068$) and March ($Z = -0.365, p = 0.715$).

(a)



(b)



(c)

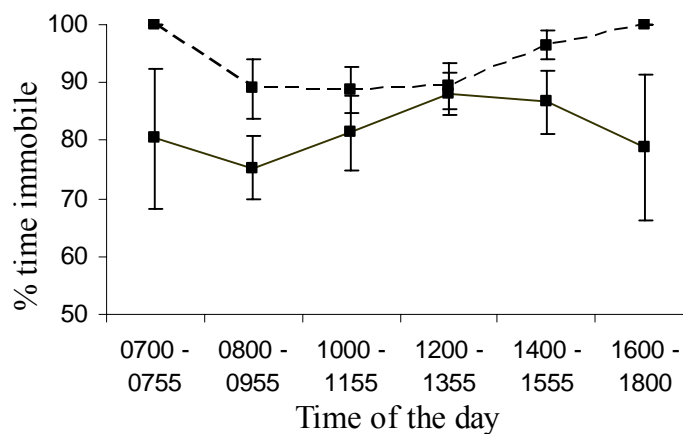


Figure 3: Mean (\pm SE) percentage time spent immobile by 49 males (—■—) and 28 females (--■--) over the day in (a) January, (b) March and (c) April.

Effect of temperature and humidity on immobility

As the diurnal immobility patterns showed a difference between males and females (Fig. 4a), I examined the possible relationship between inactivity and the mean monthly temperature and humidity (Fig. 4b), individually for the two sexes. The variation in diurnal immobility, however, did not correspond to the trend in diurnal variation of temperature or humidity for either sex over the study period. Immobility in males as well as females, thus, failed to show a significant correlation either with temperature or humidity (R_s from -0.095 to 0.588, $p < 0.07$).

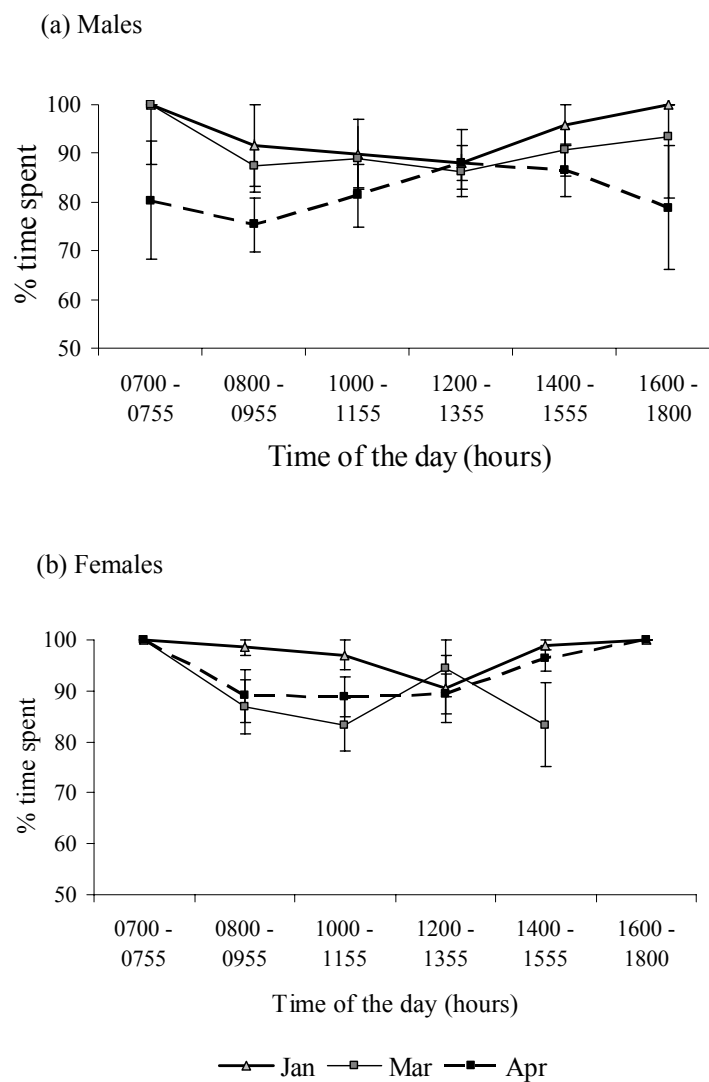


Fig 4a: Diurnal variation in immobility (mean \pm SE of the percentage time spent) of 49 male and 28 female lizards in three months

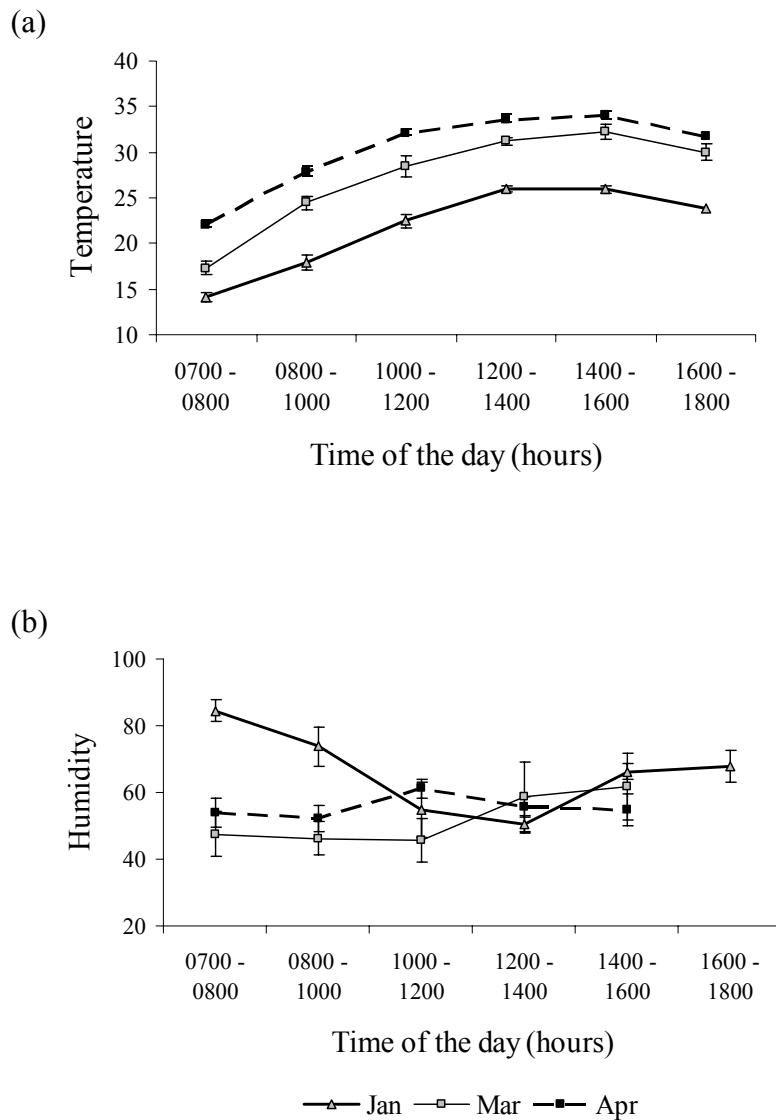


Fig 4b: Diurnal variation (mean \pm SE) in (a) temperature and (b) humidity over months

Behavioural profiles

I conducted focal animal sampling on 106 individuals (62 males, 42 females) and examined the variation in the frequency of four behavioural events, moving, feeding, gular flashing and gliding, exhibited by them during the two seasons (Fig 5).

The flying lizards showed a high activity period during midday in winter, with males exhibiting a single peak between 1200 hours and 1600 hours, while the females showed a more dispersed period of activity extending 1000 hours to 1600 hours, during which they

performed all the four behaviours at relatively lower frequencies. In summer, however, the males displayed two activity peaks, during late morning, (1000 to 1200 hours), and evening (1600 to 1800 hours) for all the behaviours, except feeding. Females, in contrast, showed only a single activity period, and that too only during afternoon.

Within seasons, males indulged in various activities more than females showing a significant difference during summer (Table 2a). Between seasons, males as well as females showed a significant increase in the frequencies of gular flashing and moving, whereas feeding and gliding was significant only in males during the forenoon (Table 2b).

		Forenoon	Afternoon	Forenoon	Afternoon
Gular flashing	Z	-0.356	-0.427	-3.457	-0.688
	p	0.722	0.670	0.001	0.491
Moving	Z	-0.839	-0.661	-4.223	-2.670
	p	0.402	0.509	<0.001	0.008
Feeding	Z	-0.486	-0.331	-1.988	-2.447
	p	0.627	0.741	0.047	0.014
Gliding	Z	-0.598	-0.730	-3.989	-1.968
	p	0.550	0.466	<0.001	0.049

Table 2a: Results of Wilcoxon signed-rank test for differences in the frequency of gular flashing, moving, feeding and gliding displayed between 62 male and 44 female lizards over the day within each season

		Males		Females	
		Forenoon	Afternoon	Forenoon	Afternoon
Gular flashing	<i>Z</i>	-4.996	-2.739	-2.696	-4.342
	<i>P</i>	<0.01	0.006	0.007	<0.001
Moving	<i>Z</i>	-5.962	-4.991	-3.811	-5.563
	<i>p</i>	<0.01	<0.01	<0.01	<0.01
Feeding	<i>Z</i>	-3.170	-0.350	-1.047	-2.478
	<i>p</i>	0.002	0.726	0.295	<0.05
Gliding	<i>Z</i>	-3.567	-1.645	-0.889	-0.369
	<i>p</i>	<0.01	0.100	0.374	0.712

Table 2b: Results of Mann Whitney U test for differences in the frequency of gular flashing, moving, feeding and gliding, displayed by 62 male and 44 female lizards over the day across two seasons

I saw flying lizards position themselves along ant trails, constantly picking up ants from the bark during the entire feeding bout. Of all the instances of gliding I observed during sampling, gliding distances ranged from 0.5 to 27.13 m.

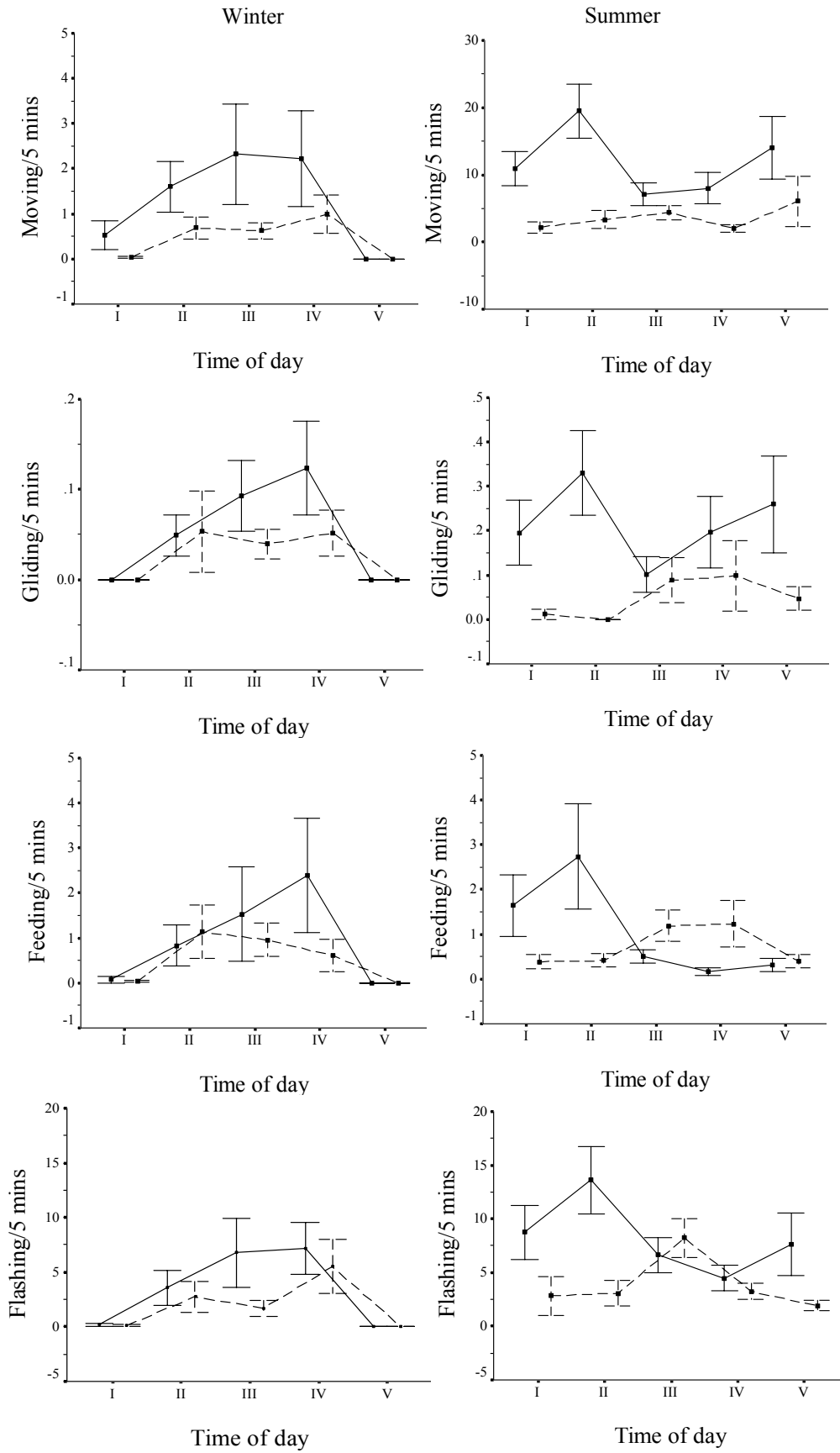
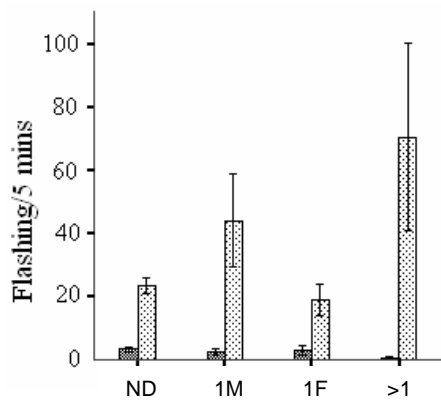


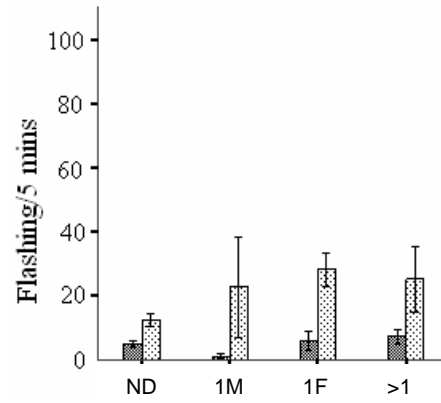
Fig 5: Frequency of feeding and gular flashing per five minutes for males (—) and females (---) across seasons

Gular flashing in the presence of conspecifics

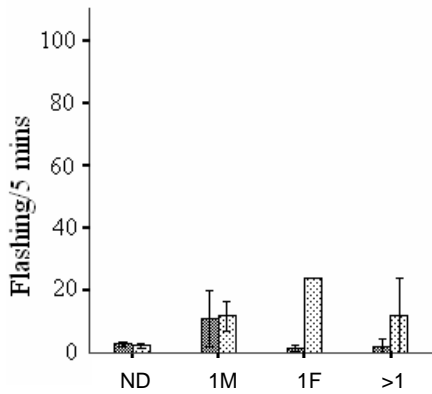
Males showed increased rate of gular display in the presence of conspecifics only during summer. During forenoon, elevated levels of display were observed in the presence of conspecific males and more than one individual, whereas the presence of females remained similar to that in the apparent absence of conspecifics (Fig. 6a). During afternoon, the rate increased, but showed no difference across the sex of conspecifics (Fig. 6b). Females on the other hand showed increased gular display in the presence of other females during both seasons, whereas in the presence of males elevated gular display was observed in the forenoon during winter as well as summer (Fig. 6c and 6d).



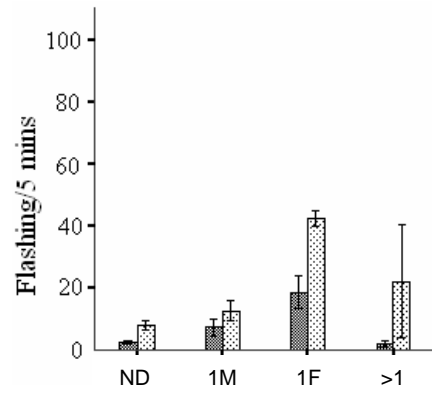
(a) Males during forenoon



(b) Males during afternoon



(c) Females during forenoon



(d) Females during afternoon

Fig 6: Differences in gular flashing rates of individuals in the presence of conspecifics: ND = Non-detection, 1M = Single male, 1F = Single female and >1 = More than one individual

DISCUSSION

My study on the activity budget and behavioural profile of the Western Ghats flying lizard, *Draco dussumieri*, in the Dandeli Tiger Reserve revealed five common behaviours in this lizard – immobility, moving, gular flashing, feeding and gliding. Among these, all, except immobility, occurred in discrete bouts. The time-activity budget of the species, in fact, shows that the lizards spent a remarkably high percentage of time being immobile (80-90%), with moving, gular flashing feeding and gliding represented at a very low percentage (Fig.2).

Prolonged periods of inactivity in reptiles are often attributed to thermoregulatory behaviour, with ectotherms spending a relatively high amount of time in basking in order to regulate their physiological state (Bogert, 1949; Jenssen et al., 1996). However, in tropical forests, where flying lizards are found, ambient temperatures do not fluctuate to extreme levels, and therefore, stable body temperatures can be attained without investing in specialised thermoregulatory behaviours (Shine & Madsen, 1995). The immobility of *D. dussumieri* failed to show a significant correlation with either the mean diurnal temperature or humidity (Table 1). In addition, the study lizards were not observed basking by positioning themselves in sunlight for long durations or by shuttling between shade and light in either winter or summer, suggesting that although the variation in temperature on a larger temporal scale may influence the activity of these lizards, it may not be the sole overriding factor leading to such a high degree of immobility. Therefore, though the classical belief of active thermoregulation by basking still holds true for reptiles belonging to temperate regions, my study suggests that *D. dussumieri* in Dandeli may also resort to thermoconformity as the benefits of thermoregulation may not outweigh their costs; this has, in fact, earlier been shown for several forest-dwelling

species of lizards as well as other reptiles (Rose 1981; Shine 1998; Vitt 1983, Huey & Slatkin, 1976). Previous studies examining the effect of temperature on the behaviour of *D. volans* (Mori and Hikida, 1993; Alcalá, 1967) have yielded ambiguous results and hence, the thermal activity of flying lizards, particularly in relation to seasonal changes in temperature, needs to be further investigated.

Being highly cryptic with bright accessory appendages, flying lizards may exercise immobility as an antipredatory behaviour. Long durations of immobility, interspersed by bouts of concentrated activity, could potentially increase the survival rate of such animals and may, therefore, have evolved as a survival strategy in response to the evolution of bright coloration (Rose, 1981). I, however, failed to observe a single case of predation on flying lizards during my entire observation period. Mixed avian hunting parties were frequently encountered in the intensive study site through the day and several instances of close encounters with birds like black drongo (*Dicrurus macrocercus*), Eurasian golden oriole (*Oriolus oriolus*) and Malabar grey hornbill (*Ocyrceros griceus*), known to feed on agamids, were observed (Ali & Ripley, 1983; Balachandran, 1998). In all these cases, the lizards remained motionless, either flat on the bark or with their head slightly raised above the substratum, even at a proximity of less than 1.5 m from the birds. Previous observations of predation on *D. dussumieri* are restricted only to a single published note on predation by a golden oriole (Balachandran, 1998) and an ornate flying snake (*Chrysopelea ornata*) (*pers. comm.*).

My results indicate a significant difference in activity levels, displayed by the lizards, between winter and summer, the two study seasons. It is also noteworthy that a unimodal activity peak was observed in winter, during the earlier part of the study, and this shifted

to a distinctly bimodal pattern in summer, towards the end of the study. Seasonal changes in abiotic (temperature and humidity) and biotic (reduced canopy cover during summer) factors may have influenced this transformation in activity patterns. Summer also marked the commencement of breeding in flying lizards as had earlier been established for the agamids occurring in this region (John, 1967; Daniel, 2002).

Male *D. dussumieri* indulge in all behaviours at a significantly higher frequency than do females, particularly important being the gular display, a difference also observed earlier in *D. volans* (Mori & Hikida, 1994). During summer, the breeding season of agamids, these males showed a large increase in the frequencies of moving, gliding, gular flashing and feeding from that in winter while the females maintained lower activity levels throughout the two seasons. Gular flashing in males and females showed a segregated pattern during the day, with males displaying mainly during forenoon and females during afternoon. This provides strong evidence for female dormancy during courtship displays in this species. I observed a similar behaviour during the sampling *ad libitum* of social interactions during my study (data not shown). This appears to confirm a possible absence of courtship behaviour in female *D. dussumieri*. Other studies have shown that the dichromatism in ornamentation, related to social display, is a result of sexual selection and therefore, the sexes in many such species show a high degree of dimorphism in displays and movement, with males performing at significantly higher frequencies (Mori & Hikida, 1994; Stuart-Fox & Ord, 2004).

A typical courtship display that I observed during this study was similar to that observed by John (1967). I, however, observed two kinds of female behaviours. One kind of behaviour involved the females exhibiting what could be interpreted as rejection or threat

behaviour on seeing the approaching male. The female extended her ribs exposing the bright coloured patagial membrane, followed by an attempt to escape, occasionally accompanied by the flashing of the gular appendage. Such displays often ended without copulation and were mostly observed during the early part of the breeding season, from March to late April. The other kind of behavioural response by the females, referred to as assertion behaviour and observed on five occasions between 24 April and 3 May 2008, did not include patagial displays and the females remained dormant through the complete courtship behaviour of the males, these attempts terminating in successful copulation. These observations thus raise the possibility that female *D. dussumieri* may actively use behavioural defences against courting males if they are not sexually receptive, particularly at the beginning of the breeding season.

Like all agamids, male flying lizards are known to be territorial (John, 1970). Having adapted to a specialized myrmecophagous diet (Herre, 1958; Mori & Hikida, 1994) where food is not a limiting resource due to high abundance of ants, typically in tropical forests, the males exhibit little territorial behaviour during the non-breeding season (Mori & Hikida, 1994). The lack of elevated levels of gular displays in the presence of conspecifics during winter, observed in my study, also supports the idea that male territoriality may develop in this species only during the breeding season. This hypothesis, however, needs to be investigated for females as well; it could not be accomplished in the present study due to low sample size. Further studies on the nature and context of gular display are required to facilitate better understanding of the social behaviour of flying lizards.

John (1962) and Smith (1935) had observed *D. dussumieri* in pairs, whereas observations of *D. volans* by Mori and Hikida (1994) suggest polygyny with males possessing harems. My opportunistic observations on the courtship display and mating of *D. dussumieri* support the polygyny hypothesis, but my inability to individually identify the lizards and the termination of my study at the commencement of the breeding season make it difficult to draw any firm conclusions. The mating system of these flying lizards thus remains to be better understood, although the identification of the specialized behaviours that they exhibit and the disproportionate investment made by the males and females in these behaviours, such as the gular display, suggest that the mating system of *D. dussumieri* may be of interest among the agamid lizards.

LITERATURE CITED

- Alcala, A. C. 1967. Population biology of the “flying” lizard, *Draco volans*, on the Negros Island, Philipines. Natural and Applied Science Bulletin. 20: 335-372.
- Ali, S. and Ripley, S. D. 1983. Handbook of the birds if India and Pakistan. Compact edition. New Delhi: Oxford University Press.
- Altmann, J.1974. Observational study of behaviour: Sampling methods. Behaviour. 49: 227-267.
- Balachandran, S. 1998. Golden oriole *Oriolus oriolus* preying on flying lizard *Draco dussumieri* Dum. & Bibr. Jornal of Bombay Natural History Society.
- Bogert, C. 1949. Thermoregulation in reptiles, a factor in evolution. Evolution. 3(3): 195-211.
- Daniels, J. C. 2002. The Book of Indian Reptiles and Amphibians, BNHS & Oxford University Press, Mumbai.
- Herre, A. W. 1958. On the gliding of flying lizards Genus *Draco*. Copeia. 4:338-339.
- Huey, R. B. & Slatkin, M. 1976. Costs and benefits of thermoregulation. The Quarterly Review of Biology. 51(3): 363-384.
- Janssen, T. A., Congdon, J. D., Fischer, R. U., Kling, E. D., Edmands, S. and Berna, H. 1996. Behavioural, thermal and metabolic characteristics of a wintering lizard (*Anolis carolinensis*) from South Carolina. Functional Ecology. 10: 201-209.
- John, K. O. 1962. Notes on the bionomics of the flying lizard, *Draco dussumieri* Dum. & Bib. Journal of the Bombay Natural History Society. 59: 298-301.
- John, K. O. 1967. Observations on the mating behaviour and copulation in *Draco dussumieri* Dum. & Bib. (Reptilia: Sauria). Journal of the Bombay Natural History Society. 64: 112-115.

- John, K. O. 1970. "Territorial behaviour" in the South Indian flying lizard, *Draco dussumieri* Dum. & Bib. British Journal of Herpetology. 4: 169-172.
- Mori, A. and Hikida, T. 1993. Natural history observations of the flying lizard, *Draco volans sumatranus* (Agamidae, Squamata) from Sarawak, Malaysia. Raffles Bull. Zool. 41(1): 83-94.
- Mori, A. and Hikida, T. 1994. Field Observations on the social behaviour of the flying lizard, *Draco volans sumatranus*, in Borneo. Copeia. (1): 124-130.
- Rose, B. 1981. Factors affecting activity in *Sceloporus virgatus*. Ecology, 62(3), 706-716.
- Santharam, V. 2003. Distribution, ecology and conservation of the White-bellied Woodpecker *Dryocopus javaensis* in the Western Ghats, India. Forktail. 19.
- Shine, R. & Madsen. T. 1995. Is thermoregulation unimportant for most reptiles? An example using water pythons (*Liasis fuscus*) in tropical Australia. Physiological Zoology. 69(2): 252-269.
- Shine, R., Keogh, S., Doughty, P. and Giragossyan, H. 1998. Costs of reproduction and the evolution of sexual dimorphism in a 'flying lizard' *Draco melanopogon* (Agamidae). Journal of Zoology. 246: 203-213.
- Siegel, S. and Castellan, N. J. 1988. Nonparametric statistics for the behavioural sciences. 2nd edn. McGraw-Hill Book Company.
- Smith, M. J. 1935. The fauna of British India Ceylon and Burma. Reptilia and Amphibia Vol II. Today and Tomorrow's Printers and Publishers.
- Stuart-Fox, D. M. and Ord, T, J. 2004. Sexual selection, natural selection and evolution of dimorphic coloration and ornamentation in agamid lizards. Proceedings of the Royal Society of London. 271: 2249-2255.

Vitt, L. J. and Goldberg, S., R. 1983. Reproductive ecology of two tropical iguanid lizards: *Tropidurus torquatus* and *Platynotus semitaeniatus*. *Copeia*. 1: 131-141.

Appendix 1: Behaviours displayed by male and female *Draco dussumieri*

Immobile

Motionless, with the body either flat along the tree trunk with head resting on the surface, head raised above the surface by extending the forelimbs, or the body raised above the surface by extending the forelimbs as well as hindlimbs.

Moving

The forward, reverse or lateral movement of the individual resulting in displacement along the substratum.

Gular display/flashing

The action of extension of the dewlap, either perpendicular to the body or beyond the jaw, and its retraction occurring parallel the body, performed repeatedly.

Feeding

The protrusion of tongue beyond the jaw, followed by the act of picking up prey from the substratum.

Gliding

The propulsion of the body from one substratum to another, caused by falling at less than 45 degrees from the horizontal, facilitated by the expansion of the patagium.

Patagium expanded

Expansion of the ribs exposing the bright colour pattern on the patagial membrane.

Head bobbing

Vertical movement of the head by extending and folding the forelegs.