ECOLOGY AND BEHAVIOUR OF TRAVANCORE TORTOISE (*Indotestudo travancorica*) IN ANAMALAI HILLS, WESTERN GHATS

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CERTIFICATE

This is to certify that the work described in the thesis titled **"Ecology and Behaviour of Travancore tortoise (*Indotestudo travancorica*) in Anamalai hills, Western Ghats"** carried out by Mr. V. Deepak MSc., was under my guidance and supervision and that he has completed the period of research required under the regulations of the University. The contents of the thesis did not form basis of the award of any previous degree to Mr. V. Deepak. Considering the quality of the thesis, I recommend the same for submission for the degree of Doctor of Philosophy in Wildlife Science of the Saurashtra University. There is nothing in his habits and character, which may debar him from being admitted to the degree of Doctor of Philosophy in Wildlife Science of the Saurashtra University.

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(V. Deepak)

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIX

ABSTRACT

Tortoises belonging to the genus *Indotestudo* are medium sized (330 mm) tortoises, found in the tropical forests of Asia and South East Asia. Out of the three known species of *Indotestudo* two (*Indotestudo elongata* & *I.travancorica*) are known from India. Travancore tortoise (*I. travancorica*, Boulenger, 1907) is an endemic tortoise found in Western Ghats of southern India. They inhabit diverse habitats in the moist tropical forests of Western Ghats. The current state of knowledge on the species ecological requirements and population estimates are lacking to suggest any conservation measures. To supplement the existing knowledge on the species this PhD study was carried out.

Based on previous knowledge on the tortoise distribution, the study was decided to be carried out in two protected areas namely the Anamalai Tiger Reserve and Parambikulam Tiger Reserve. Located in the southern Western Ghats between 10°13- 10°33' North latitude and 76°37'-77°21' East longitude. This study investigated the proportion of the site occupied by Travancore tortoises, their diet, home range, activity and habitat use. The findings of this study along with the existing information were used to formulate a conservation action plan for Travancore tortoise.

Populations of Travancore tortoises were monitored during the monsoon and post monsoon months during 2006 – 2009, twenty five trails located in four different habitat types were surveyed. Occupancy was modelled as a function of anthropogenic disturbance levels and environmental variables. Detection probability was modelled as a function of year, effort and environmental variables. Occupancy of Travancore tortoise was negatively influenced by anthropogenic disturbance level. Detection probability was positively influenced in sites with more number of water bodies and longer extent of grass

marshes. Travancore tortoises are well camouflaged, 98% of the individuals found were hidden in vegetation, burrows or leaf litter which in turn deters our ability to detect them.

Feeding ecology of Travancore tortoise was studied for four years (2006-2009) in the Anamalai hills, Western Ghats. The diet of the species was examined and quantified from their faecal matter and direct feeding observations. It was primarily herbivorous feeding on herbs, grass and fruits but also fed on animals including invertebrates (insects, millipedes, molluscs, scorpions and crabs) and carcass of vertebrates.

Five individuals of Travancore tortoise (2 males and 3 females) were attached with transmitters and monitored between February 2008 and March 2010. The tortoises were located using portable radio telemetry receiver and hand held collapsible antenna. Home range sizes were estimated using 100 % minimum convex polygon (MCP) and 95 % Kernel. The MCP home ranges varied between 5.2 and 34 ha. Kernel home ranges were varied between 1.0 ha and 9.8 ha

Location data of individual tortoises collected from radio-tracking were used to investigate their spatial and temporal movement. An intensive study area of 110 ha was marked and divided into 100 x 100 grids, the corners of each grid were permanently marked with paint on trees or rock. Microhabitat variables were collected within each 100 x 100 m grid. The maximum linear distance moved by radio tracked tortoise varied between 245 m and 665 m. Autologistic model analysis revealed that the spatial movement of Travancore tortoise was influenced by distance to the edge of evergreen and bamboo lantana grass habitat.

Temperature loggers were programmed to collect temperature at intervals of 360 seconds. These loggers were attached on the carapace of the radio tracked tortoises using epoxy adhesive. Rainfall in the study area was measured to the nearest mm using a rain gauge. Velocity of movement was calculated between two radio locations. Generalized linear model (GLM) with binomial errors and logit link function was used to find out the factors influencing activity. Idiosyncrasies were found in the temporal activity of Travancore tortoise. The overall activity of all the four Travancore tortoises was positively influenced during monsoon and was negatively influenced by post monsoon and summer season. Rainfall, minimum and maximum did not have any direct influence on the TTs activity. The percentage monthly activity pattern of individuals appears to be seasonal, their activity was increased during the rainfall months (June to October) and reduced during the drier months (November to February).

Evidence suggests that *I. travancorica* is facing exploitation. Removal of adults from the populations might affect the long term survival of the species. Ensuring protection of populations within the protected areas by creating more awareness among the protection staff and local people is needed. Grass marshes "*vayals*" are crucial microhabitats for the species to forage. Protection and monitoring should be of importance for the persistence of the tortoise population in the reserves. Little is known about their breeding biology and nesting in the wild. Future studies on their breeding biology will be important to understand their life history and breeding habitat requirements. The array of food intake by *I. travancorica* shows the complexity in their diet which needs to be taken into consideration while maintaining them *ex-situ*. Conservation breeding programs should be taken up in a coordinated manner by establishing multiple captive populations. A Conservation Action Plan is proposed based on the findings from the study

CHAPTER 1

INTRODUCTION

1.1. Freshwater turtles and tortoises of India

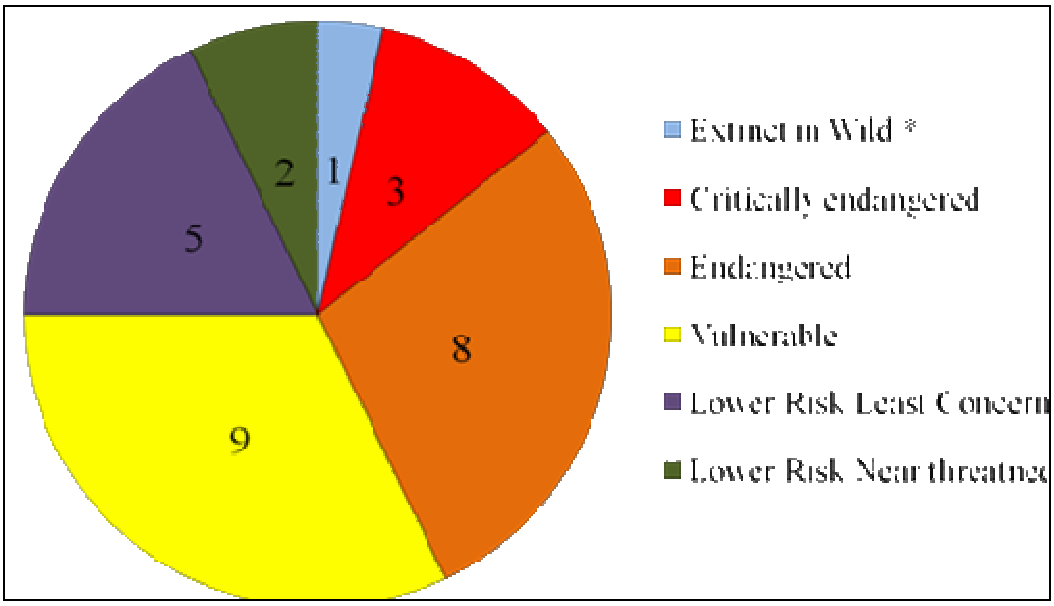
There are twenty eight species of freshwater turtles and tortoises in India. They are reported from different biogeographic zones of the country. The Ganges-Bramhaputra river basin of India and Bangladesh is the world's most diverse region for freshwater turtle species (Buhlmann *et al*., 2009). Seventy five percent of the India's freshwater turtles and tortoises are listed under threatened category (Fig. 1.1) (IUCN, 2010). *Batagur baska* and *Batagur kachagu* are listed as the top 25 + endangered freshwater turtles and tortoises of the world (Rhodin *et al*., 2001). The species richness of turtle fauna is the greatest in north and north eastern part of the country; endemism is the greatest in peninsular India. Three endemic turtle species found in this region are: Leith's softshell turtle (*Nilssonia leithii*) a riverine species; cane turtle (*Vijayachelys silvatica*) a rainforest dwelling species restricted to this habitat in the Western Ghats; the Travancore tortoise (*Indotestudo travancorica*) a moist forest and riparian forest dwelling species restricted to the Western Ghats.

1.2. Genus "Indotestudo" distribution and natural history

The Genus Indotestudo is currently represented by three distinct species viz., *I. travancorica, I. elongata* and *I. forsteni* (Fig. 1. 2). *Indotestudo elongata* is a widely distributed species found in East and North East India, Bangladesh, Nepal, Bhutan, Thailand, Vietnam, Cambodia, Laos, Malaysia and Indo-China (Fig. 1. 3). *Indotestudo forstenii* and *I. travancorica* have restricted distribution, to Sulawesi and Halmahera Islands (Fig. 1.3) and the Western Ghats respectively (Fig. 1.3).

Indotestudo travancorica was earlier thought to have introduced in the Sulawesi and Halmahera Islands giving rise to disjunct populations. Phylogenetic analysis suggests that *I. travancorica* is more closely related to *I. elongata* than to *I. forstenii* (Iverson *et al*., 2001). *Indotestudo elongata* is reported from Sal (*Shorea robusta*) forest habitats, evergreen and semi-evergreen forests in India and it occupies lowland evergreen, mixed Dipterocarp forest, bamboo brakes, evergreen dense monsoon limestone tropical forests in its geographic range (van Dijk, 1998; Platt *et al*., 2004 and 2007; Teynié *et al*., 2004). In Thailand *I. elongata* is found in elevations between 225 - 560 m a.s.l which is also the elevation range within which the deciduous forest span. *I. forstenii* is reported from primary and secondary lowland forests in Sulawesi Island (Ives *et al*., 2008). *I. travancorica* is reported from evergreen, semi-evergreen and moist deciduous forests in the Western Ghats from 10 to 1000 m a.s.l.

Figure 1.1 Status of Indian freshwater turtles and tortoises (IUCN, 2010).



*Wild populations of *N. nigricans* were reported from Assam (Praschag *et al*., 2007)

Figure 1.2 Photographs of the three species of tortoises belonging to genus *Indotestudo*.

Indotestudo travancorica

Location: Parambikulam Tiger Reserve, Kerala

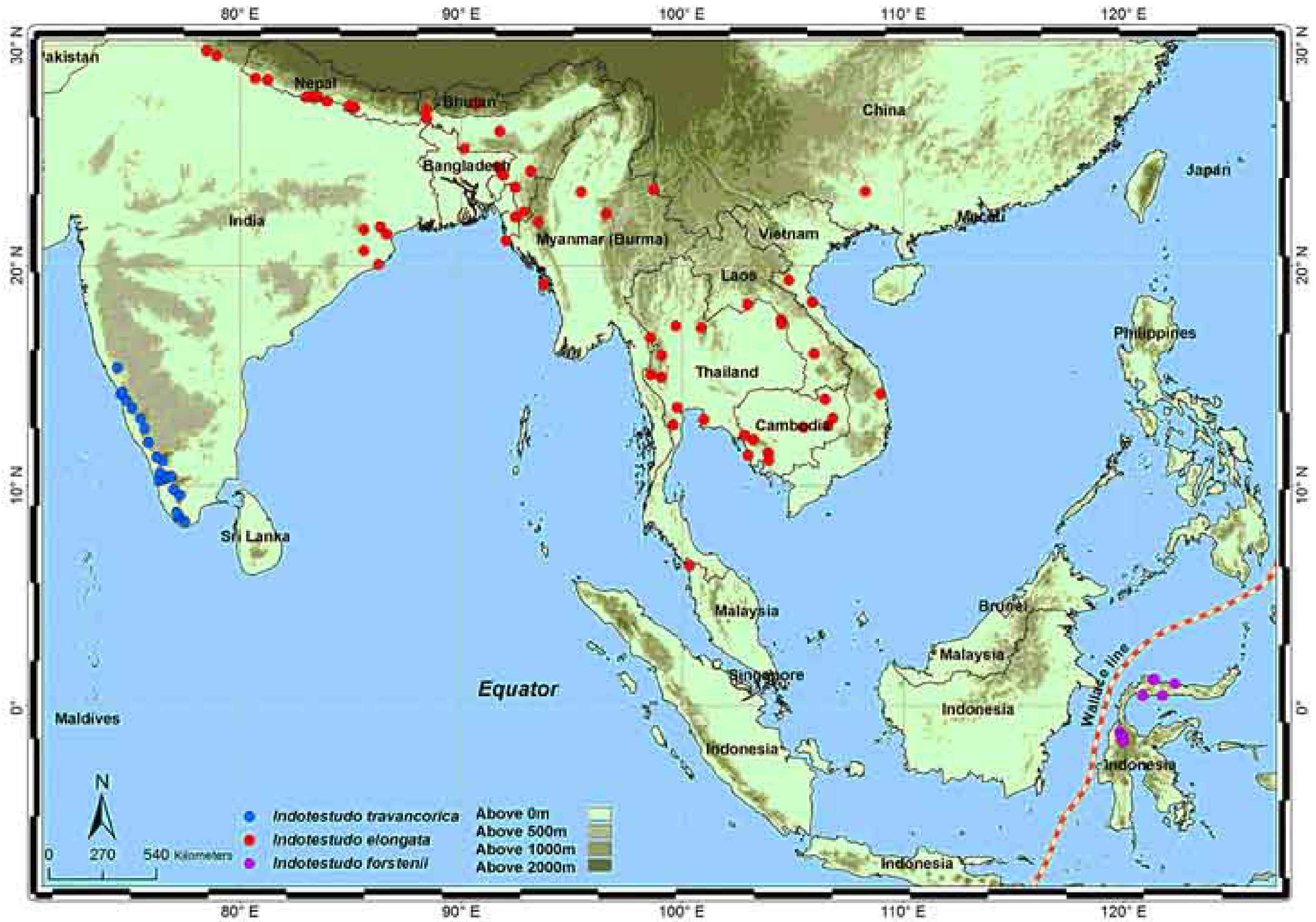
Indotestudo elongata

Location: Manas National Park, Assam

Indotestudo forstenii

Location: Borneo (captivity)

Figure 1.3. Distribution of Genus *Indotestudo* in south and south East Asia.



Source for tortoise locations: Smith (1931), Das (1990 & 1991), Iversion (1992), Thirakhupt and van Dijk (1994), Javed and Hanfee (1995), Zug and Mitchell (1995), Datta (1997), Das et al (1998), Zug et al (1998), Pawar and Choudhury (2000), Pawar and Birand (2001), Platt et al (2001, 2004 & 2007), Stuart and Platt (2004), Teynié et al (2004), Grismer et al (2006 & 2007), Ying et al (2007), Ives et al (2008), Bezuijen et al (2009), Dutta et al (2009), Jha (2009), Pauwels et al (2009), Mahony et al (2009), Aryal et al (2010), Linthoi and Sharma (2010), Murthy and Das (2010), Deuti and Das (2011) and references therein.

1.2.1. *Travancore tortoise (Indotestudo travancorica)*

Indotestudo travancorica was described by Boulenger in 1907 based on specimens collected by Ferguson, who believed it to be common in the Travancore hills of Kerala, southwestern India. The records of the species after its description until 1982 were sparse after which the number of records of the species have increased till date (Fig. 1.4). It has been mainly reported in the moist forests of Western Ghats. There are scattered reports from evergreen, semi-evergreen, moist deciduous, bamboo forests, rubber plantations and teak plantations, marshes and rocky outcrops (Vijaya, 1983; Bhupathy and Choudhury, 1995; Ramesh, 2008a). They are reported to feed on grass, herbs, crabs, mushroom and frogs (Vijaya, 1983; Das, 1991; Ramesh and Parthasarathy, 2006).

Indotestudo travancorica is protected under Schedule IV of the Indian Wildlife (Protection) Act (1972) and listed as vulnerable in the IUCN Redlist. Detailed ecological studies on the species are lacking and population estimates are not available (Frazier, 1989; Moll, 1989). Therefore, conservation measures have not been taken up apart from listing the species in the wildlife (protection) Act, 1972. Information available on the species is sparse, largely confined to anecdotal observations, locality records and short term studies (Vijaya, 1983; Frazier, 1989; Bhupathy and Choudhury, 1995; Sharath, 1990; Radhakrishnan, 1998; Ramesh, 2008a).

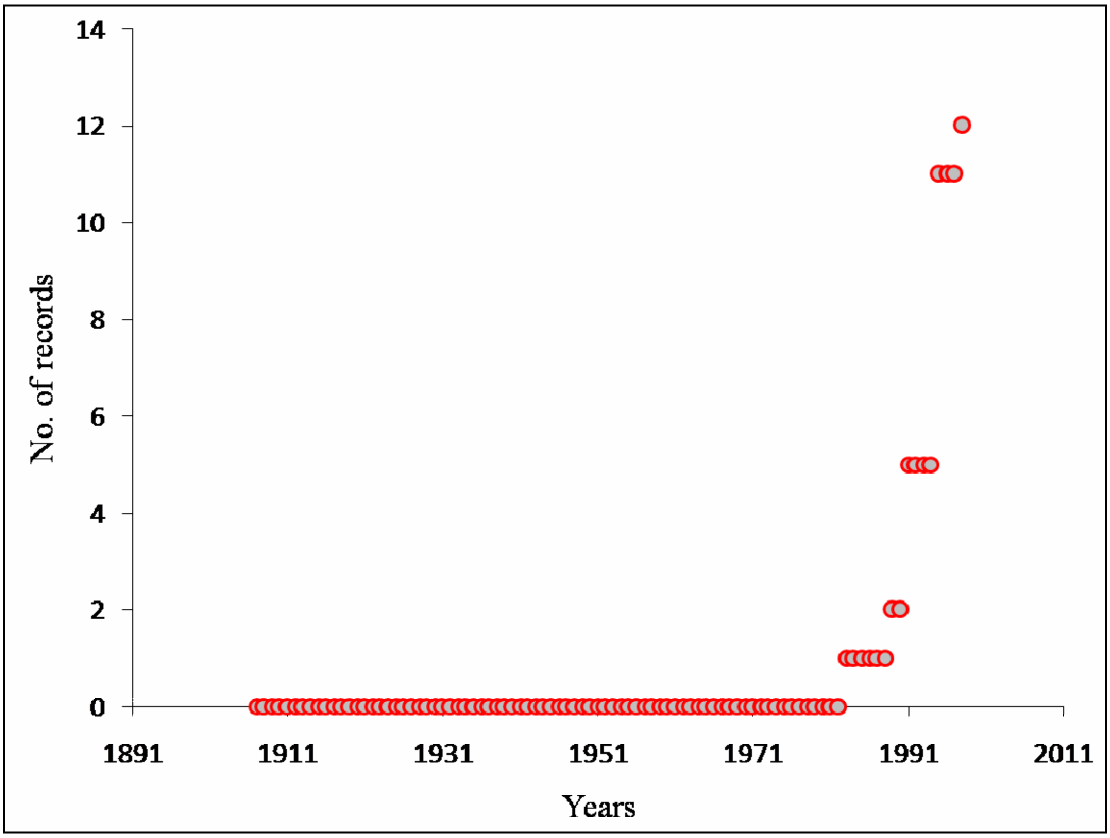
Extensive surveys on the species were conducted in 1993-94, which gave an insight to their current distribution in Western Ghats (Bhupathy and Choudhury, 1995). The northern most locality of the species is Dandeli Wildlife Sanctuary in Karnataka 15.5^{o} N latitude and southern most is Kodayar in Tamil Nadu 8.3^{o} N latitude (Bhupathy and Choudhury, 1995). All locality records of the species known till date fall within this latitudinal range (Vijaya, 1983; Frazier, 1989; Appukuttan, 1991; Sharath, 1990; Radhakrishnan, 1998; Ramesh, 2008a, Vasudevan *et al*., 2010).

1.2.2. *Description of the species*

Adult.- *I. travancorica* has an elongated shell, usually flattened at the vertebral region with margins that may be reverted and mildly serrated at the anterior and posterior ends. Carapace and plastron are brown to chocolate brown and may have black blotches; blotches on the vertebrals are usually surrounded by a central brown blotch that might fade into the marginals (Fig. 1.5). Head is cream or yellowish-brown with pinkish-red colouration around the orbital skin and nares. Iris dark brown; upper mandible slightly hooked and tricuspid. Large, uneven, imbricate scales cover anterior part of the forelimbs. Tail ends in claw-like spur (Boulenger, 1907; Das, 1991; Pritchard, 2000). Absence of the nuchal scute (or if present, wedge-shaped), and the interhumeral seam, which is 1-1.4 times the length of the interpectoral seam, differentiate it from its congeners *I. elongata* and *I. forstenii* (Pritchard, 2000).

They are sexually dimorphic species. The abdominal region of the plastron is concave in males and flat in females. The tail claw is long and hooked in the males, while in the female tail is small and conical (Auffenberg, 1964b; Vijaya, 1983; Das, 1991). There is no significant size difference between the sexes (Ramesh, 2008a). Their straight carapace length ranges from 55 mm to 330 mm, and they weigh between 35 g to 4010 g (Sane and Sane, 1988; Appukuttan, 1991; Bhupathy and Choudhury, 1995; Das, 1995; Ramesh, 2008a; Deepak and Vasudevan, 2010)

Figure 1.4. Number of new records (n=7) on *I. travancorica* since its description.



Hatchlings.- It is usually uniformly brown though in a few, carapace or plastron might be mottled with darker spots. The entire shell is malleable rubbery to touch. The carapace is rounded and anterior, posterior marginals have sharp transparent edges (Fig. 1. 6). Age or size at sexual maturity is unknown, but a male having 160 mm SCL had a distinctly concave plastron and hooked tail claw suggesting that males at this size attain sexual maturity (Ramesh, 2008b).

1.3. Population monitoring

Population monitoring is critical for species conservation. It provides information that is necessary to identify threats to the population at an early stage and facilitate species conservation (Hellawell, 1991). A variety of methods are employed in population monitoring programs, focused on estimating animal abundance (e.g Ralph and Scott, 1981; Lancia *et al*., 1994). These methods involve collection of some sort of count data based on encounter of the animal or their signs. The method that are used to collect such data include, point-counts, line transects, and mark-recapture. Another form of data that is collected during the surveys is presence or absence of species during each survey. This data if collected with an appropriate design could yield a measure of occupancy or proportion of area occupied by the species after incorporating detection probability (MacKenzie *et al*., 2002). In this study field surveys were carried out to measure occupancy. Information on the trends in occupancy and the factors influencing it become important for management of the reserves and conservation of the species.

Figure 1.5. Lateral and ventral view of an adult female (A & C) and male (B & D) *Indotestudo travancorica*.

Figure 1.6. Hatchling of *Indotestudo travancorica*. Arrow pointing the sharp edges of the anterior marginal scutes.

1.4. Feeding ecology

In most studies mammals and birds are considered to be important seed dispersers in the tropical forests and the role played by other animal groups remains poorly explored (Jerozolimiski *et al*., 2009). Tortoises have long been considered as seed dispersers (Ridely, 1930). Germination of 28 species of grass, herbs and woody plants were reported from the feaces of Aldabran giant tortoises (Hnatiuk, 1978). These tortoises were reported to be responsible for the introduction of plant species from Madagascar to Aldabra (Hnatiuk, 1978). A short term study in the neotropics on the *Geochelone carbonaria* and *Geochelone denticulate* suggested that the diversity and proportion of viable seeds consumed by the tortoises, combined with the seed retention time and daily movement, they might be effective seed dispersal agents (Strong and Fragoso, 2006). In another study on *Geochelone denticulate* it was found that they play an important role in seed dispersal in the Amazonian forests (Jerozolimiski *et al*., 2009). During the dry season on an average, seeds were dispersed 174 m and during rainy season the mean distance increased to 277 m (Jerozolimiski *et al*., 2009). Studies on frugivory in reptiles and their role as seed dispersers in the oriental region are sparse (Corlett, 1998). *I. travancorica* and *I. elongate* are reported feeding on fruits (Vijaya, 1983; van Dijk, 1998).

1.5. Spatial and temporal ecology

The extent to which animals move around their environment is usually described by the size and/or shape of their home range, which is defined as the area over which an animal moves in order to perform its activities (Burt, 1943). Space used by animals are related to their body size and population density (eg: McNab, 1963; Witting, 1995; Blackburn *et al*., 1997; Jetz *et al*., 2004). Temporal changes in tortoise activity and the abiotic factors influencing these changes in activity/behaviour have been studied in different species of tortoises (Moskovits and Kiester, 1987; Geffen and Mendelssohn, 1989; Duda *et al*., 1999; Ramasay *et al*., 2002). Understanding spatial requirements of a species and the factors influencing their movement in space and time would provide insights for habitat management strategies.

Studies on spatial and temporal movement pattern of tortoises and their response to the abiotic factors have been studied in the deserts, temperate regions and in the new world tropics (Auffenberg and Weaver, 1969; McGinnis and Vogit, 1971; Swingland and Frazier, 1979; McRae *et al*., 1981; Bury, 1982; Moskovits and Kiester, 1987; Geffen and Mendelssohn, 1989; Bulova, 2002). Similar studies have been carried out in the Old World tropics sparingly (Ramasay *et al*., 2002; Luiselli, 2005; Walker *et* *al*., 2007).

1.6. Thermoregulation

Reptiles are known to respond to variation in environmental temperature by exhibiting behaviours such as, changing microhabitats or activity periods (Hertz and Huey, 1981; Christian *et al*., 1983). In chelonians, thermoregulatory behaviour has been observed in terrestrial, semi-aquatic and marine forms (Avery, 1982). Tortoises exhibit various kinds of behavioural thermoregulations. Limited or complete absence of basking is reported in terrestrial tortoises (*Testudo* spp and *Gopherus* spp; Boyer, 1965); avoidance of exposure to sunlight is recorded in many tortoises (*Chelonoidis nigra*: MacKay, 1964. *Gopherus* spp: Brattstrom, 1965; McGinnis and Voigt, 1971; Voigt, 1975. *Kinixys erosa* and *Kinixys homeana*: Luiselli, 2005. *Dipsochelys dussumieri*: Frazier, 1973);) aestivation is reported in *Gopherus berlanderi* (Voigt and Johnson, 1976).

1.7. Conservation action plan

Habitat fragmentation, declining ecological integrity, increasing biotic pressures and incompatible land uses are increasingly pushing a wide range of wild animals and plants species to the brink of extinction (Noss, 2000 and references there in). Conserving such threatened species requires a holistic and multi-disciplinary action plan that should be implemented (Anonymous, 2009).

1.8. Objectives

1) To estimate site occupancy of *I. travancorica* and identify factors that influence their occupancy.

2) To quantify diet of the species and describe its feeding ecology.
3) To quantify the activity, habitat use and ranging pattern of *I. travancorica* within the intensive study area.
4) To formulate a conservation action plan for *I. travancorica*.

1.9. Organization of thesis

The findings of the field study that spanned for four and a half years has been summarized into six chapters viz. 1) Introduction, 2) Study area, 3) Population monitoring, 4) Feeding ecology, 5) Home range, movement and microhabitat use and 6) Conservation action plan. Chapter 1 gives a general introduction to the study, fresh water turtles and tortoises of India and details on the study species based on a complete literature review of the study species, Chapter 2 describes in detail on the physical and abiotic attributes of the study area using Geographical Information System. Land use conservation history and people residing in the study area was collated from literatures. Chapters 3 to 5 form results of the study, they have been written as standalone chapters that could be submitted as manuscripts to peer-reviewed journals. Chapter 3 deals with site occupancy and detection probability of Travancore tortoise and the factors that influence their site occupancy and detection in the study area between 2006 and 2009. Chapter 4 describes the feeding ecology of the Travancore tortoise based on direct observation and examination of faecal remains. Chapter 5 deals with the home range, movement and habitat use of Travancore tortoise. Factors influencing movement of Travancore tortoises in space and time is investigated in this chapter. A Conservation Action Plan for Travancore tortoise is presented in Chapter 6. This chapter assesses their status, threat to their population and habitat and recommendations for effective conservation of the species. Finally, the literatures cited in all the chapters have been compiled together and sorted name under the section References.

CHAPTER 2

STUDY AREA

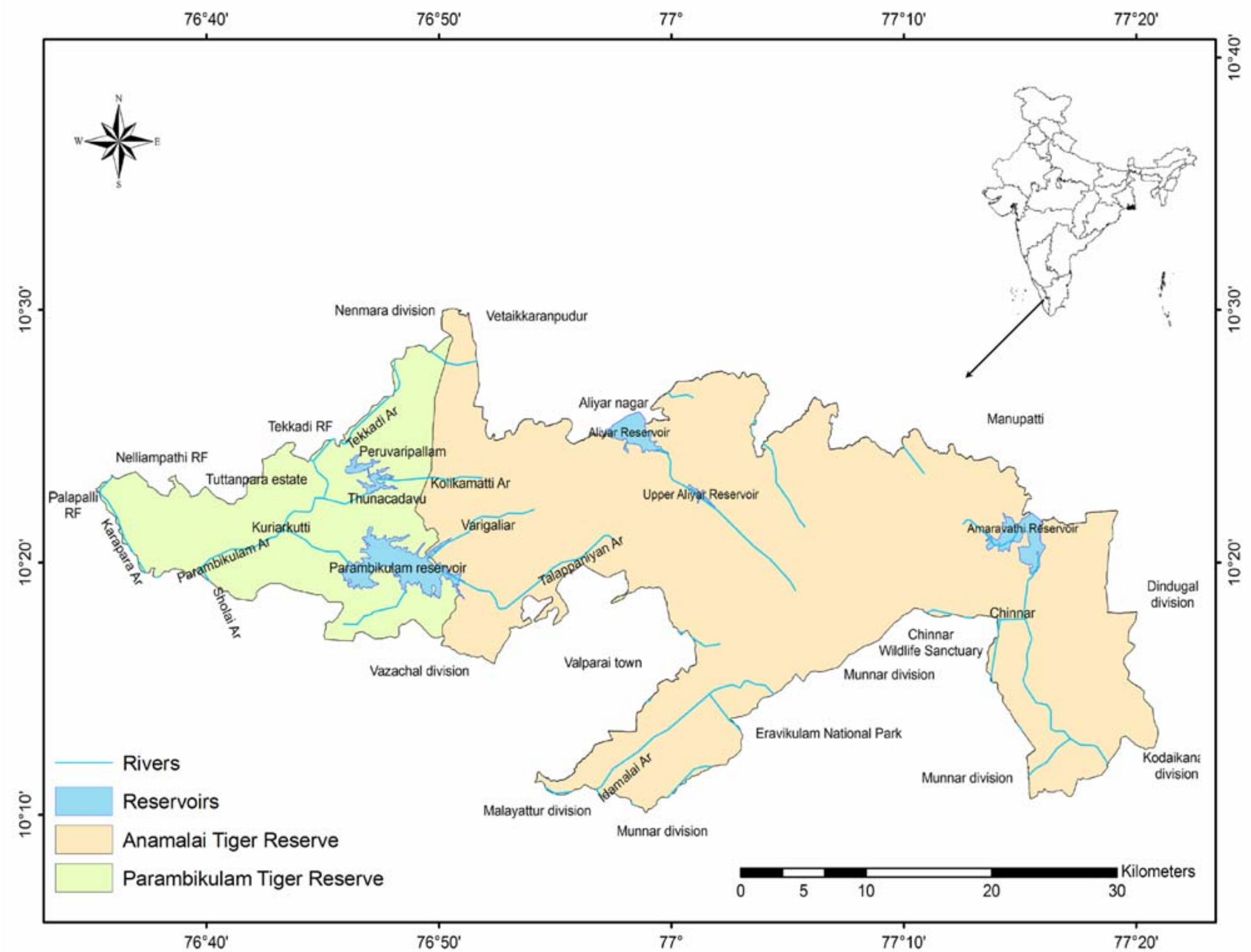
1.1. Introduction

The Anamalais falls under the biogeographic zone – 'Western Ghats Mountains' 5B (Rodgers and Pawar, 1988). The Anamalai Tiger Reserve (ATR) and Parambikulam Tiger Reserve (PTR) are contiguous hill ranges in the southern Western Ghats. This hill range supports diverse variety of endemic flora and fauna. The mosaic of vegetation types in a gradient of elevation along with the diversity, density and endemic species make them one of the unique reserves in the entire Western Ghats.

2.2. Location

The Anamalai Tiger Reserve is situated in the Coimbatore district of Tamil Nadu and the Parambikulam Tiger Reserve is situated in the Palakad district of Kerala state. the Anamalais is located between $10^{o}13'$- $10^{o}33'$ North and $76^{o}37'$-$77^{o}21'$ East. It is located immediately south of the Palghat gap in the Western Ghats. The northern slopes of the hills descend precipitously to the cultivated plains of Pollachi Taluk. The moderately undulating hills are contiguous to the Nelliyampathy Reseve Forest to the north West, Chalakudy Reserve Forest towards the west and Vazhachal Reserve Forest to the south west. At the southern part of the mountain range lies the Valparai plateau, with vast area dominated by tea and coffee plantations. South eastern parts are connected to the highest mountain in Eravikulam National park, Munnar Reserve Forest and Kodikanal Forest Divisions to the south and Dindugal Forest Division to the east (Fig. 2.1).

Figure 2.1. Geographical location of Anamalai and Parambikulam Tiger Reserves with its adjoining areas.



2.3. Area

The study area includes a total of 1244 km^2, representing 959 km^2 in the Anamalai Tiger Reserve (ATR) and 285 km^2 in Parambikulam Tiger Reserve (PTR). In the PTR the areas spread over a large valley. This area includes three connected man-made reservoirs namely Parambikulam, Thunacadavu and Peruvaripallam covering an area of 28.5 km^2. In ATR the Ulandy valley and Manampalli are contiguous to Parambikulam in the west. ATR includes three National parks namely Karian shola (108 km^2), Manjampatty (72 km^2) and Grass hills (31 km^2).

2.4. Etymology

In Tamil language, Anai = Elephant, Malai = mountains hence, the name 'Anamalai'. Various documents in the late 1800's have referred to them as 'Anamallays' or 'Annamullay' (Beddome, 1878; Hamilton, 1892). The recent name 'Anamalais' will be used in this thesis (Congreve, 1942; Wilson, 1973; Sekar and Ganesan, 2003). In Malayalam language Parambikulam: Parambu = bamboo, Kulam = lake thus the name Parambikulam.

2.5. Land use and conservation history

There is sparse documentation on the history of the Anamalais prior to British arrival. Since 1846, the British colony carried out a series of large scale habitat conversions (Wilson, 1973; Sekar and Ganesan, 2003). In the Valparai plateau majority of the forests was converted into coffee and tea plantations. Felling and extraction of teak and other valuable timbers were carried out in Sichalli valley, Vengoli and Umayamalai areas (Wilson, 1973; Sekar and Ganesan, 2003). Attempts to establish teak plantations prior to 1880 were not successful. Within a short span of less than 40 years these forests were clear felled. By 1880, most of the forest had disappeared and the forests were given rest between 1880 - 1885. In 1882 the Madras Forest Act was introduced and the reservation of forest commenced. Reservation of most of the forest took place between 1883 and 1885 (Wilson, 1973; Sekar and Ganesan, 2003). Systematic management of forests for timber and silvicultural practices started from 1889. In 1976 the Anamalais in Tamil Nadu was declared as Indira Gandhi Wildlife Sanctuary. Recently the sanctuary was notified as Anamalai Tiger Reserve in the year 2007. The necessity for the protection of the unique biological diversity of this region, besides the significant populations of endangered species such as lion-tailed macaque (*Macaca silenus*), Nilgiri tahr (*Nilgritragus hylocrius*), great hornbill (*Buceros bicornis*), and Asian elephant (*Elephas maximus*), was instrumental in bringing this area within the country's network of protected areas (Rodgers and Pawar, 1988).

The Tamil Nadu part of Anamalais was part of the Madras Presidency and the Parambikulam part was under the Cochin State. Cochin did not have a good deal of resource as a state; all they had was 50,000 ha of forest towards the east and a couple of westward flowing rivers and a natural harbour. The king of Cochin planned to modify the state into an important trading place in the west coast. While planning for a modern port, the British business man drew attention towards the huge untapped resources of teak, rose wood and other forest produces in the mountains (Varma *et al*., 2005). The next couple of years (until 1812) saw some unsystematic and destructive attempts to harvest forest products and timber around Chalakudy basin that extended up to Parambikulam and Nelliyampathy hill ranges (Varma *et al*., 2005). Forest lands were leased to private individuals with no limits on felling. Large forest areas were depleted, till 1812, when some sensible reforms were made on lease conditions.

Despite these efforts from 1855 to 1875 clear felling of land for agriculture resulted in destruction of vast tracts of forest in the state (Varma *et al*., 2005). The first conservator of forests of Cochin was appointed in 1894. After 1897 profitable management of forests came into existence under the control of Cochin King with the help of Madras Presidency. Restriction on the collection from forests was implemented and the Cochin Forest Act was implemented in 1905. This law was based on the earlier Madras Forest Act 1882 (Varma *et al*., 2005). Around this time, a 12 mile long Cochin forest tramway was planned for extraction of timber from the relatively unexplored Parambikulam forests. Over the years after examining the feasibility of the original plan a modified plan for 49.5 miles of tramway was proposed. After six and a half years of construction the tramway became functional in 1907. Out of the total 49.5 miles, 16.5 miles was inside the Parambikulam Tiger Reserve. An estimated area of 32,000 ha of forest area was exploited during this period (Varma *et al*., 2005). In 1949, the Anamalai road from Chalakudy to Valparai was constructed and timber was carried using motor vehicles and this diminished the utility of the tramway (Varma *et al*., 2005). The gradual depletion of forests could not justify the capital expenditure of the Kerala State and in 1951, the tramway seized to function (Varma *et al*., 2005). Parambikulam was later notified as a special teak plantation division in the year 1962. In 1985, the wildlife sanctuary was reorganized and it was notified as Parambikulam Tiger Reserve in 2010.

Post-independence the republic initiated developmental projects in the region in 1954. The Parambikulam - Aliyar project directed six west flowing rivers to the drier plain in the east, through a series of canals and tunnels linking eight different medium sized dams. An additional two dams were built submerging an area of 54.5 sq km^2

most of which was forests (Wilson, 1973; Sekar and Ganesan, 2003).

Forest fires are prevalent in the deciduous forests in the Anamalais. On an average 29 km^2 (1951-1962) of forests in the ATR (Thunacadavu range). In PTR area forest fire was experienced near pandaravara (Sungam range) in 2003 and in Vengoli area (Parambikulam range) in 2003 and 2004 (Source: Kerala Forest Department). Control fire measure practices are being followed in both ATR and PTR.

2.6. Abiotic attributes

2.6.1. Topography

Plains to moderately undulating terrain and highly undulating to steep slopes are characteristics of the topography of Anamalais of ATR & PTR (Fig. 2.2). The elevation in ATR ranges from 300 m (mostly north of the reserves near Sethumadai, Aliyar and Amaravathi), 37% of the area is below 800 m a.s.l (Table 2.1) and in the remaining area is above 800 m a.s.l. Peaks such as Thanakamalai (2613 m) and Akkamalai (2483 m) are present in the higher reaches of ATR. In PTR majority of the area (79%) is below 800 m a.s.l. (Table 2.1), with few isolated peaks. The highest peak in PTR is Karimala which is 1439 m a.s.l.

2.6.2. Hydrology

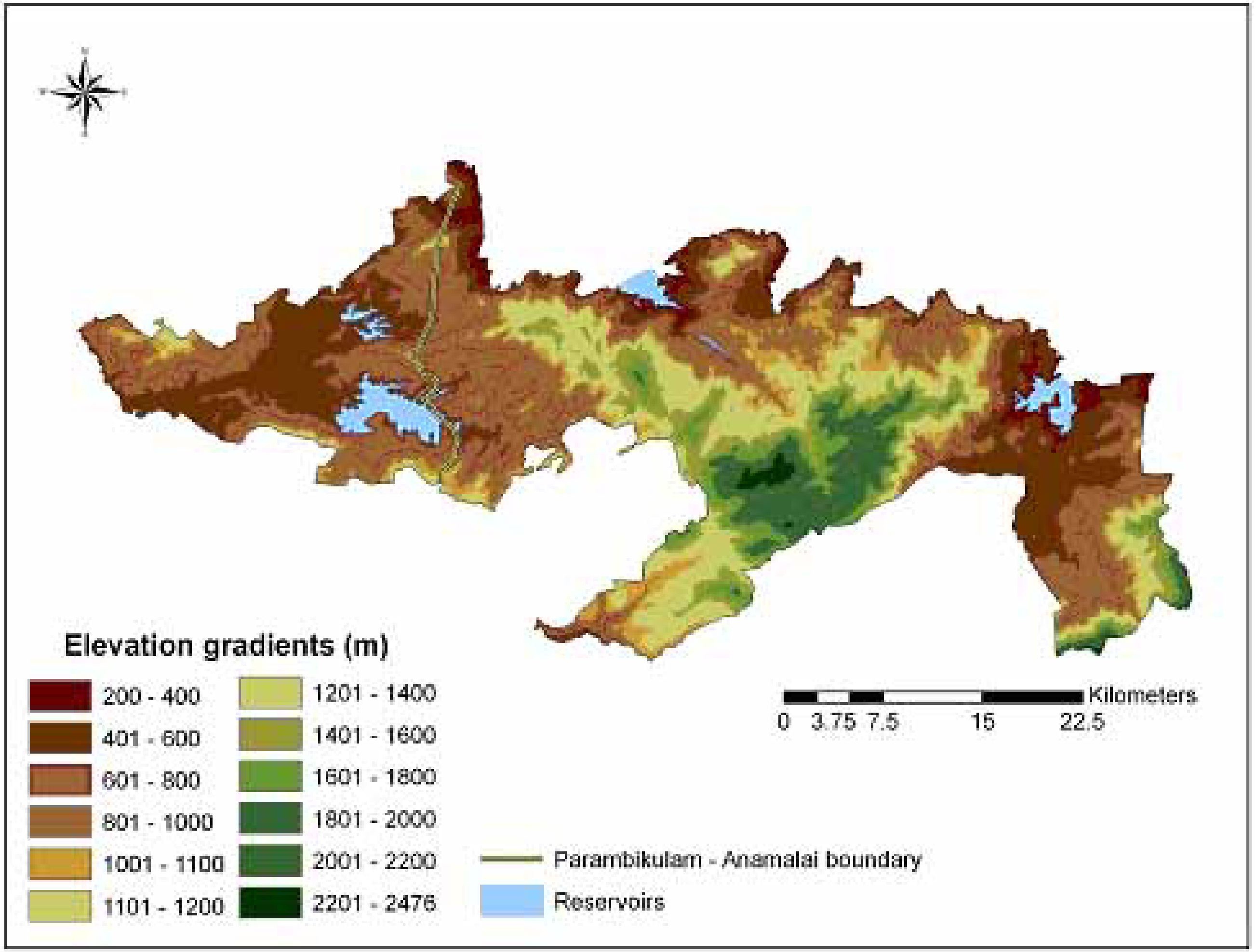
The streams of the Anamalais and the Nelliampathi hill (hills located in the north east of PTR) range and of the areas in their immediate vicinity drains into three main systems, namely the Cauvery, the Ponnani and the Periyar (Silas, 1951). On the east of Anamalai hills, a tributary of the Amaravati originates and joins the River Cauvery further east (Silas, 1951). The Rivers on the western and south-western faces of the Anamalai and Nelliampathy hills are separated from the watersheds of the north-eastern face by the intervening high hill ranges. The River Chalakudi receives a tributary from the Anamalai and Nelliampathi hills, flows due south-west and joins the River Periyar close to the Cochin (Arabian Sea). The River Anamalai originates from the eastern slope of the Anamalais and flow in a north-west direction before turning due west and joins the River Ponnani which empties into the Arabian Sea (Silas, 1951).

In ATR, in the Ulandy valley, Chinnar, Periyar, Aliyar, Thorakadavu, Kallar, Itliar, Sholayar, Amaravathi and its tributaries (Tenar, Chinnar and Pambar); Sholayar, Karapara, Thekkadi and Parmbikulam are all perennial rivers (Fig. 2.1). There are six reservoirs inside ATR & PTR and water is stored throughout the year.

Table 2.1. Distribution of areas in different elevation categories. Data extracted from 30 m ASTER DEM. Note: total area size varies from the actual area of the park.

Elevation category in m a.s.l	Area km^2 (%)	
	ATR	PTR
200-400	51.2 (5.4)	0.9 (0.3)
401-600	131.7 (14.0)	123.7 (45.8)
601-800	163.9 (17.4)	89.9 (33.3)
801-1000	145.4(15.5)	38.2 (14.1)
1001-1200	141.4 (15.0)	16.8 (6.2)
1201-1400	102.9 (10.9)	0.8 (0.3)
1401-1600	69.2 (7.4)	0.0 (0.0)
1601-1800	51.7 (5.5)	0.0 (0.0)
1801-2000	52.9 (5.6)	0.0 (0.0)
2001-2200	23.9 (2.5)	0.0 (0.0)
2201-2476	6.3 (0.7)	0.0 (0.0)
Total	940.7 (100)	270.3 (100)

Figure 2.2. Digital elevation model of ATR & PTR. Source: ASTER DEM: 30 m resolution.



2.6.3. Climate

The study area has some high as well as low rainfall area. The Valparai plateau and the adjoining areas in ATR receive more than 2400 mm mean annual rainfall. Similarly the western part of PTR receives more than 2400 mm rainfall annually. In contrast, majority of the eastern slopes receive less than 1000 mm mean annual rainfall (Fig. 2.4). Precipitation pattern in north western part of ATR bordering PTR (Topslip) showed two seasonal peaks each year: one during the South West monsoon from June to August and the other during the North East monsoon from September to November (Fig. 2.3).

Figure 2.3. Mean monthly rainfall in Topslip (ATR)

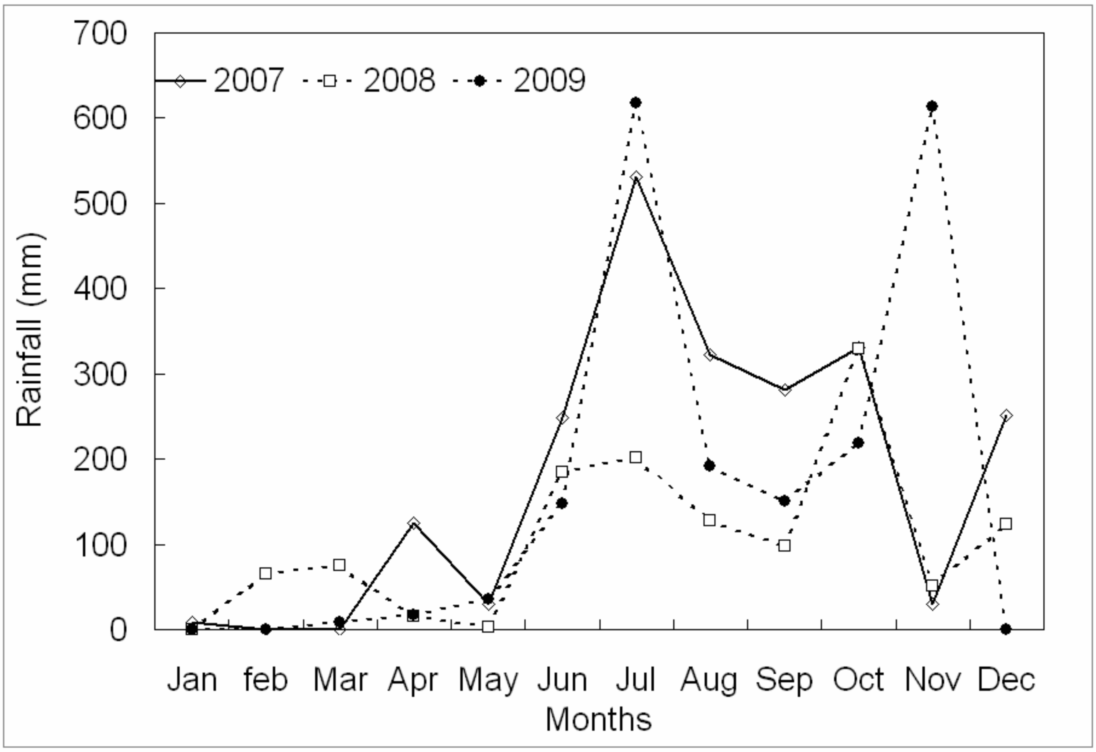
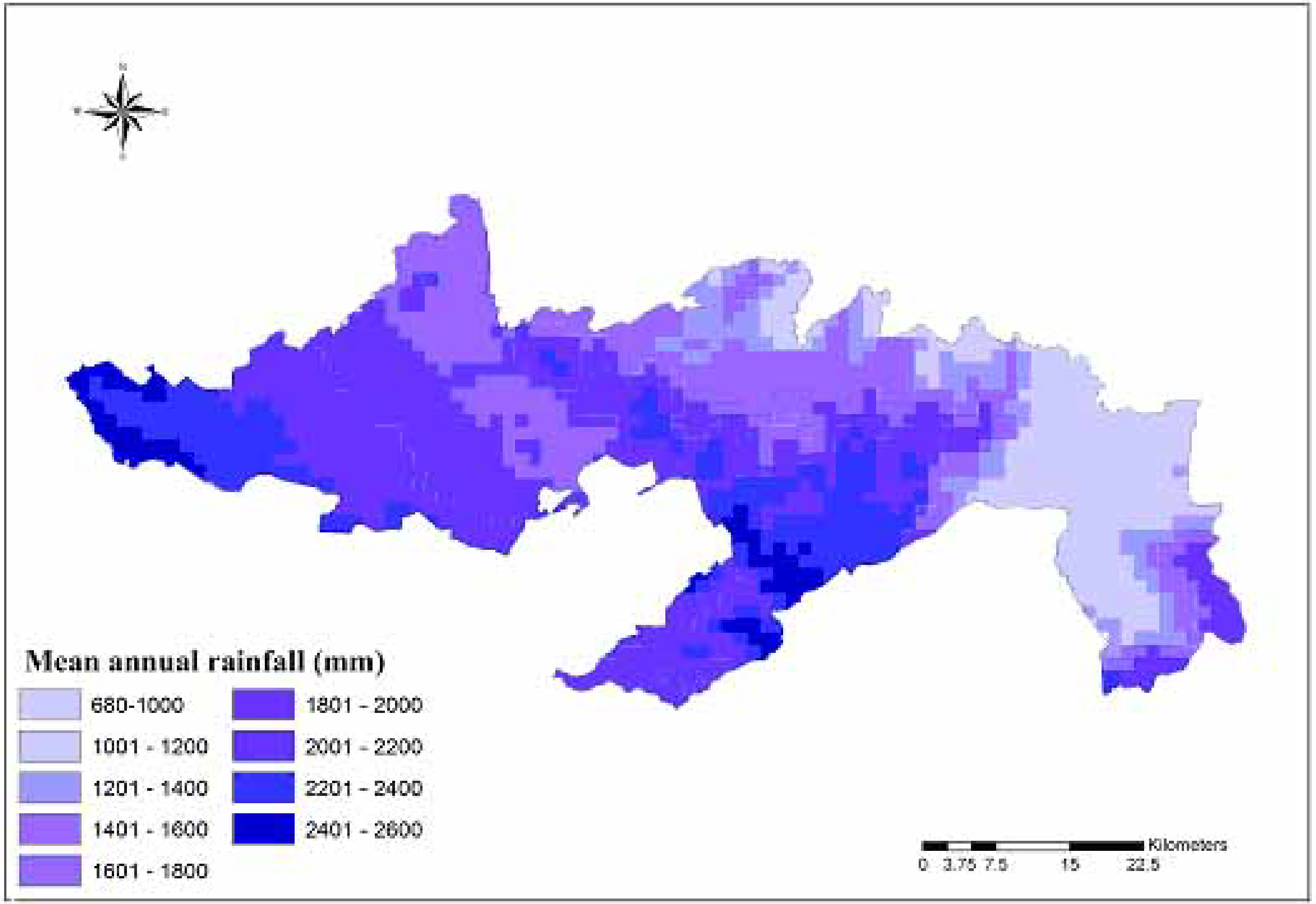


Figure 2.4. Depiction of variation in mean annual rainfall in mm (Years: 1950 -2000). Source: worldclim database grids = 1 km^2 resolution.



2.7. Ecological attributes

2.7.1. Vegetation types

The study area has a mosaic of vegetation types namely: southern tropical wet evergreen forest (Fig. 2.5A) consisting of *Dipterocarpus bourdilloni – Strombosia ceylanica* type (Pascal *et al*., 2004); bamboo forest (Fig. 2.5B) with mixed deciduous tree dominated by *Grewia telifolia, Terminalia tomentosa, Lagerstromia lanceolata* and *Cassia fistula*; moist deciduous (*Terminalia tomentosa, T. bellarica*, *T. paniculata, Dalbergia sissoo, D. latifolia* and *Dillenia pentagyna*); southern subtropical hill forests; southern montane wet scrub and grassland (Fig. 2.5C); reed brakes composed of *Ochlandra travancorica, O. rheedi* and *O.brandisii*; southern dry thorn forest; dry savannah forest in the eastern slopes (Champion and Seth, 1968); riparian forests have been characterised as distinct vegetation types in this region (Sekar and Ganesan, 2003). Thirty three percent (ATR = 2.8%; PTR = 31.9%) of the protected area is under monoculture teak plantations (Fig. 2.5D) (Wilson, 1973).

2.7.2. Faunal Diversity

The array of elevation along with different habitat types are abode for a wide variety of animals. Montane shola – grassland (cloud forests) holds some unique endemic herpetofauna which is not found elsewhere in the Western Ghats.

Mammals

Mammals are represented by more than 130 species (Nameer *et al*., 2001). This region is diverse in carnivore, felids include Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), leopard cat (*Prionailurus bengalensis*), rusty spotted cat (*P. rubiginosus*) and jungle cat (*Felis chaus*). Canids include Indian wild dog (*Cuon alpinus*) and Jackal (*C. aureus*).

Figure 2.5. Different vegetation types: A. Southern tropical wet evergreen forest; B. Bamboo mixed forest; C. Montane shola-grassland; D. Monoculture teak plantations.

Ursids is represented by sloth bear (*Melurus ursinus*), the most frequently sighted mammal during this study. Mustelids include common (Eurasian) otter (*Lutra lutra*), smooth coated otter (*Lutragale perspicillata*), Oriental small-clawed otter (*Amblonyx cinereus*) and the endemic Nilgiri marten (*Martes gwatkenski*). Other endemics such as lion-tailed macaque (*Macaca silenus*), Nilgiri langur (*Semnopithecus johnii*), jungle striped squirrel (*Funambulus tristriatus*), brown palm civet (*Paradoxurus jerdoni*), spiny dormouse (*Platacanthomys lasiurus*) and Nilgiri thar (*Nilgiritragus hylocrius*) (Nameer *et al*., 2001). Other arboreal mammals include Indian giant flying squirrel (*Petaurista philippensis*), Travancore flying squirrel (*Petinomys fuscocapillus*) and Indian giant squirrel (*Ratufa indica*) A recent study findings suggest that the arboreal mammals have persisted and increased in abundance over the last decade, particularly in private fragments (Shridhar *et al*., 2008). Herbivores such as Asian elephant (*Elephas* maximus), sambar (*Cervus unicolor*), chital (*Axis axis*), gaur (*Bos gaurus*), barking deer (*Muntiacus muntjak*), mouse deer (*Tragulus meminna*) are known from this region.

Birds

More than 320 species of birds have been recorded from this region (Sekar and Ganesan, 2003). The great hornbill (*Buceros bicornis*), Ceylon frog mouth (*Batrachostomus monilger*), black baza (*Aviceda leuphotes*), oriental bay owl (*Phodilus* badius) and Wayanad-laughing thrush (*Trochalopteron sp)* are some of the notable avifauna found in this region.

Herpetofauna

Forty species of amphibians and 87 species of reptiles are recorded from the Anamalais (Smith, 1943; Vasudevan, 2000; Ishwar, 2001). Endemic genera of frogs *Nasikabatrachus*, *Nyctibatrachus*, *Ghatixalus*, *Micrixalus*, *Melanobatrachus*, *Indirana, Ghatophryne*, and *Raorchestes* are known from this region. Sixty two species of snakes were reported from this region (Smith, 1943; Ishwar, 2001). Lizards such as *Hemidactylus anamallensis*, *Salea anamallayana, Ristella beddomei, Kaestlea travancorica* are highlights of the endemic lizards in this region. In the case of reptiles, few new records have been added to the regions snakes (Harikrishnan *et al*., 2007; Deepak *et al*., 2010). Four species of turtles were known from this region which includes *Melanochelys trijuga cornata, Vijayachelys silvatica, Lissemys punctata* and *Indotestudo travancorica.* Marsh crocodiles (*Crocodylus palustris*) are found in the reservoirs and in the rivers downstream of Kuriyarkutti.

Terrestrial invertebrates

Out of the 269 species of land snails from the Western Ghats 210 species are found in the southern Western Ghats (Aravind *et al*., 2005). The most common snail in the areas below 1000 m a.s.l in the Anamalais includes *Ariophanta basilessa* in the evergreen, moist deciduous and teak plantations. Another common snail in this region is *Indrella ampulla*. Other species belonging to genus *Streptaxis*, *Ennea*, *Ariophanta*, *Theobaldius*, *Cyathopoma*, and *Mychopoma* are found in the Anamalais (Blanford and Godwin-Austen, 1908; Gude, 1921). Spiders belonging to 27 known families are known from this region (Kapoor, 2006). I came across Indian ornamental spider (*Poecilotheria regalis*) in evergreen forests and teak plantations, and other interesting species like *Anchonastus sp* and the funnel nesting spiders *Hippasa sp*. The scorpion fauna of Western Ghats and its environs are poorly documented (Sureshan *et al*., 2007). *Lychas tricarinatus*, *L. albimanus*, *Isometrus brachycentrus*, *I. sankeriensis*, and *Heterometrus kanarensis* are some of the scorpion species found in PTR (Sureshan *et al*., 2007). Hymenopteran diversity is high in this region, 108 species belonging to 15 families are reported from PTR (Sudheendrakumar and Mathew, 1999).

2.8. Human habitation and forest dwellers

According to the Scheduled Tribes and Forest Dwellers (Recognition of Forest Rights) Act 2006 forest dwelling schedule tribes are defined as the member or community of the Schedule Tribes who primarily reside in and who depend on the forests or forest lands for bona fide livelihood needs and include the pastoralist communities (The Gazette of India, 2006). Depictions of various rituals and pictographs of prehistoric human activities are found in some overhangs as rock paintings within the Anamalai Tiger Reserve (Subramanian, 2007). Large stone dolmens found in various locations in the hilltops are evidence of early human occupation in this region (Chandi, 2008).

Most ethnography on the tribes in the Anamalais has been conducted during the early half of the previous century, excepting a few academic studies including genetics and the shifting cultivation system of the region conducted later (Chandi, 2008). This region is known for its anthropogenic diversity; indigenous people living in the Anamalais include Kadars, Malasar, Malaimalasar, Pulaiyar, Muduvar and Eravalar (Sekar and Ganesan, 2001; Chandi, 2008 and references therein). Though most of these communities were hunter-gatherers in the past, they now live in sedentary units within the ATR largely along its fringes (Chandi, 2008) and few in the interiors of PTR. Livelihood activities for some of the communities documented in the past range from natural resource gathering, cultivation of subsistence and cash crops and limited employment with forest department and private plantations (Chandi, 2008). A detailed account on the transformation of livelihood of tribal communities, especially the Kadar tribes was provided by Chandi (2008):

In the Anamalais, exploration by pioneer explorers and planters who the Kadar brought into the hills in 1858 saw the region being opened for plantations of tea, coffee and cardamom in 1864 (Congreve, 1942). The Kadars worked as guides and offered little labour as coolies and in clearing the forest for which plains people were employed. A recent chronicle of the ecological history of the region regarding conversion of virgin forests to plantations, logging for timber and the construction of a series of dams is described in Sekar and Ganesan (2003) and Mudappa and Raman (2007). Congreve in his account of the growth of the plantations also chronicled the relationship they had with the kadar and other tribes of that time (1858-1940) in the plateau. It was through the development of an economy around the plantations and the attempt by the then government (pre-independence) to safeguard the economic interests of the Kadar of the region that an apparent transformation from foraging and hunting, toward a sedentary economy emerged. The Kadar system of barter with the plains people was their method of acculturation and adaptations in a life largely determined by natural events and resources of the forest. An interesting paper by Hornell in 1924 on south Indian crossbows, boomerangs and blow guns describes those articles in great detail in an effort to document material culture rapidly falling into disuse by that time. At the same time adoption of practices in the social hierarchy and of materialism of the plains also crept into the life of foraging forest dwellers such as the kadar. Thurston in 1909, Hermanns in 1955 and Ehrenfels in 1950 give some insight into these changes that have occurred largely with the Kadar in spheres such as religious beliefs and transformation. Some of these events are woven into stories and narratives that are known, albeit in changed circumstances of comprehension even today. This spread in many directions including a *most influencing facet, that of language. Writing on the influence of dominant languages and cultivated languages, Thundiyil (1975) offers empirical evidence to show that minority tribal groups may be forced to change the surrounding dominant majority with a cultivated literary language. He reported that the kadars as a whole were slowly becoming "Tamilized or Malayalamized" due to the spread of literacy and education.*

Documented history suggests that agriculture was brought into the hills by the Mudhuvars (Chandi, 2008). Shifting cultivation technique was practiced in many regions in the mountains until restrictions on the practice were made by the Forest Department (Chandi, 2008). The practice was not confined to the tribes of the region but was also used by the Forest Department with a modified system named "Kumri" cultivation (Wilson, 1973). This system refers to the regeneration of commercially important trees as plantations by clear felling the native forest for timber and initially regenerating the forest by using a crop such as tapioca, or millets for a year by a right to "kumri", which was sold through an auction. The land was grown with cash/agricultural crop along with silvicultural species such as teak, eucalyptus or other trees (depending on the working circle). The soil was repeatedly worked through weeding, thinning and irrigation to benefit the silvicultural crop as well. This process continued over several years by tending the silvicultural crop through thinning, exploitation of the agricultural crop, amongst several other subsidiary silvicultural operations. The labour for such work were usually imported; occasionally adjacent tribal communities were also engaged (Wilson, 1973).

At present, people from the Malasar communities in Kolikammuthy settlement in ATR are engaged as Mahouts in the elephant camp run by the Forest Department (ATR). More than 100 people belonging Malasar, Malai malasar and Kadar communities are employed as guides for tourist in PTR. Some of them, Kadar communities in the fringes of ATR work as daily wage labour in tea and coffee estates in the Valparai plateau (Chandi, 2008). There are 36 human settlements in the Anamalai Tiger reserve and 7 settlements in the Parambikulam Tiger Reserve. A recent study on eight human settlements including Kadar, Muthuvar and Malai Malasar communities reported a 180% increase in the population in over three decades (Chandi, 2008).

CHAPTER 3

POPULATION MONITORING

3.1. Introduction

Growing concern over human impact on the environments has raised an increasing need for the development of techniques to assess the current state of many animal and plant populations. Hence there is a need to monitor biodiversity and assess which populations are threatened, and develop management strategies for the conservation of these populations.

Monitoring of animal populations can be defined as the estimation of absolute or relative abundance for the purpose of drawing inferences about variation in abundance of animals over space and/or time (Nichols and Karanth, 2002). Inferences about animal population involve counting organisms. Count statistics are provided by direct counts of animals or animal signs/indirect evidences such as tracks, scats, and prey species in fecal matter. Estimation of animal population size from these count statistics involves two basic problems *viz*: observability and spatial sampling (e.g. Thompson, 1992; Skalski, 1990; Yoccoz *et al*., 2001; Nichols and Karanth, 2002; Williams *et al*., 2002). Observabilty refers to the ability to detect only a fraction of all animals present, in an area regardless of the survey method used. With respect to animal signs/indirect evidences such as tracks, scats, and prey species in fecal matter, observability refers to an inequality between the count statistic and the true number of animals. Spatial sampling refers to extent of the area where inferences on the population are applicable. It is addressed by drawing sample locations from the entire area, so the counts of animals made on these locations can be used to draw inferences about the animals in the entire area.

Data from field studies on amphibians and reptiles are typically reported in the form of count statistic reflecting population size, species presence/absence, or species richness (Mazerolle *et al*., 2007). For example, depending on the objective and methods, the data might include the number of tortoise captured in a forest patch per man hour or per kilometer of search (visual encounter survey) or, the number of control and treatment sites where particular species of frog were heard calling. In other cases, the number of previously marked individuals caught on an occasion (i.e., a recapture rate) might be used. These indices of count or capture are then used analyses to infer patterns and test hypotheses (Mazerolle *et al*., 2007). These methods have been extensively criticized in the literature because they do not account for imperfect detection of individuals in a population (Preston, 1979; Nichols, 1992; Pollock *et al*., 2002; Williams *et al*., 2002) or species communities (Mackenzie *et al*., 2004). In a population study, the expected value of the total number of individuals counted (C = total number of observed, heard, captured, etc.) during a sampling period is given by the product of the probability of detection (P) and the true unknown total number of individuals (N) in the population such that $E(C) = PN$, Where $E(C)$ denotes the expected value or expectation of C (Otis *et al*., 1978; Nichols, 1992; Anderson, 2001; Williams *et al*., 2002).

In the case of studies on tortoise populations, capture-recapture and lines transect distance sampling methods have been used (e.g. Freilich *et al*., 2000; Anderson *et al*., 2001; Kazmaier *et al*., 2001). Line transect involves counting individuals on a series of marked transect lines, the observer also records the perpendicular distance to the animal. Transects are monitored repeatedly (in most cases), to estimate abundance of animals within a given area. The data thus collected is used to estimate abundance incorporating imperfect detectability. Mark-recapture method involves capturing and marking individuals and constructing a history of detection and non-detection of marked individuals (Karanth and Nichols, 1998) and thereby, estimating the population size.

Measuring occupancy or estimating proportion of area occupied by a species (PAO) as a surrogate of population size of species that have low detection probabilities (MacKenzie *et al*., 2002). It has become popular among wildlife biologists in recent years. Occupancy studies have been widely used in monitoring populations and identify abiotic or human induced factors influencing the occupancy and the detection probability in different species for example in, insects (MacKenzie *et al*., 2005), amphibians (Bailey *et al*., 2004), reptiles (Zylstra and Steidl*,* 2010; Griffiths and McKay, 2007), and mammals (MacKenzie *et al*., 2005; MacKenzie, 2006; Buij *et al*., 2007; Linkie *et al*., 2007). Single season occupancy models developed by MacKenzie et al (2002) allows estimation assumes closure (i.e., no immigration or emigration) of occupancy after incorporating imperfect detection. This multiple season model includes colonization and extinction probabilities and allows estimation of occupancy over a time period (MacKenzie *et al*., 2003). It is used to study interactions among populations and in metapopulation studies.

These models are useful, because they facilitate evaluation of hypothesized relationships between occupancy and factors in species' environment, and they could be used species that are rare or difficult to detect (MacKenzie *et al*., 2006). The patterns of detection and non detection over the multiple visits in each site permits estimation of detection probability and occupancy (MacKenzie *et al*., 2002). Model averaging and weighted estimates of a set of models have been considered as a better approach compared to inferences based on single superior models (Burnham and Anderson, 2002). Inferences based on model averaging results have been made in studies using single season occupancy models (Mazerolle *et al*., 2005; Pellet and Schmidt, 2005; MacKenzie *et al*., 2006; Griffiths and McKay, 2007) and multi season occupancy models (Olson *et al*., 2005; MacKenzie *et al*., 2006; Hossack *et al*., 2007). There are also studies that used multi season models and based their inferences on the top ranking models (Buij *et al*., 2007).

When this study was initiated there was only study on the encounter rate of Travancore tortoise (here after referred to as TT) population in the Western Ghats (Bhupathy and Choudhury, 1995). This gave an impression that both line transect and mark-recapture methods might be inefficient due to poor detection. It was decided that presence/absence surveys on marked trails will be carried out in the occupancy frame work. Another paper published on TT population provided an index of the population (Ramesh, 2008a). These studies revealed that 50% of all tortoises detected were near streams and grass marshes and the remaining were inside forests (Ramesh, 2008a; Bhupathy and Choudhury, 1995). Because TT is cryptic and distributed over a large area of mosaic of habitats, it was necessary to carry out a survey that estimates the population over a large area. In this study, an estimate of site occupancy in roughly 367 km^2 of area in two PAs in the southern Western Ghats. Habitat variables influencing their occupancy and detection probability were identified based on the data collected from 2006 – 2009 in the study area.

3.2. Intensive study area

The elevation range in the ATR and PTR ranged from 200-2500 m above sea level (a.s.l). The intensive study was carried out only below 1000 m a.s.l, where the tortoises were likely to be found (insert Fig. 3.1).The largest potential area and habitat available for TT is only 33 %, a total of 395.5 km^2 area was delineated (Fig. 3.1). Sampling was carried out in four major vegetation types classified as southern tropical wet evergreen forest (Champion and Seth, 1968), *Dipterocarpus indicus-D. bourdilloni – Strombosia ceylanica* type (Pascal *et al*., 2004); Bamboo brakes with mixed deciduous trees (*Grewia telifolia, Terminalia tomentosa, Lagerstromia lanceolata* and *Cassia fistuala*); Moist Deciduous (*T. tomentosa, T. bellarica* & *T. paniculata, Lagerstromia lanceolata, Schleichera oleosa, Pterocarpus marsupium, Anogeissus latifolia* and *Dillenia pentagyna*) and Teak plantations (*Tectona grandis*). Monoculture teak plantation covers thirty three percent (ATR = 2.8 %; PTR = 31.9 %) of the protected area (Wilson, 1973). There are three reservoirs in the study area covering an area of 28.5 km^2 (Fig. 3.1). There are twelve human settlements in the study area with a total population of 2066 people (Fig. 3.1 & Table 3.1).

3. 3. Methods

3.3.1. *Field sampling*

The intensive study area had two seasonal peaks each year, one during the south west monsoon from June to August, and the other during the north east monsoon from September to November (Kannan and James, 1999). Local peoples' knowledge on the species helped us design the sampling strategy; intensive sampling was carried out during the monsoon months, when the tortoises were reportedly active. Searches conducted previously between 1400 – 1900 h in the study area yielded more detections (Ramesh, 2003). Further, the local peoples' knowledge of tracks and signs and method of searching for the tortoises during the late evening hours prompted to carry out the surveys between 1600 - 1900 h.

Indirect evidence such as tortoise trails with or without spoors, bite marks on grass and herbs, and shell of dead tortoises were recorded as presence of TT (Fig. 3.2). The shapes of the bite marks on the leaves by TT were tricuspid (Fig. 3.2). Their trails made an impression by flattening of the grass or herbs or shrubs, which were identified with the help of local assistants. Tortoise trails varied depending on the ground vegetation they moved on, it was prominent on grasses during monsoon and post monsoon, when the grass were tall. The width of the tortoise trails were between 15 to 25 cm. The Indian black pond turtle (*Melanochelys trijuga*) was found in the study area and their tracks could not be distinguished. However, the error in identification from TT was minimized by using more than one evidence such as, bite marks which were characteristic of TT to denote presence of the species during each survey.

A stratified random sampling approach was followed to sample TT population in the study area. Twenty five trails were marked in four different habitat types (moist deciduous, evergreen, bamboo mixed forest and teak plantation). The start point of the trails is shown in Fig (3.1), were determined randomly. All the trails were marked permanently with a red paint on trees and rock boulders along the trail. The trails traversed through a single habitat type, if the trail passes through another habitat, the direction of the trails were changed and new trails were made to pass through the same habitat type. Each trail dissected through multiple microhabitat types such as, grass marshes, rocky outcrops and streams. Some trails were straight, some were curved but none of them were circular and they did not overlap with neighboring trails. The width of the trails varied between 0.5 m to 2 m. The trail width keeps changing over period depending on the usage by wild animals and human beings. Each trail (site) was sampled between 0-7 meters on either side of the trail by two observers. Twenty five trails were sampled during monsoon and post monsoon seasons. In all 5, 3, 7 and 3 surveys were carried out during the year 2006, 2007, 2008 and 2009 respectively. During these 450 surveys in the 25 sites, 108 surveys were not carried out. These were attributed to constraints in reaching the sampling sites and conducting the survey. Because the detection of TT and signs of TT required experience field personnel, an initial set of 23 surveys were carried out to train the observers. The data collected during these surveys were not used for analysis. Each survey was carried out by two trained observers. I was involved in 247 out of the 342 total surveys total surveys carried out in the study area.

Figure 3.1. Intensive study area in ATR & PTR showing the largest potential habitat available for Travancore tortoises. Numbers correspond to those of Table 3.1. ASTER 30 m resolution elevation layer & IIRS WG 56 m grassland layer are used in this map.

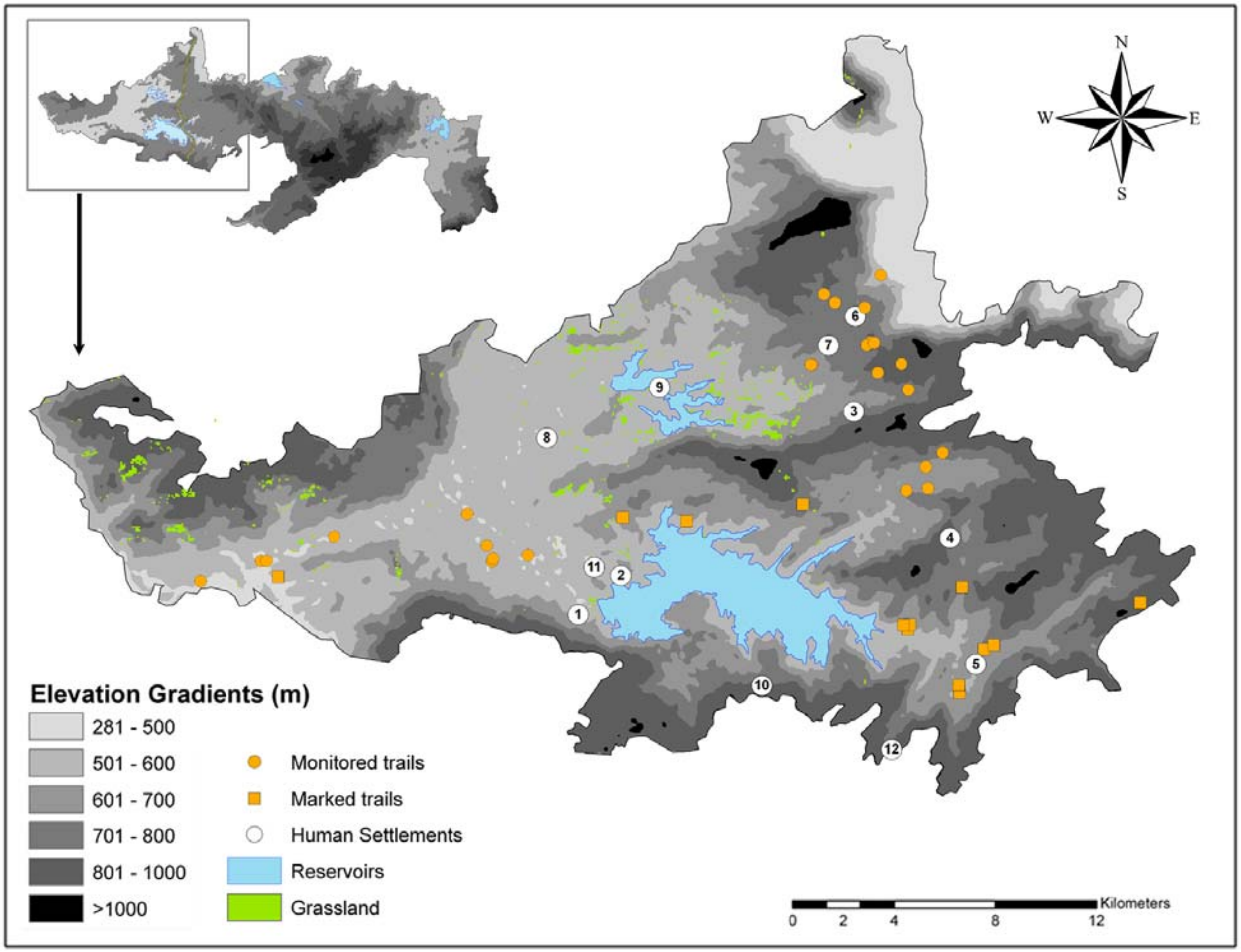
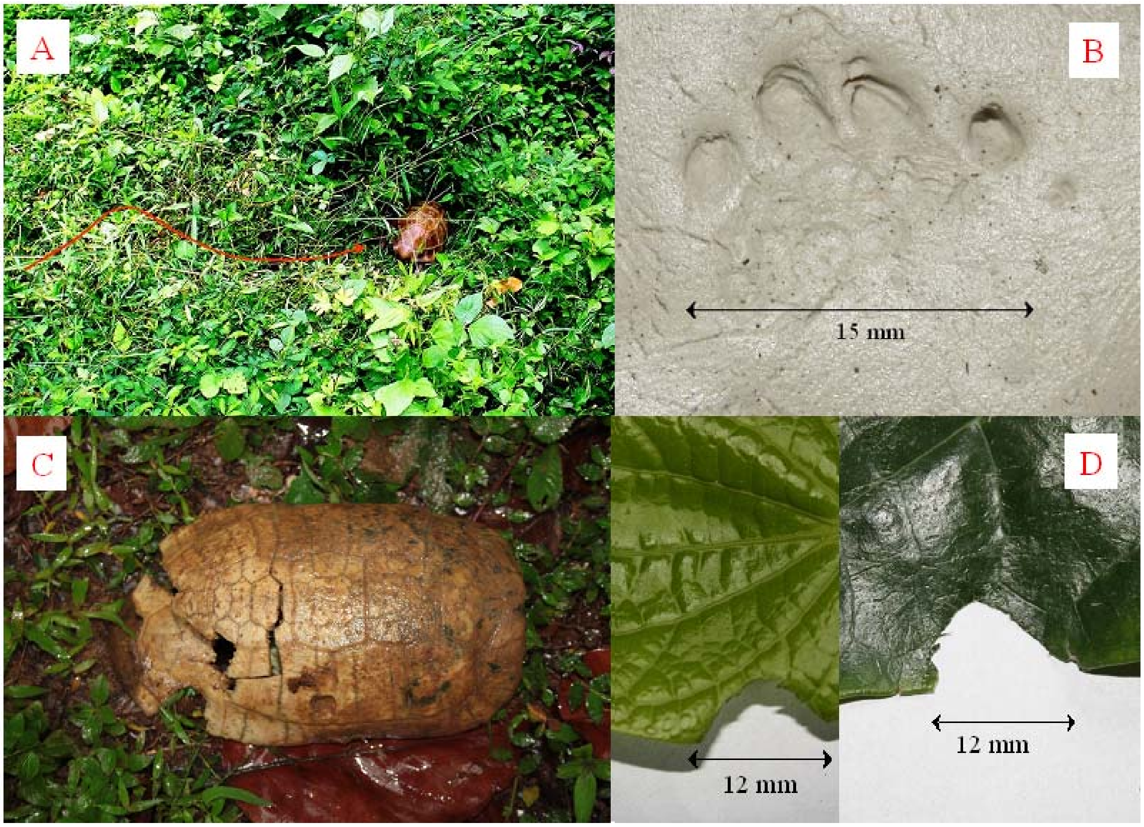


Figure 3.2. Different indirect evidences/signs used to record Travancore tortoise presence: (A) trail, (B) forefoot spoor mark, (C) shell remains and (D) bite marks on leaves.



3.3.2. Covariates

There are two types of covariates which can be modelled in Program PRESENCE: 'site covariates' and 'sampling covariates'. Site covariates are those that remain constant for the duration of the season, for example, habitat type, site size, site isolation, elevation, distance from some focal point and weather conditions (MacKenzie *et al*., 2006). Sampling covariates are those that may vary from one survey to another, such as local environmental conditions, time of day, or surveyor experience. Inclusion of covariates allowed hypothesizing the relationship between occupancy (ψ) and site specific characteristics; and between detection probability (*p*) and survey specific characteristics (MacKenzie *et al*., 2006).

Table 3.1. Number of human habitations inside the study area and their population size. Source: Tamil Nadu & Kerala Forest Department.

No	Settlement name	Population
1	Earth dam	101
2	P.A.P + Kadavu colony	407
3	Kolikamuthy	290
4	Kummaty	157
5	Manamboli	60
6	Topslip	75
7	Erumapara	188
8	Kuriyarkutti	253
9	Sungam	320
10	Poopara	174
11	Anjacolony	56
12	Palakanar	45
	Total	2066

The probability of a site being occupied and the probability of detecting the species in a survey was not assumed to be equal across sites. A logit link or logistic equation is used in covariate modelling in program PRESENCE by doing so parallels can be drawn with logistic regression techniques (Mackenzie *et al*., 2006):

$$\theta = \frac{e^{\beta_0 + \beta_1(x_1) + \ldots + \beta\ (x_n)}}{1 + e^{\beta_0 + \beta_1(x_1) + \ldots + \beta\ (x_n)}} \qquad \text{(Equation 1)}$$

In equation-1 θ represents the parameter of interest (e.g., occupancy or detection probability), β_0 is the intercept, the β_1 to β_n are regression coefficients, and the x_1 to x_n are site covariates.

In this study, four site covariate and one survey covariate were measured. The site covariates were: (i) The extent of grass marshes in each site was measured using measuring tape to the nearest centimeter; (ii) Number of water bodies within 10 m distance on either side of the trail (ponds, streams) were counted; (iii) Extent of anthropogenic disturbance was ranked from 0 to 5. This rank was the sum of individual score assigned to each site based on the following attributes. The presence of the attributes would result in assigning a score of one each and absence would result in assigning a score of zero. A score of one for each human activity if present or zero if it was absent was assigned and summed up to obtain a cumulative score for anthropogenic disturbance for each site. The activities scored were (a) Intensively used human trail; (b) tuber (*Hemidesmus indicus* and other edible species) collection; (c) nearest distance at any point in the trail to the human habitation (> 1 km = 1 (high), < 1 km = 0 (low); (d) firewood collection and (e) domestic dogs seen at least once during the study (0/1). (iv) The four different vegetation types: bamboo mixed, moist deciduous and evergreen forest and teak plantation (section 3.2) were included as categorical variable in order to examine if site occupancy was influenced by vegetation type. The survey covariate collected was the time spent in each trail during sampling. In the analysis it was coded as site covariate, (v) the mean of the time spent in each site each year and used as the site covariate.

3.3.3. Occupancy modelling

Multiple season occupancy models described by MacKenzie et al (2003) were used to estimate occupancy (ψ) and detection probability (p) taking into account colonization (γ) and local extinction probabilities (ε). Out of the four different default models incorporated in the program PRESENCE (Hines and MacKenzie, 2004). Default model framework two in the PRESENCE program was used in the present study because it allowed testing the hypotheses given in (Table 3.2). In model frame two the seasonal occupancy (ψ), colonization (γ) and extinction (ε). The site and survey covariates can be modelled with ψ, p and γ.

In Program PRESENCE, when the analysis was carried out using the entire data set the estimates had large standard errors and their values converged at parameter boundary. Therefore the model evaluation was carried out in two sets viz: *Model set 1*: detection probability was modeled with time (year), vegetation type, number of water bodies, extent of grass marsh, sampling effort and surveys. All the models for p were run keeping ψ constant. *Model set 2*: The factors influencing ψ of TT was identified by regressing time (year), vegetation type, number of water bodies, extent of grass marsh and anthropogenic disturbance level. The factors influencing *p* of TT were identified using time (year), vegetation type, number of water bodies, extent of grass marsh, average sampling effort for each site in a year and occasions. Some models yielded unrealistic estimates that approached parameter boundary values ($\psi = 1$; Anderson, 2008), and they were removed before model averaging was performed.

3.3.4. Model selection and goodness of fit

The best fit models were sorted based on ΔAIC values and AIC weights to determine which model was best supported by the data. ΔAIC values and AIC weights quantify the strength of evidence in support of a particular model in a set of models being evaluated (Burnham and Anderson, 2002). Top models are those that are ranked $\Delta AIC \leq 2.0$ from the models (Burnham and Anderson, 2002). These models were explained separately before model averaging. Those models with AIC model weight > 0.01 were kept, so that the weights of the top-ranking models summed to 100% and then the overall model averaged estimate of occupancy (ψ) was computed (MacKenzie and Bailey, 2004).

For single season models proposed by MacKenzie et al (2006) there is a goodness of fit test (MacKenzie and Bailey, 2004). No specific procedure exists for calculating goodness of fit for multi season occupancy models (MacKenzie and Bailey, 2004). Therefore, the models used in model averaging could not be tested for goodness of fit. Relative importance of the weights of the variables was calculated following Burnham and Anderson (2002). This was done by summing the AIC model weights across all the models that had the variable of interest.

Table 3.2. Hypotheses used to test the influence of covariates on occupancy and detection probability of Travancore tortoise in the study area between 2006 and 2009.

Parameter	Hypothesis	Notation
Occupancy	Is constant across years	ψ (.)
	Varies from year to year	ψ (Year)
	Is influenced by disturbance level	ψ (disturbance)
	Is influenced by number of water bodies	ψ (water)
	Is influenced by extent of grass marshes	ψ (grass)
Detection probability	Is constant across years	*p* (.)
	Varies from year to year	*p* (Year)
	Is influenced by number of water bodies	*p* (water)
	Is influenced by extent of grass marshes	*p* (grass)
	Is influenced by effort	*p* (effort)
	Is influenced by vegetation type	*p* (veg.type)
	Is influenced by survey	*p* (survey)

3.3.5. Layers and softwares

Distance to human settlements from the trails, and maps were made in ArcMap v9.2 GIS software package (ESRI Inc, Redlands, CA). Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER) layer with 30 m resolution and IIRS WG 56 m resolution layers was used to extract information on elevation and grass marsh (ASTER

GDEM is a product of METI and NASA; Indian Institute of Remote Sensing, 2002). To calculate the area in different elevation zones the total number of cells in different elevation category were multiplied by the area of each cell. The analysis on occupancy was done using the program PRESENCE 3.1(Hines and MacKenzie, 2004).

3.4. Results

3.4.1 Presence – absence surveys

A total of 40 trails were surveyed between 2006 and 2009. Including the repeats 481 trails were walked. In all 962 km were walked in the study area searching for TT. A total of seventy eight tortoises were found in the entire study period. There were only three recaptures during the entire study. Forty five individual tortoises were recorded from 25 trails in and out of occupancy surveys between 2006 and 2009. This included 24 females, 16 males, 3 hatchlings and 2 juveniles, out of which, two males and one female were recaptured during the study period. A frequency distribution of straight carapace length (SCL) is given in Figure (3.3).

Thirty nine individuals and 61 indirect evidences through signs were found in the 25 sampling trails. (Fig. 3.4). Presence of TT was inferred from 14 direct sightings and 13 indirect evidences during the 2006 surveys, one direct sighting and seven indirect evidences during 2007, one direct sighting and twenty four indirect evidences, and thirteen direct sightings and one indirect evidence during the year 2009. Encounter rate of

TT was highest during the year 2009 0.13 per km (n = 150 km) and it was lowest during the year 2008 0.004 per km (n = 230 km). Encounter rate was 0.08 per km (n = 224) in 2006 surveys and 0.01 per km (n = 80 km) during 2007. Encounter rate of indirect evidences of TT was highest during 2008 (0.16 per km) and lowest during 2009 (0.01 per km). Encounter rate of indirect evidences of TT during the year 2006 was 0.07 per km and it was 0.09 per km during the year 2007.

Figure 3.3. Frequency histogram of straight carapace length in *Indotestudo travancorica* (mean = 21.9; SD = 5.0; n = 45) measured in the study area between 2006 and 2009.

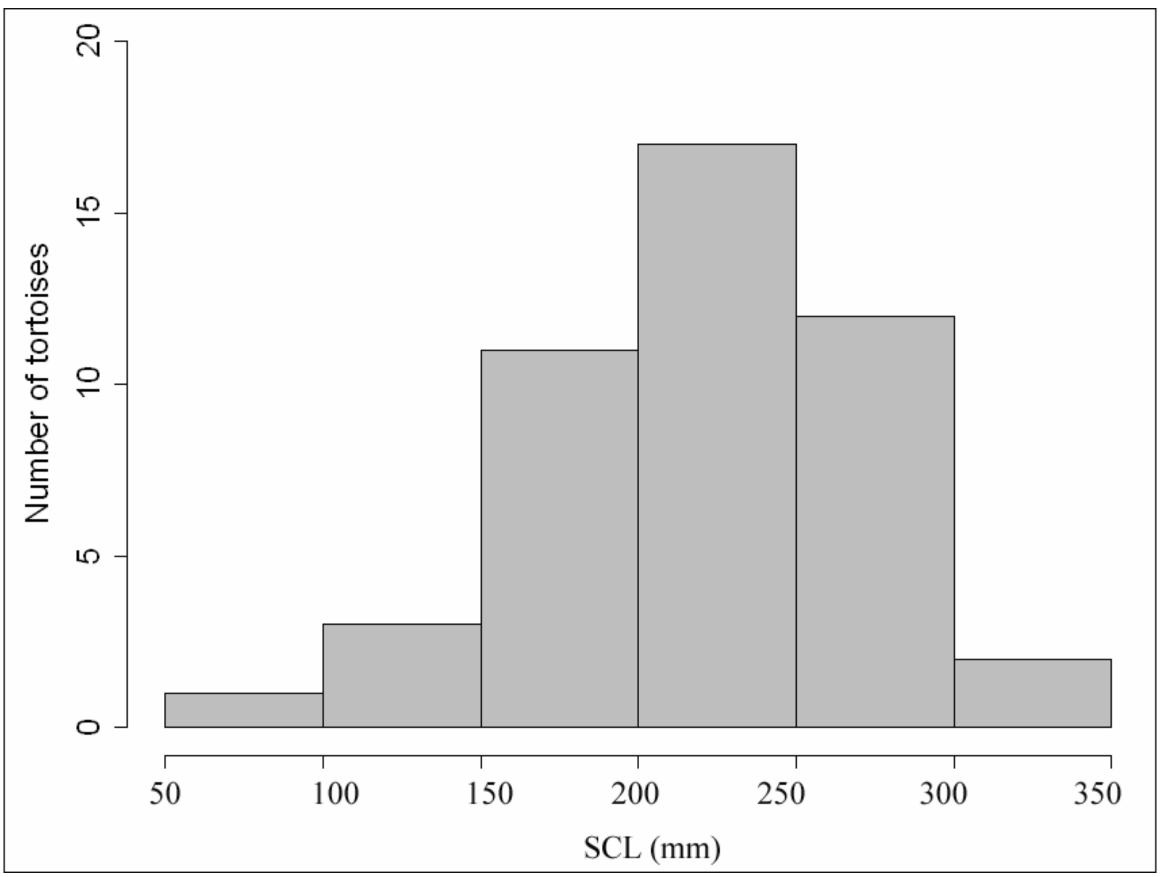
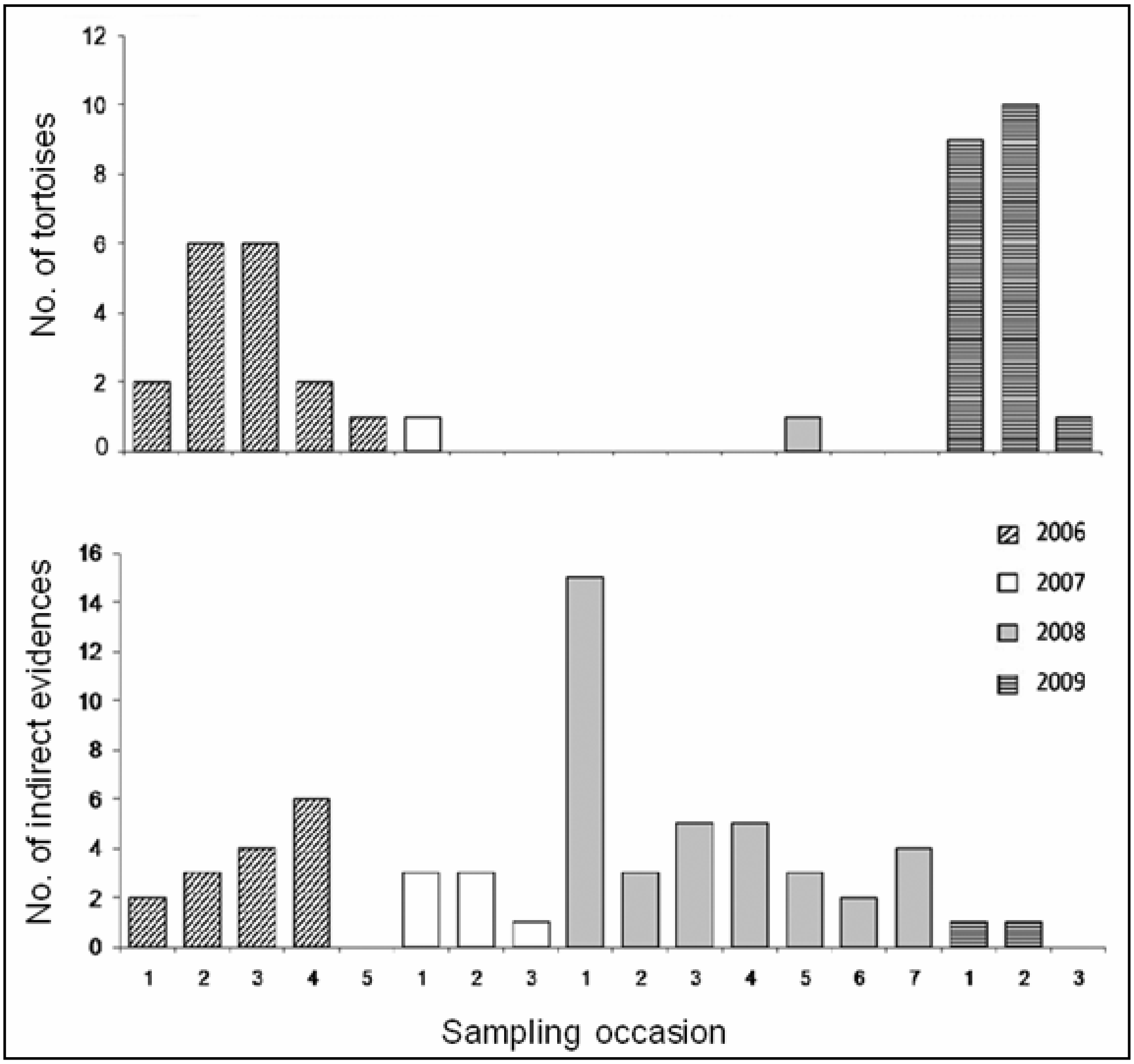


Figure 3.4. Distribution of records of tortoises and their signs in different sampling occasions in the study area between 2006 and 2009.



3.4.2. Detection probability & Occupancy

Model set 1(detection probability)

Detection probability of TT in each site ranged between 0.14 and 0.45. One model with 0.54 AIC weight was the top ranking model .This model had year, effort, water bodies and extent of grass marshes as variables that influenced detection probability (Table 3.3). Another model with AIC weight of 0.23 had ΔAIC value ≤ 2.0 and his model had number of water bodies and extent of grass marshes as the factors influencing detection probability (Table 3.3). Number of water bodies was the most important variable influencing detection probability and it accounted for 91 % of the AIC model weights, and followed by the extent of grass marsh (83 %), the year (62 %) and the sampling effort (61 %) (Table 3.3). Vegetation type, surveys did not have any influence on detection probability (Appendix 1). In total 15 models were analysed to test different hypotheses (Appendix 1)

Model set 2 (Occupancy & detection probability)

Model 1 had AIC weight of 0.47 (ΔAIC = 0) and was the best model that explained occupancy. There was one more model that had ΔAIC ≤ 2.0 which was model 2 and it had AIC weight of 0.18. The other competing models had ΔAIC values > 2 and therefore not used for drawing inferences (Table 3.4). The detection probability of TT for each survey ranged from 0.15 to 0.45 in model 1, and 0.00 to 0.74 in model 2. Detection probability was positively influenced by number of water bodies and extent of grass marshes in both model 1 & 2 (Table 3.5). Year and effort along with grass marshes and water bodies was influencing detection probability in model 2 (Table 3.4). The sign of the model coefficients for the top-ranked models revealed that detection probability increased with increase in the extent of grass marshes (Table 3.5). Abundance of water bodies and grass marsh accounted for 88 % AIC weights in the models that explained heterogeneous detection probabilities (Table 3.4).

Table 3.3. Results of models investigating relationships between site covariates and detection probability of *Indotestudo travancorica* based on surveys from 2006-2009. K= no. of parameters; -2Log*L* = Log likelihood; ΔAIC = Delta AIC; AIC *wt* = AIC model weight.

S. no	Models	K	-2Log*L*	ΔAIC	AIC
1	ψ(.) γ (.) *p* (Water + Grass+ Year + effort)	12	310.52	0.00	0.54
2	ψ(.) γ (.) *p* (Water + Grass)	5	326.24	1.72	0.23
3	ψ(.) γ (.) *p* (Water)	4	330.19	3.67	0.09
4	ψ(.) γ (.) *p* (Water + Year + effort)	11	317.24	4.72	0.05
5	ψ(.) γ (.) *p* (Grass)	4	331.54	5.02	0.04
6	ψ(.) γ (.) *p* (.)	3	334.68	6.16	0.02
7	ψ(.) γ (.) *p* (Grass+ Year + effort)	11	319.15	6.63	0.02
8	ψ(.) γ (.) *p* (Water + Year)	7	329.25	8.73	0.01

The competing models for occupancy had negative coefficients for anthropogenic disturbance suggesting that it negatively influenced TT population (Fig. 3.5). The estimate of occupancy were however not different in these models (Fig. 3.5). Anthropogenic disturbance level was the most important variable influencing occupancy and it accounted for 73 % of the AIC model weights, and it was followed by abundance of water bodies which accounted for 20 % of the AIC model weights (Table 3.4). The naïve occupancy of TT in the study site was 0.84. The estimated occupancy for model 1 varied between 0.41 – 0.97 and for model 2 the estimated occupancy was between 0.50 and 0.99. Seventeen different models were analyzed to test different hypotheses (Appendix 2)

Table 3.4. Top models investigating effect of site covariates on occupancy and detection probability of *Indotestudo travancorica* based on data from 2006 – 2009 in the study area.

S. no	Models	K	-2Log likelihood	ΔAIC	AIC *wt*
1	ψ (Dist) γ (.) *p* (Water + Grass)	6	319.77	0.00	0.47
2	ψ (Dist) γ (.) *p* (Water + Grass+ Year + effort)	13	307.86	1.91	0.18
3	ψ (Water) γ (.) *p* (Water+ Grass + Year + effort)	13	309.21	3.44	0.08
4	ψ (Water) γ (.) *p* (Water+ Grass)	6	323.59	3.82	0.07
5	ψ (Dist) γ (.) *p* (.)	4	327.86	4.09	0.06
6	ψ (Grass) γ (.) *p* (Water+ Grass + Year + effort)	13	310.47	4.70	0.04
7	ψ (Water) γ (.) *p* (.)	4	328.52	4.75	0.04
8	ψ (Grass) γ (.) *p* (Water+ Grass)	6	325.42	5.65	0.03
9	ψ (Dist + Year) γ (.) *p* (.)	7	324.58	6.81	0.01

Figure 3.5. Estimated occupancy of Travancore tortoise showing decreasing trend with increasing anthropogenic disturbance level. (A) Model 1 and (B) Model 2 corresponds to first two models Table 3

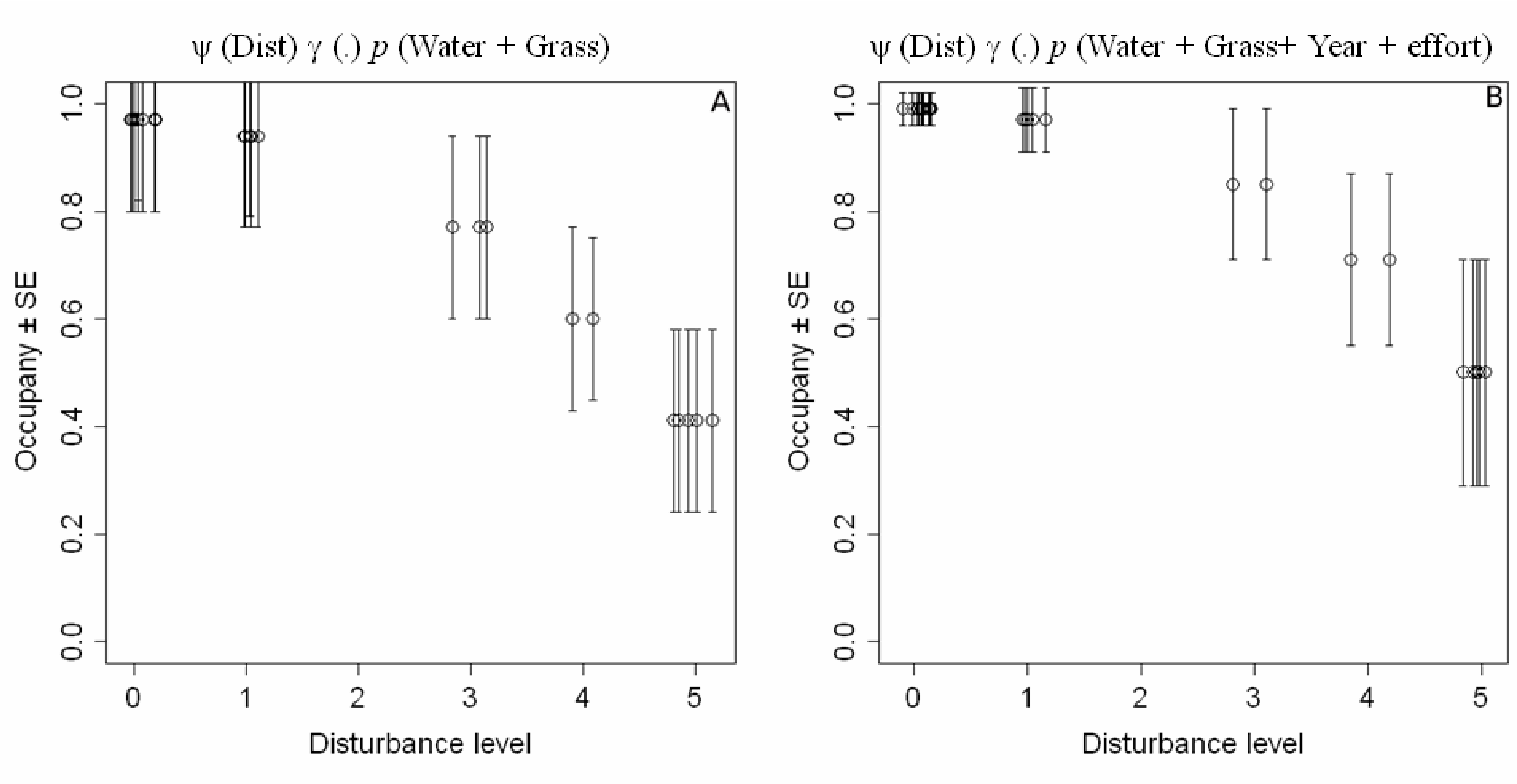


Table 3.5. Untransformed coefficients of covariates and standard error of the two models with ΔAIC ≤ 2.0.

Model.	Parameter + covariates	Coefficient	S.E.
1	ψ + disturbance level	-0.78	0.42
	p + Water bodies	0.28	0.13
	p + extent of grass marsh	0.21	0.11
2	ψ + disturbance level	-0.89	0.59
	p + Water bodies	0.34	0.14
	p + extent of grass marsh	0.24	0.14
	p + year_2006	-1.87	0.42
	p + year_2007	-1.25	2.53
	p + year_2008	-1.66	0.45
	p + year_2009	-2.63	0.62
	p + effort_2006	0.22	0.23
	p + effort _2007	-0.78	3.60
	p + effort _2008	0.54	0.39
	p + effort _2009	1.43	0.54

3.4.3. Model averaged estimates

In all there were eight models in model set 1 with values above 0.01 and there were nine models with AIC *wt* above 0.01 in model set 2. (Table 3.3 & 3.4). The model averaged estimate coefficients value had a large SE (Appendix 3 & 4), which made the model average estimates uncertain.

3.5. DISCUSSION

3.5.1. Presence-absence surveys

Indirect evidences of TT presence can provide valuable information for occupancy surveys. During the year 2008 97 % of the presence of TT was inferred based on indirect evidences. In contrast indirect evidences were lowest during the year 2009, only 5 % of the presence was inferred based on indirect evidences. This also suggest that it occupancy surveys on TT cannot be based on sign surveys alone. Occupancy studies can serve as an effect tool for monitoring TT. However the man power and time need for such studies is extensive. The extensively monitored year 2008 (230 km) had an encounter rate (ER) of 0.004/km for TT and 0.16/km for indirect evidences. During the year 2006 a total of 224 km was sampled and the ER was 0.08/km for TT and 0.07/km for indirect evidences.

3.5.2. Detection probability

The top two models in model set 1 (detection probability model) the variables influencing detection probability was similar to that of the top two models in model set 2. The most influencing variable was abundance of water bodies and grass marshes. The comparative results of model set 1 and model set 2 emphases that irrespective of occupancy being constant or changing the variables influencing detection probability remains the same with top ranking models in the model sets (1 & 2).

Active searches carried out for TT in year 1991 yielded one tortoise every 6.7 man hours of search in the Anamalais (Bhupathy and Choudhury, 1995). In the same area in 2002 – 2003, yielded one tortoise in 3.4 man hours of search (Ramesh, 2008b). The present study yielded one tortoise in 17.0 man hours spent search for them. These findings clearly indicate that success of detecting TT in the Anamalais is varied. The factors that determined their detections or occurrence in an area was not known.

The visibility in areas with grass marshes and water bodies is higher than in forest interiors. Moreover the tracks and signs are easily identifiable in the grass marshes than in the forests. The overall probability of detecting TT during the study was 32 %, which means, that given the tortoise is present, only once in three times a tortoise was detected by the observers. Clearly, TT is cryptic and its presence in an area could be easily over looked. The detection probability of TT in the study area was influenced by number of water bodies and extent of grass marshes in both models sets I & II (Table 3.3 & Table 3.4). In all the models with AIC weights, the relative weight of models which contained water bodies were 88 % in model set 1 and 91 % in model set 2. The relative weights of the models which contained extent of grass marsh was 88 % in model set 1, and 83 % in model set 2.

The overall detection probability of TT was 0.3 in the year 2008 followed by 0.27 in 2007, 0.25 in 2006 and 0.20 in 2009. This heterogeneous detection probability which is governed by microhabitat choice and the idiosyncratic behaviour of individual tortoises. While the overall activity of the animal is probably governed by habitat mosaics and seasonality, individuals seem to have their own characteristic behaviour resulting in variation that cannot be solely explained by abiotic factors alone (see section in 5.5.3 in chapter 5). Another important factor that was not accounted for in this study was the quality for food or microhabitat availability for the TT. Variation in the quality of the food or the microhabitat could have also resulted in the heterogenous detection probability. Three rainforest tortoises belonging to the genus *Kinexys,* in Niger delta were traditionally venerated and subjected to subsistence hunting by locals (Luiselli, 2003). Hunting of TT could be one of the reasons why there were low detections in the study area, given that the reserve has a long history of human activity (Chandi, 2008).

3.5.3. Occupancy

Multi-season occupancy models can serve as an efficient tool for long term monitoring of species with very poor detection probability (MacKenzie *et al*., 2005). Among the two competing multi-season models that had $\Delta AIC \leq 2.0$, anthropogenic disturbance had negative influence on the occupancy of TT. The sites with highest disturbance level (5) had the lowest occupancy estimates 0.41 (SE = 0.17) in model 1 and 0.50 (SE = 0.21) in model 2. Where as the sites with no disturbance (0) had an estimate of 0.97 (SE = 0.17) in model 1 and 0.99 (0.03) in model 2.

In its distribution range in Western Ghats TT is so far reported only from locations below 1000 m a.s.l (Deepak and Vasudevan, 2010 and reference there in). The areas available for TT below 1000 m a.s.l in the two reserves (ATR & PTR) are 61% of the reserves total area. All the locations of TT from previous studies and the present study are so far known only from the western slopes of the mountains in the reserves (Bhupathy and Choudhury, 1995; Ramesh, 2008 a & b; Deepak and Vasudevan, 2010). The eastern slopes in the southern Western Ghats are drier than the western slopes. The vegetation type on the eastern slope is mostly scrub thorn forests, dry deciduous, riparian forests and dry savannah forest (Sekar and Ganeshan, 2003). The Indian Star tortoise (*Geochelone elegans*) is reported from the drier plains on the eastern side of the reserves, which is a typical scrubland dweller. The climatic condition and habitat type are not suitable for TT to occur on the eastern slopes of the reserves. The largest potential area available in the western slopes with vegetation types similar to which TT was previously recorded is 25.4 % (367 km^2). The Western Ghats is one of the hotspots with highest density of human population (Cincotta *et al*., 2000). The largest potential distribution range of TT 25.4 % (367 km^2) also holds twelve human settlements with a total population of 2066 people (Fig. 3.1 & Table 3.1). Hunting and consumption of the TT is documented in its entire range. In the Western Ghats locals belonging to the tribes *Kadar*, *Malai Pandaram, Kani*, *Malasar and Malaimalasar* hunt them using dogs or by following their tracks (Vijaya, 1983; Frazier, 1989; Moll, 1989; Bhupathy and Choudhury, 1995; Deepak and Vasudevan, 2010). In the current study area, hunting of TT was reported (Bhupathy and Choudhury, 1995; Chandi, 2008). In nine out of the 25 trails sampled during this study, domestic dogs along with local people and on one occasion with a tortoise in their possession. Elsewhere domestic dogs were more efficient in detecting tortoises in vegetation than human observers (Nussear *et al*., 2008).

3.5.4. Model averaging

The estimates of coefficient from the model averaging in this study were not significantly different from zero. The reason for these unreliable estimates could be because there are some models with over dispersion or the other models in the top ranking models had poor influence on the estimated parameter which may have influenced averaged estimates. Previous studies using multi season models have based their inferences based on top ranking models without model averaging (Buij *et al*., 2007).

3.5.5. Conservation implication

Indotestudo travancorica has been listed as Vulnerable on the IUCN Red List since 2000 (www.iucnredlist.org). It is included in Appendix II of CITES under Testudinidae spp. In India, it is protected under Schedule IV of the Indian Wildlife (Protection) Act (1972). TT occurs in 16 Protected Areas (PA's). Protection in these PA's has been carried out traditionally with the notion that the threats are external, it is surely not the case for TT. There is sufficient published information to suggest that TT's are hunted within the PA's. Removal of adults from the populations might affect the long term survival of the species. Species with slow rates of development and prolonged reproductively active periods are particularly sensitive to losses of mature, reproducing adults (Blasco *et al*., 1986 – 87; Hailey *et al*., 1988 and Lambert, 1982). Captive population of Travancore tortoise reveals that it takes approximately 11 years for an individual (International Species Information System (ISIS) # 10169) to reach a size of 163 mm (Nikhil Whitaker pers. comm.). Age or size at sexual maturity of Travancore tortoise is poorly documented in the past, the above mentioned captive individual female laid a miniature egg measuring 3 mm which is an indication of female sexual maturity. Previous workers necropsied TT in the wild one female measuring 192 mm had one oviductal egg in the right and left oviduct (Nikhil Whitaker pers. comm.). Carapace lengths of two necropsied males were 150 mm and 159 mm respectively and they had well developed testes (Nikhil Whitaker pers. comm.). A male having 160 mm SCL had a distinctly concave plastron and hooked tail claw (Ramesh 2008b) indicating probable size of male sexual maturity. Ensuring protection of TT populations at least in the protected areas by creating awareness among the protection staff and the local people is necessary. Removal of domestic dogs from PA's will also considerably reduce the threat of exploitation of the species. Only one percent (3.7 Km^2) of the potential area contains grass marshes (*Vayals*). These habitats requires area-specific protection and management since *vayals* provide an important foraging area for TT during the dry season and probably serve as refuge during forest ground fires.

CHAPTER 4

FEEDING ECOLOGY

4.1. Introduction

The diet of a species is key to its survival. An understanding of the diet of a species also provides information on the role it plays in the ecosystem. Numerous studies have attempted to identify factors that are important in the selection of diet (for review see, Pyke, 1984).

Most reptiles are carnivores but numerous turtles and lizards are at least partly herbivores and many species are known or suspected to play a role in seed dispersal (Braun and Brooks, 1987; Macdonald and Mushinsky, 1988; Moskovits and Bjorndal, 1990; Moll and Jansen, 1995 and reference therein; Mason *et al*., 1999; Strong and Fragoso, 2006). Few in-situ studies have been carried out on the diet of reptiles in the oriental region (Corlett, 1998). Tortoises such as, *Geochelone pardalis* (Milton, 1992; Van Zyl, 1966), *G. sulcata* (Cloudsley-Thompson, 1970), *Gopherus polyphemus* (Macdonald and Mushinsky, 1988), are herbivorous. Species such as *Kinixys spekii* (Hailey *et al*., 1998), are omnivorous and some species such as, *Geochelone carbonaria* and *G. denticulate* are frugivorous depending on the availability of food in their environment and intra and inter specific competition (Moskovits and Bjorndal, 1990).

Faecal remains analyses have been widely used to examine dietary components of tortoises (MacDonald and Mushinsky, 1988; Moskovits and Bjorndal, 1990; Mason *et al*., 1999; Hailey *et al*., 2001). The ranging pattern, foraging behaviour, population size and ecology of the Travancore tortoise (*Indotestudo travancorica*) living in a mosaic of habitat type in the tropical forest might be affected by the availability of the key nutrients. The diet of the Travancore tortoise (here after referred to as TT) mainly constitutes grass, bamboo shoots, herbs, fruits, insects, millipedes and frogs. This information on the free-ranging individuals is limited to brief notes based on anecdotal observations (Vijaya, 1983; Ramesh and Parthasarathy, 2006) and observations in captivity (Das, 1991). In this study, the diet of TT was quantified and described based on direct observations and analyses of faecal remains.

4.2. Methods

Faecal samples were collected to identify their diet content. All individuals captured were kept individually inside a large airy cotton cloth bag for about 12 h, during which they usually defecated. The feces of individual TTs were thus collected and dried under a 40 W incandescent lamp. The dried material was then examined using a 10X hand-held lens and separated into diet components of: grass, scorpions, molluscs, insects, millipedes, seeds, other plant materials (other than seeds) and sand. Animal hairs were identified using microscope Leica EZ4 (TM) at 35 x magnification, a mammal hair identification key was used to identify the hair (Bahuguna *et al*., 2010). Components of diet in individual faecal samples were scored as 1 – low, 2 – medium and 3 – high, based on the relative quantity of dried material found in each faecal sample. Whenever possible, direct observations were also made on the feeding of the tortoises. Ad-libitum observations were made by a single observer located 8-10 m away from the animal to avoid disturbing the animal. The plant or animal parts which were fed by the tortoise were collected and identified. Individuals below 160 mm SCL were considered as juveniles, males were differentiated from females based on the concavity in the plastron of the adult males. Females have a flat plastron.

The data was separated into plants and animals category diet and chi-square test for proportions (Gibbons, 1971) was used to test differences in the proportion of different diet categories in (i) Monsoon (June to November), Post monsoon (December to February) and summer (March-May) (ii) male, female and juvenile.

4.3. Results

Thirty two faecal samples were collected from 8 males, 15 females and 9 juveniles during the study. All faecal samples contained the remaining of at least one diet item. The diet item in the samples had more representation of plant matter: 90.6 % had grass and bamboo remains, 93.8 % had other plant materials (leaf remains, fiber and twig); 37.5 % had seeds; 75 % had insect remains; 62.5 % had sand; 21.9 % had vertebrate remains (hair, bones and scales); 18.8 % had mollusc; 9.1 % had crab and scorpion (*Heterometrus sp*) remains and 3.1 % had millipedes. There were some remains which were too small to identify and assign to any of the diet categories these were classified as "unidentified", 71.9 % had such remains. Millipede remains were found only in juvenile faecal samples and the rest of the diet item were represented in males, females and juveniles (Fig. 4.1A). However, the proportion of different plant and animal components in the diet of different sexes were not significantly different from each other (Table 4.1). Different plant remains (Grass, seeds & other plant matter) in the diet were found across all the season. All diet components, both plant and animal remains of different category were present in the samples during monsoon. The proportion of other plant matter in the diet was significantly different across season (Table 4.1). Proportion of grass and seeds were not significantly different across season. Scorpions, mollusc and millipede remains were not found in the samples during summer; Crabs and millipede remains were not found in samples collected during post monsoon (Fig. 4.1B). There was no significant difference in the animal matter represented in the samples across seasons. The seeds in the faecal samples were identified as *Grewia tilaefolia, Lantana camera*, *Dillenia pentagyna* and *Gomphandra sp.* Seeds were present in the samples collected from all the sex classes and the proportion of the seeds found in different sexes was not significantly different (Table 4.1). Seeds were represented across all the seasons and their proportion of occurrence in the samples was not significantly different across seasons (Table 4.1). Ten out of the 32 samples (37.5 %) contained seeds which indicate that considerable proportion of their diet contained fallen fruits. This emphasized their role as seed dispersers. Animal remains included scales of skink, hairs of a stripe necked mongoose (*Herpestes vitticollis*) and sambar deer (*Cervus unicolor*) and vertebrae of an unidentified species of rodent. Plant remains such as bamboo shoots were identified as *Bambusa arundinacea.* One occasion, an adult male and two juveniles were observed feeding on Basidiomycetes in the forest floor (Fig. 4.2). Twenty five direct observations on feeding of tortoises were recorded. In two different occasions, tortoises scavenged on carcasses (Fig. 4.3), a female tortoise was found scavenging on sambar carcass and one juvenile scavenging on a dead rodent. On two occasions, a male and a female were found feeding on *Mimosa pudica* (herb) and *Synedrella nudiflora* (shrub) both are exotics found in the study area. On seven occasions TT was found feeding on the grass (*Paspalum sp.*). Details on the date and time of different feeding observations made during the study are given in Table 4.2.

Figure 4.1. Mean score of different diet item in the 32 faecal samples of Travancore tortoise: (A) for different sex (B) and in three seasons in ATR and PTR from 2006-2009.

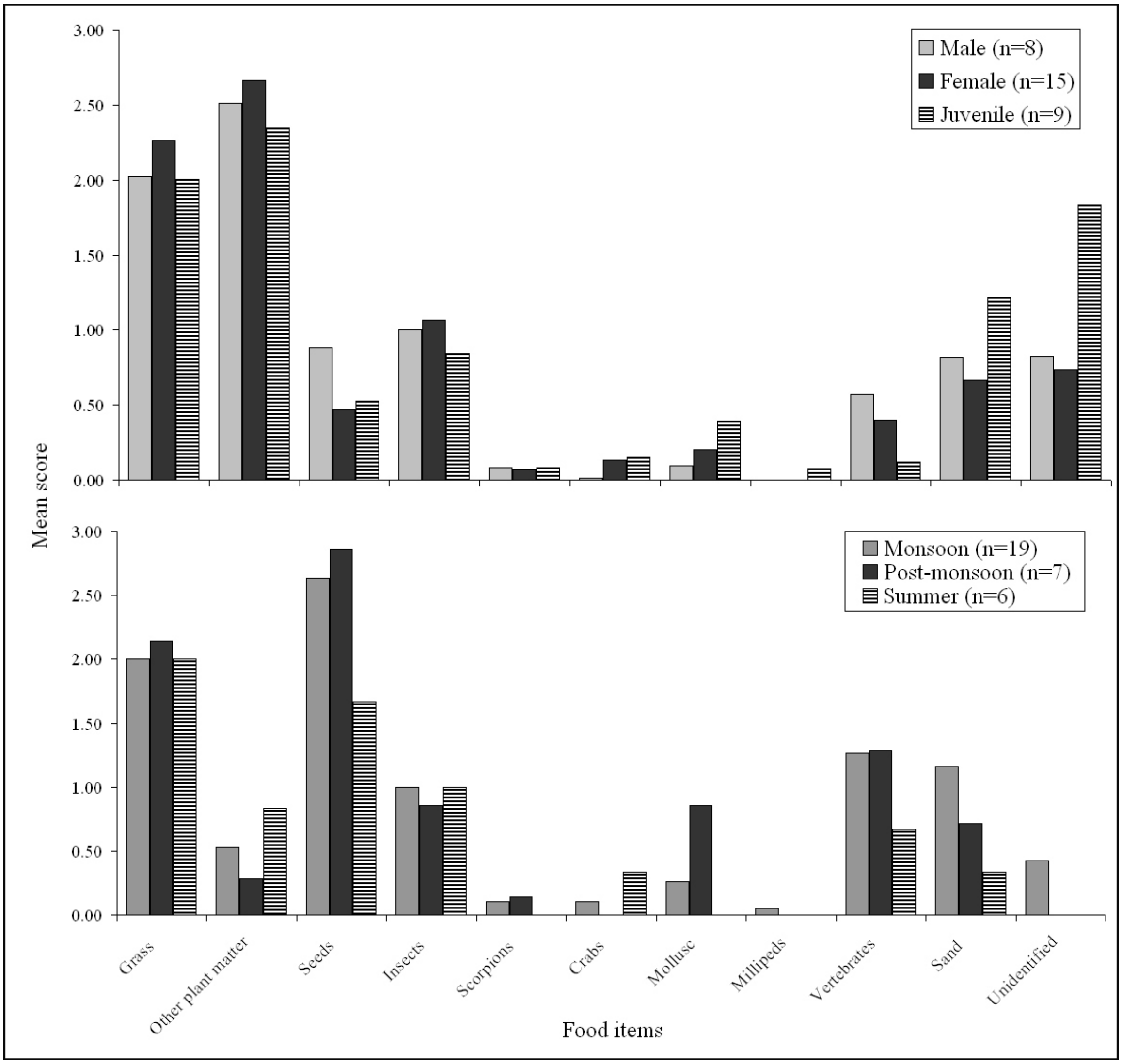


Table 4.1. Percentage composition of plant and animal components in the diet of Travancore tortoise of different sex classes and across seasons. (* $P < 0.05$).

Categories	Plant components in diet			Animal components in diet					
	Grass	Seeds	Plant matter	Insects	Scorpions	Crabs	Vertebrates	Millipedes	Molluscs
Sex									
Male % (n = 8)	24.10	33.30	23.30	25.00	33.30	0.00	28.60	0.00	0.00
Female %(n = 15)	48.30	50.00	50.00	54.20	33.30	66.70	57.10	0.00	50.00
Juvenile % (n=9)	27.60	16.70	26.70	20.80	33.30	33.30	14.30	100.0	50.00
χ^2 , df = 2	0.25	1.46	1.89	2.90	0.25	1.14	0.86	3.09	3.12
Season									
Monsoon% (n =19)	58.60	66.70	63.33	62.50	66.67	66.67	57.14	100.0	100.0
Post-monsoon%(n = 7)	24.14	16.67	23.33	20.83	33.33	0.00	42.86	0.00	0.00
Summer% (n = 6)	17.24	16.67	13.33	16.67	0.00	33.33	0.00	0.00	0.00
χ^2 , df = 2	1.12	0.45	9.24*	0.43	0.85	1.55	3.49	0.71	5.05

Figure 4.2. Juvenile Travancore tortoise found feeding on fungi on 12th October 2009 (17.11 h) in Orukomban range of Parambikulam Tiger Reserve.

4.4. Discussion

Plant matter constituted 45 % of the total diet, which indicated that they are primarily herbivores (Fig. 4.1A). Twenty nine out of the 32 faecal samples contained grass blades and bamboo shoots and 30 out of the 32 faecal samples had other plant remains. TT is known to feed on herbaceous plants such as *Synedrella nudiflora, Desmodium repandum, Senecio scandens,* and *Veronica buabaumii* (Ramesh and Parthasarathy, 2006). The fecal remains of plant matter in males, females and juveniles were not significantly different (Table 4.1).

Figure 4.3. Female # 5 scavenging on a sambar carcass in Kothala, PTR on 23rd December 2006.

Table 4.2. List of the direct observations on feeding tortoises. J = Juvenile and H = hatchling from 2006 to 2009 in ATR & PTR.

S. no	Date	Time (hr.min	Location	Sex & ID	Feeding
1	08.03.06	18.45	Pandaravarai	♂ 1	feeding on *Paspalum sp*
2	18.04.06	17.00	Varagaliar	♂ 4	feeding on *Paspalum sp*
3	30.04.06	18.10	Sichali	♀ 1	feeding on *Paspalum sp*
4	21.05.06	17.45	Orukomban	♂ 5	feeding on fruits of *Dillenia pentagyna*
5	02.06.06	18.00	Sichali	♂ 6	feeding on *Paspalum sp*
6	02.06.06	18.00	Sichali	♀ 2	feeding on herb climber (unidentified)
7	30.06.06	17.10	Sichali	♂ 7	feeding on grass (unidentified)
8	03.08.06	17.25	Kothala	♀ 7	feeding on herb climber (unidentified)
9	18.08.06	17.00	Topslip	♂ 10	feeding on *Paspalum sp*
10	24.11.06	17.45	Karian shola	♂ 12	feeding on *Mimosa pudica*
11	09.12.06	18.15	Varagaliar	J # 2	feeding on *Paspalum sp*
12	13.12.06	17.52	Orukomban	♀ 11	feeding on *Paspalum sp*
13	23.12.06	18.30	Kothala	♀ 5	feeding on sambar carcass
14	29.01.07	18.00	Mandhrimed	♀ 12	feeding on *Synedrella nudiflora*
15	30.01.07	17.45	Manamboli	J # 4	feeding on rodent carcass
16	13.06.07	18.10	Karian shola	♂ 8	feeding on grass (unidentified)
17	07.05.08	17.16	Karian shola	♂ 12	feeding on *Strobilanthus sp*
18	14.12.08	17.30	Orukomban	♂ 16	feeding on grass (unidentified)
19	13.06.09	18.00	Karian shola	J # 9	feeding on grass (unidentified)
20	07.07.09	17.00	Topslip	♂ 17	feeding on grass (unidentified)
21	09.07.09	17.15	Erumapara	♂ 18	feeding on grass (unidentified)
22	10.07.09	17.30	Anaikundhi	H # 1	feeding on grass (unidentified)
23	12.10.09	17.10	Orukomban	♂ 22	feeding on Basidiomycetes (unidentified)
24	12.10.09	17.11	Orukomban	J # 11	feeding on Basidiomycetes (unidentified)
25	12.10.09	17.50	Orukomban	J # 12	feeding on Basidiomycetes (unidentified)

Plant matter was significantly different across seasons and the proportion of other plant matter remains during summer was considerably less (Table 4.1). This might be due to lesser availability of other plant matter during the summer than in other seasons or due to less intake, or both. However this needs further studies to confirm with more samples collected across season and sexes.

Travancore tortoises are known to feed on fallen fruits of *Artocarpus spp, Dillenia pentagyna* and *Ficus virens* (Vijaya, 1983; Ramesh and Parthasarathy, 2006). Fallen fruits also appear to be a major food item of tortoises in the Oriental region including *Indotestudo elongata* and species belonging to genus Manouria and Geochelone (Ernst and Barbour, 1989). *Indotestudo elongata* are known to feed on fruits of *Dillenia* spp, *Ficus racemosa, Cyanotis cristata* (van Dijk, 1998).

Invertebrates are an important part of diet in the African tortoise *Kiniyxs spekii* in Zimbabwe (Hailey *et al*., 2001) and invertebrates eaten were mostly slow moving (millipedes and beetles), which was expected considering the slow movement of terrestrial chelonians (Klimstra and Newsome, 1960). Twenty six out of the thirty two faecal samples examined (16.5%) contained invertebrate remains including millipedes, insects, mollusc, scorpion and crab. Faecal samples of *I. elongata* from Thailand had mollusc, crab, insect, maggot and spider remains (van Dijk, 1998). In captivity TT feed on animals such as frogs, insects and millipedes (Das, 1991, 1995). Three independent observations on them scavenging on carcasses and seven out of the thirty two faecal samples contained vertebrate remains (4.4%). Overall 28% of the faecal samples examined contained animal matter which show considerable consumption of animal matter by the TT (Fig. 4.1). However, the score of animal matter were lower than that of plant matter (Fig. 4.1A). The proportions of animal matters were not significantly different for different age-sex classes and they were not different across seasons (Table 4.1). The tortoises probably consume more or less equal proportion of animal matter irrespective of the age-sex class they belong to and the season during which they forage.

Animal matter provides additional source of high quality protein, calcium and high sodium potassium for tortoise diet (Hailey *et al*., 1998; Manson *et al*., 1999; Hailey *et al*., 2001). Animal matter has been previously reported in the diet of some herbivorous and frugivorous tortoises such as, *Geochelone paradalis* (Van Zyl, 1966; Milton, 1992), *G. sulcata* (Cloudsey-Thompson, 1970), *Gopherus polyphemus* (MacDonald and Mushinsky, 1988) *Geochelone denticulata* and *G. carbonaria* (Moskovits, 1985; Moskovits and Bjorndal, 1990), *I. elongata* (van Dijk, 1998).

All species of the Genus *Kinixys* (*K. erosa, K. homeana, K. lobatsiana, K. spekii, K. belliana and K. natalensis*) are reported to feed on fungi and/or invertebrates (Villiers, 1958; Blackwell, 1968; Bertram, 1979; Branch, 1988; Lambiris *et al*., 1989; Broadley, 1989 &1993; Hailey *et al*., 1997). One species of desert tortoise (*Gopherus agassizii*) fed on fungi (Hansen *et al*., 1976). Two species of the Amazonian tortoises *Geochelone carbonaria* and *G. denticulata* are known to feed on fungi (Moskovits and Bjorndal, 1990). *I. elongata* is often found feeding on mushrooms in bamboo forests of central Rakhine (Arakan) state in Myanmar (Platt *et al*., 2007). van Dijk, (1998) reported *I. elongata* feeding on two species of mushroom *Termitomyces sp* and *Russula sp* from

Thailand. Hailey et al (1997) suggested that consumption of fungi and arthropods by *K. spekii* shows their ability to digest chitin and the cell walls of Basidiomycetes. Our observations on Travancore tortoises revealed that they feed on mushroom (Table 4.2). The Basidiomycetes in the forest floor were ephemeral and patchily distributed in the study area (Fig. 4.2).

Sand and small stones were reported from the diet of many species of tortoises (Sokol, 1971, Moskovits and Bjorndal, 1990; van Dijk, (1998)). The presence of sand in fecal samples might be due to accidental ingestion or consumption to aid in digestions. Sand might be important abrasive agent enhancing digestion of fibrous plant material (Sokol, 1971; Luckenbach, 1982; Marlow and Tollestrup, 1982), which constitutes an important part of the diet of TT.

CHAPTER 5

HOME RANGE, MOVEMENT AND MICROHABITAT USE

5.1. Introduction

Travancore tortoise is one of the few tropical forest dwelling tortoises in Asia. It is an endemic to Western Ghats of south India (Iverson *et al*., 2001), is reported from a variety of vegetation types such as evergreen, moist deciduous, bamboo forest, semi evergreen forests, rubber and teak plantation. They are omnivorous and fed on grass and herbs. Their diet also consists considerable amount of animal matter which includes insects, scorpions, crabs and mammal carcasses. There are very few studies are available on the ecology of the species.

Among terrestrial animals the use of two-dimensional surfaces is strongly related to body size and it has been an important measure in understanding the ecology of species (McNab, 1963; Witting, 1995; Blackburn and Gaston, 1997; Jetz *et al*., 2004). The aerographic area used by animals and its relationship with population density and home range size were the focus of many. The use of space by an animal involves a combination of intrinsic factors such as, physiology and morphology and extrinsic factors such as, environment, distribution of food resources, inter and intra specific competition, and interaction with predators.

Behavioural thermoregulation includes restriction of activity periods and microhabitat selection (Huey, 1982; Minnich, 1982; Heatwole and Taylor, 1987). Behavioural and ecological studies on terrestrial ectotherms have emphasized the limits imposed by ectothemy by focusing on small bodied ectotherms, or ones that inhabits arid environments. Few large terrestrial Testudinids that have been well studied, live in desert or in scrub habitats. e.g., *Gopherus spp* in North America (Bury, 1982); *Geochelone gigantia* in Albadra (Swingland and Frazier, 1979). These habitats have extreme temperatures and unpredictable food resources, which in turn favour behavioural adaptations in tortoises. They show daily and/or seasonal activity patterns in such extreme environmental conditions (e.g. Auffenberg and Weaver, 1969; McGinnis and Vogit, 1971; Swingland and Frazier, 1979; MacRae *et al*., 1981). *Gopherus agassizii,* retreats into underground burrows in order to seek refuge from lethal surface temperatures (Brattstrom, 1965; Voigt, 1975; Ruby *et al*., 1994; Zimmerman *et al*., 1994). Recent studies on the *Kinixys erosa* and *Kinixys homeana* from tropical Africa, has shown that these tortoises perform behavioural thermoregulation (Luiselli, 2005). In order to avoid overheating temperatures, they seek refuge in forest habitats (Luiselli, 2005).

Different methods have been proposed for the estimation of home-range size and shape. A widely used method is the Minimum Convex Polygon (MCP; Mohr, 1947 cited in Harris *et al*., 1990). The MCP is a polygon that includes all locations where all vertices are convex. It has the advantage of being simple measure, and because it has been in use for a long time, it allows comparisons with findings from previous studies (Harris *et al*., 1990). However, several studies have concluded that this method overestimates the area animals used and is strongly influenced by outliers (i.e. locations reflecting excursions;

e.g. Worton, 1995a). Because of these reasons, kernel estimators became increasingly popular (Worton, 1989, Seaman and Powell, 1996; Marzluff *et al*., 2004). Kernel home-ranges are estimated in the form of probability distributions arrived based on the locations within a home range. Each location is assumed to have an area of influence in the form of a bivariate normal kernel. The extent of this area is constrained by a smoothing parameter (h). It can have profound effect on the estimates and there has been considerable debate on its measurements (see: Seaman and Powell, 1996). These debates promoted researchers to subjectively assess the value of 'h' (Silverman, 1986; Pope *et al*., 2004). Recently, the non-parametric Local Convex Hull (LCH), method was shown to be more appropriate than parametric kernel methods in construction of home ranges and area utilization distributions, because of its ability to identify hard boundaries (e.g., rivers, cliff edges) (Getz and Wilmers, 2004; Getz *et al*., 2007). Further the values converge to the true utilization distribution as the sample size increases (Getz *et al*., 2007). In contrast to the above mentioned methods, the Brownian bridge (BB) method (Bullard, 1991), makes use of spatial & temporal autocorrelation (i.e. data in which the time, and the distance travelled between successive points are correlated) to determine movement paths, home ranges and migratory routes of animals.

Species distribution data exhibit spatial autocorrelation, i.e. locations close to each other cannot be considered as spatially independent locations. If this pattern exists in the raw data, any further statistical analysis would increase type I errors (falsely rejecting the null hypothesis). In order to overcome this, various statistical methods have been developed to incorporate spatial autocorrelation in the analysis (Dormann *et al*., 2007). Spatial autocorrelation analysis of species distributional data has advanced with a number of different methods. The type of error distribution in the response variable is an important criterion for choosing these methods (Dormann *et al*., 2007). For normally distributed data, Generalised Least Squares (GLS), Simultaneous Autoregressive Models (SAR) and Conditional Autoregressive Models (CAR) could be used (Dorman *et al*., 2007). The most flexible methods that addresses spatial autocorrelation for different error distributions are spatial Generalized Linear Mixed Models (GLMM), Generalized Estimation Equations (GEE), Spatial Eigenvector Mapping (SEVM) and logistic regression with autocovariate function (Dormann *et al*., 2007).

Similar to spatial dependence ecological data are often temporally correlated (Stevens and Pearson, 2000). Statistical analyses developed for independent data were frequently used on ecological data in the past (Stevens and Pearson, 2000). This had led to inefficient parameter estimators, biased hypothesis tests, and inaccurate predictions (see review in Stevens and Pearson, 2000). Temporally dependent data are often modeled with Autoregressive Integrated Moving Average (ARIMA) models (Stevens and Pearson, 2000). A variety of response variables violate the standard assumptions, thereby making the data unsuitable for statistical analysis. Generalized Linear Models (GLMs) are considered robust at dealing this kind of data set with variables that do not fit to the assumption of constant variance or normal distribution (Crawley, 2007).

This chapter addresses the third objective of this study: Quantify activity, habitat use and ranging pattern of the TT. Addressing three main questions: (1) What is the home range of TT? (2) What microhabitat or topographic variable influence spatial movement in TT? (3) What influences the temporal activity of TT? (4) Are there threshold responses for variation in temperature and rainfall? (5) Do they perform behavioural thermoregulation?

5.2. Study area

The study was carried out in Karian shola National Park, Anamalai Tiger Reserve and adjoining areas of Karian shola in Parambikulam Tiger Reserves of Tamil Nadu and Kerala States. The habitat type is southern tropical wet evergreen forest *Dipterocarpus bourdilloni – Strombosia ceylanica* type (Champion and Seth 1968; Pascal *et al*., 2004). Until 1944 timber extraction was continued in ATR part of Karian shola, large hardwood trees like *Hopea sp* and *Syzigium sp* were extracted (Wilson, 1973). The tree density for karian shola is 755 individuals per hectare and the canopy height is 27 m ± 0.7 SE (Mudappa *et al*., 2007). The areas adjoining the perennial stream are bamboo dominated habitat with bamboo (*Bambusa arundinacea*) as the canopy, associated with *Lantana camera* and climbers in the understory and grass-herbs on the ground. The bamboo dominated habitat will be hereafter referred as "bamboo-lantana-grass (BLG)" habitat. The Karian shola also has rocky outcrops on the hill tops and stream sides. The surrounding areas of Karian shola include teak plantations, eucalyptus plantation and bamboo forest. Trees found in the study area are, *Ficus* spp., *Vitex altissima, Diospyros microphylla, Canarium strictum, Palaquium ellipticum, Bischofia javanica, Knema attunuata, Myristica malabarica, Polyalthia sp., Vateria indica, Cinnamomum* spp*, Artocarpus* spp, *Litsea sp.* A variety of mammals are found in Karian shola, including the brown plam civet (*Paradoxurus jerdoni*), brown mongoose (*Herpestes fuscus*), small indian civet (*Viverricula indica*), leopard cat (*Prionailurus bengalensis*), dhole (*Cuon alpinus*), Asian elephant (*Elephas maximus*), Indian giant flying squirrel (*Petaurista philippensis*), leopard (*Panthera pardus*) and tiger (*Panthera tigris*). Notable bird species include the great hornbill (*Buceros bicornis*), Ceylon frog mouth (*Batrachostomus monilger*), Malabar grey hornbill (*Ocyceros griseus*) and brown fish owl (*Bubo zeylonensis*). Karian shola serves as an important breeding site for the great hornbill (Kannan and James, 1999), the Malabar grey hornbill (Mudappa, 2000), migratory danaines butterflies (Kunte, 2005), the purple frog (*Nasikabatrachus sahyadrensis*; Raj *et al*., 2011) and various other undocumented endemic fauna of the Anamalai hills. The Cochin forest cane turtle (*Vijayachelys silvatica*) and Indian black pond turtle (*Melanochelys trijuga*) are the other two turtle species found in this area.

5.3. Methods

5.3.1. Radio-telemetry

An 110 ha study area was mapped into 100 x 100 m two dimensional grids using a clinometer (Suunto, Tandem) compass and measuring tape (Fig.5.1.). The use of Geographical Positioning System (GPS) in the forest with canopy cover > 95 % might have lead to erroneous coordinates. In order to avoid the error mapping was done manually using rope, clinometer and compass. Further the tortoises moved a minimum distances of 0.5 m which could not have been captured using the GPS. The elevation within the mapped area ranged between 728-785 m a.s.l. There are two perennial streams where the water flow reduced during April and May (Fig.5.1.). The grids sampled in the evergreen forest had a mean canopy cover of 91 % (1.6 S.E) and the grids covering bamboo-lantana-grass and the edges between these two habitats had 78.2% (3.2 S.E). Eleven percent (12.1 ha) of the total 110 ha study area was covered with BLG habitat.

Transmitters were attached on the tortoises using the Boarman et al (1998) protocol. Epoxy adhesive Hysol E-120 HP (Loctite Corp, U.S.A) was used to attach the transmitter on the carapace of the tortoise (Fig. 5.2). Five individuals (2 males and 3 females) of Travancore tortoise (TT) were attached with transmitters. The transmitters had a waterproof sleeved antenna (G3 type), and weighed 25-27 g (AVM instruments Co, California, U.S.A). Measurements (Straight Carapace Length in mm) of the radio tracked tortoises were as follows: ♂ 1 - 216 mm, ♂ 2 - 214 mm SCL, ♀ 1 - 179 mm SCL, ♀ 2 - 175 mm and ♀ 3- 262 mm. The expected life of the transmitter was 833 days, however the actual life of the transmitters during the study ranged from 15 days to 641 days (Table 5.1). The tortoises were located using portable radio telemetry receiver (Model: LA 12Q) and hand held collapsible Yagi antenna (AVM instrument Co, California, U.S.A). At least one location collected for each individual everyday from the corner of the permanently marked 100 x 100 grids. The locations were measured with accuracy approximating to 0.1 m.

5.3.2. Home range

Home range sizes were estimated using 100 % minimum convex polygon (MCP) and 95 % fixed Kernel with Least Square Cross Validation (LSCV) methods and the smoothing factor "h" was calculated in Program R with “adehabitat” package (Calange, 2006). Fixed Kernel showed the density of the data points including occasional outliers.

Figure 5.1. Map of physical features of the intensive study area using 100 x 100m grids. Elevation in meters.

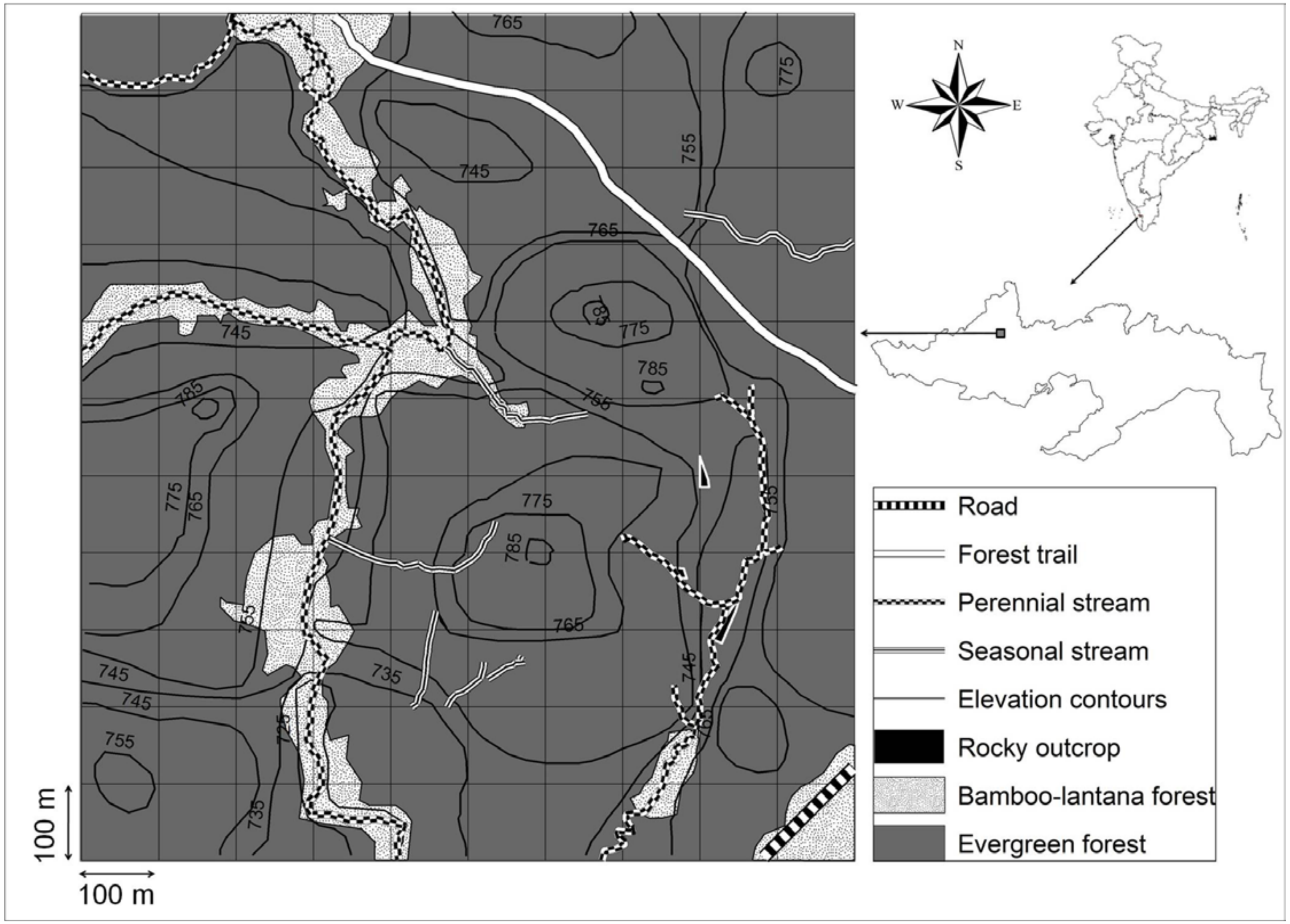


Table 5.1. Details of radio transmitter life on the five radio tracked tortoises.

S.No	Date (DD.M.YY) of attaching transmitter	Date (DD.M.YY) of detachment / failure	No of days	Individual ID & sex	Battery life
1	10.5.08	22.2.10 – detached	641	♂ 1	833
2	13.2.08	4.8.09 – detached	476	♀ 1	833
3	7.8.08	1.3.10 – detached	570	♀ 1	833
4	17.4.08	26.6.08 – failed & lost	71	♀ 2	833
5	2.6.08	16.6.08 – failed & lost	15	♀ 3	833
6	24.11.08	21.3.09 – failed & lost	118	♂ 2	833

Figure 5.2. Travancore tortoise (♂ 1) attached with a G3 type radio transmitter and a temperature data logger.

The LCH method was not appropriate for this data because all individuals had occasional outliers away from a cluster of locations. LCH method requires at least three locations in order to create an isopleth, which was not observed because, the tortoises had occasional outliers. MCP home range overlap between individuals was calculated using R overlap scripts provided in Huck et al (2008). MCP home ranges were calculated for every 20 locations for all the individuals and the values were plotted. This gives an idea about the minimum number of locations and effort required to estimate TT home range. The MCP layers were overlaid on the BLG habitat and clipped in ArcMap v9.2 GIS software package (ESRI Inc, Redlands, CA). From the clipped layer, the total area of bamboo-lantana-grass habitat inside home ranges of each individual tortoise was derived.

5.3.3. Spatial movement pattern

The study area was divided into one hundred and ten 100 x 100 grids, the corners of each grids were permanently marked with paint on trees or on rock. The 100 x 100 m grids were decided based on the feasibility of marking precise individual TT locations during the study period. The grid size (100 x 100 m) covered was 100 % of the smallest and 10 % of the largest kernel home range of the radio tracked tortoises. The grid size was decided based on two factors: (i) the smallest home range (1 ha) of the four radio tracked tortoises was roughly the size of the grid size; the tortoises also spent a maximum of 106 days continuously in a grid. (ii) the optimal number of grids for logistic regression analysis; if the grid size is large there is a greater chance of presence than absence to be recorded in each grids and if it is small there will be greater chance of absence in the grids than presence given that animals tend to move non-randomly. This could have resulted in a zero inflated data set.

The locations of the radio tracked tortoises as well as other individual tortoises found while sampling were used for the purpose of the analyses. First a 95 % kernel (home range) contour was created to delineate the probability of 100 x 100 m grids occupied by individual tortoises. Least Square Cross Validation (LSCV) method was used to calculate the kernel contours in Arcview v3.2 GIS software package (ESRI Inc, Redlands, CA). The other individual locations were plotted on a map. The grids that were occupied by the kernel contour or the non radio tracked individuals locations were assigned a value of ‘1’ the rest were assigned a value of "0". Nine grids that were not sampled frequently and were all zeros, they were removed from the analysis to avoid false absence.

Microhabitat variables were collected in four 20 x 20 m quadrats in every 100 x 100 m girds within the 110 ha intensive study area. The 20 x 20 m quadrats were placed 10 m away from the center of the 100 x 100 m grid in four perpendicular directions. Nine microhabitat and habitat variables were measured: percentage of leaf litter cover was recorded by occular scoring in four 10 x 10 m quadrats within the 20 x 20 quadrats; number of lianas, trees with buttress, fallen logs (above 250 mm width), small (>0.5m), medium (0.5 x 0.5 m) and large rocks (1 x 1 m) were counted in the quadrat. The weighted average of the size classes of rocks was used for the analysis. Canopy cover was measured using a convex canopy densiometer by taking an average of four reading in each quadrat. Distance to water and distance to the edge between BLG habitat and evergreen habitat was measured from the center of the grid. The elevation in one corner of the grid was taken with GPS with 15 m accuracy based on this point and from the clinometer readings taken at every 20 m was used to calculate the elevations in each grid. Then the coefficient of variation in the elevation (in meters) of each grid was calculated and included as one of the variable.

The microhabitat variables where checked for correlation and multi-collinearity using Variance Inflation Factor (VIF) in statistical package R (R Development Core Team, 2007). Variance inflation factor and tolerance are both widely used measures of the degree of multi-collinearity of the i^{th} independent variable in a regression model (O'Brien, 2007). However, there is no threshold value for VIF (O'Brien, 2007). When VIF values are high, researchers often reduce the multi-collinearity by eliminating one or more variables from their analysis or using Ridge Regression or combining two or more independent variables into a single variable (for review see O'Brien, 2007). An arbitrary threshold level of 5 for VIF has been used to measure multi-collinearity (Heiberger and Burt, 2004) and it was used in this study. A correlation matrix was created and variables were tested with Pearson's correlation test. Those variables which were correlated with more than one variable were removed before performing the logistic regression analysis.

Various methods have been used in spatial autocorrelation analysis of species distributional data (Dormann *et al*., 2007). Methods such as Generalised Estimation Equations (GEE) require large sample size in space which was not available in the data used in this study. Generalised Linear Mixed Model (GLMM) is flexible with the error structure of the response variable. The response variable in the data set from this study did not have any specific error structure. The direct coding of the raw data into binomial data yielded in many unoccupied grids. This was probably not true because neighboring grids might have been used during the course of movement from one grid to another. Hence, a 95 % probability kernel contour was created around the data points of radio-tracked individuals. The coded data which was binomial and the predictor variables which were both linear and discrete were used to perform logistic regression and autologistic regression.

An autologistic model takes into account spatial autocorrelation by including an autocovariate function (Augustin *et al*., 1996; Dormann, 2007). In the program Spatial Analysis in Macroecology (SAM) this was computed based on as equation 1 (Rangel *et al*., 2006)

$$Y = \rho WY$$

(Equation 1)

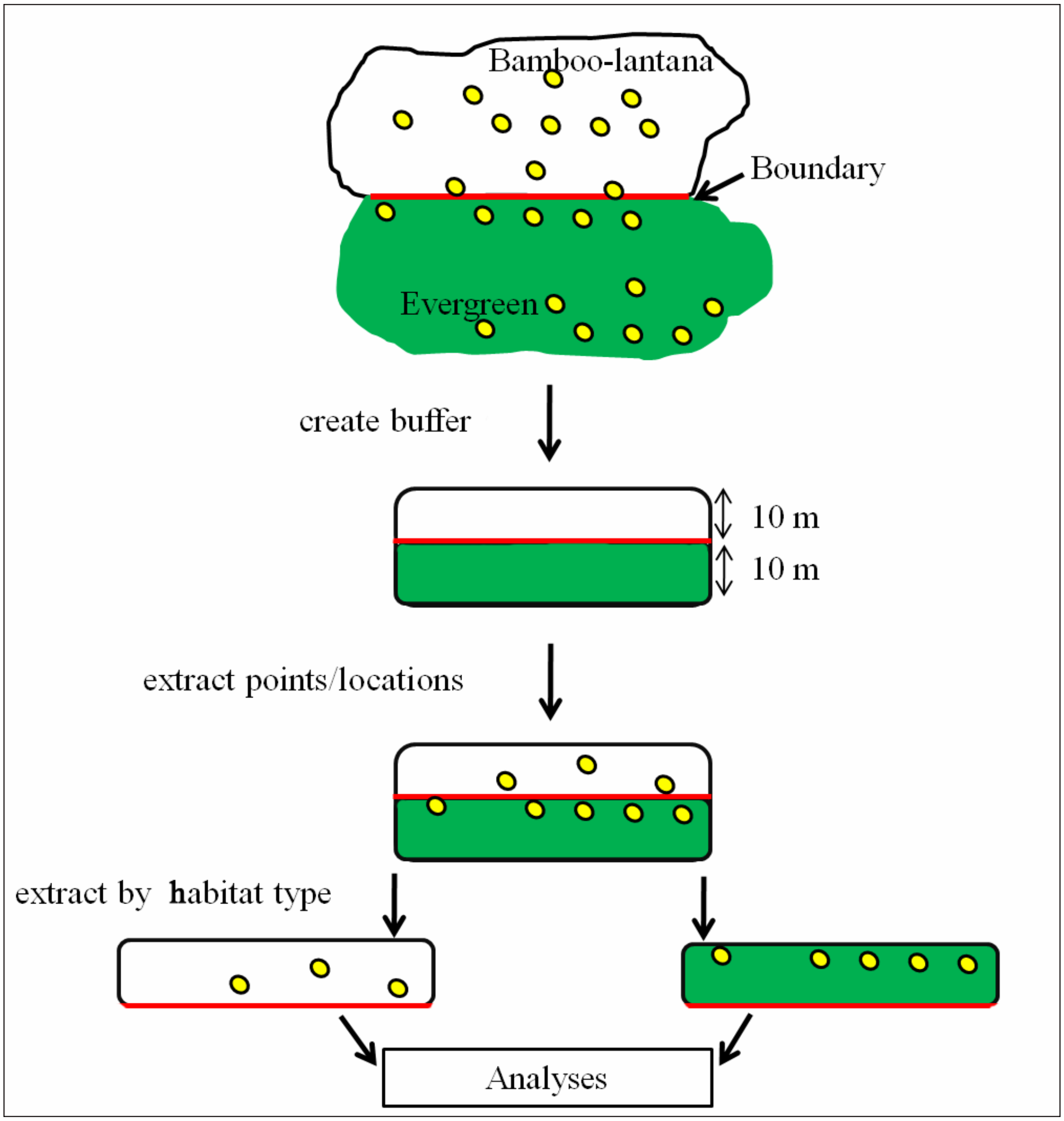
Where W is the spatial relationship matrix, Y is the 0-1 vector, ρ is the autoregressive function. The logistic and autologistic model analysis for TT spatial use was done using the Program SAM (Rangel *et al*., 2006). The tolerance value was set to default 0.75 and the autologistic model was set to alpha(α) equal to 1. "α" is an additional parameter that regulates the relationship among spatial units and that usually improves the performance of the model (Davis, 1986 cited in Rangel *et al*., 2006). During the analysis various α values from 0.1-1 was tried and α value "1" performed better than the others. Three logistic regression models were built to analyze the spatial data and the model selection was based on the lowest AIC values. Chi-square or goodness of fit test is carried out in SAM. The likelihood ratio test of a model tests the differences between -2logliklihood for the full model (model which includes all the explanatory variables) and -2 logliklihood for initial chi-square in the null model. This is also called the model chi-square test. The null model, also called the initial model, is logit (p) = the constant. The parsimonious model is tested for difference from the constant only model.

Because the intensive study had a mosaic of habitat types and there were distinct edges, it was necessary to quantify the use of these areas by TT. The intensity of habitat use by the tortoises within the BLG and the evergreen habitats and their edges was explored using GIS tools. All individual locations were pooled and plotted saved as point shapefile. A buffer was created around the boundary of the BLG and the evergreen habitat. The process was repeated with buffers of up to 100 m at every 10 m interval. In case of the BLG habitat, the buffers were up to 50 m, which was the maximum available distance from either side of the boundary considering the fact that these habitats were linear along stream courses. A pictorial flow chart of the data processing is given in Fig. 5.3.

5.3.4. Temporal activity pattern

Five temperature loggers (BoxCar Pro 4.3 Onset Computer Corporation, Bourne, MA) were programmed to collect temperature in ^{o}C at intervals of one hour. The loggers were attached on the carapace of the radio tracked tortoises using epoxy adhesive Hysol E-120 HP (Loctite Corp, U.S.A). Rainfall in the study area was measured to the nearest mm using a rain gauge located 800 m away from the centre of the study area. Straight line distances were calculated between two successive locations of radio tagged TT. There were thirty missing data points due to transmitter failure of TT went missing on certain days or when the temperature loggers were damaged. Because of these scattered missing data points, the data set used for the temporal activity data analyses was not continuous. The tracking data was coded into 1/0 (active or inactive) to fit it in a binomial model. Generalized linear model (GLM) with binomial errors and logit link was used to find out the abiotic factors influencing activity of the radio tagged TTs.

Figure 5.3. Flow chart depicting the steps followed for extract of information on the intensity of the habitat used by Travancore tortoises in ATR during 2006 and 2009.



The data set for all individuals pooled, ♀ 1 and ♂ 1 which yielded data for two years, ♀2 had data only from monsoon and summer and ♂ 2 had data sufficient data only for summer. In order to investigate influence of season and environmental variable on overall activity of all individuals pooled ♀ 1 and ♂ 1, Pearson's correlation was performed to check for the relationship between minimum and maximum temperature readings. The distinct season in the intensive study area were; monsoon, post monsoon and summer. They were coded as categorical variable in the analyses. The global model was fitted for this data set was allowed to have an interaction between rainfall and temperature and the seasons was kept separate without interaction in the model.

Model selection was based on Akiake Information Criterion (AIC), the model with the lowest AIC value is considered as the most parsimonious model. A global model (combination of interaction of all predictor variables) was built and the step AIC function in Program R was used to tease out the best model with the lowest AIC values (Crawley, 2007).

Once the most parsiomonious model was identified it is mandatory that overdispersion is addressed (Crawley, 2007). In order to check for overdispersion the residual scaled deviance should be roughly equal to the residual degrees of freedom (Crawley, 2007). It is checked by dividing the residual deviance by the residual degrees of freedom (Crawley, 2007). The days when the turtles spent inside the burrows or tree hollows where not incorporated in the GLM, this data was analyzed separately. The number of days individual tortoises was active were separated based on months and seasons to check if they follow any pattern in being active. The percent activity of TTs within each season was tested using a Chi-square test for proportions (Gibbons, 1971).

5.3.5. Microhabitat used

Microhabitat used by four radio tracked tortoises was recorded every time the animal was located in field between 6.00 h to 19.00 h. Microhabitats were broadly classified into nine different categories viz: buried under grass, buried in leaf litter, under fallen log, inside tree hole, inside rock, inside bamboo thicket, inside *Lantana* bush, inside pangolin/termite burrow and open forest floor. Percentage use of each microhabitat category was tabulated. The use of burrow by individual tortoises were analyzed separately to find if they have any preference in temperature and if burrows served as refuges during extreme thermal conditions.

Equal number of minimum and maximum temperatures on days when an individual was inside the burrows was selected randomly. A random set of 15 days before and after an individual entered a burrow was selected. A one-tailed paired-sample t-test was used to test their differences in their thermal preference when using burrow and when outside the burrow.

5.4. Results

5.4.1. Radio-telemetry

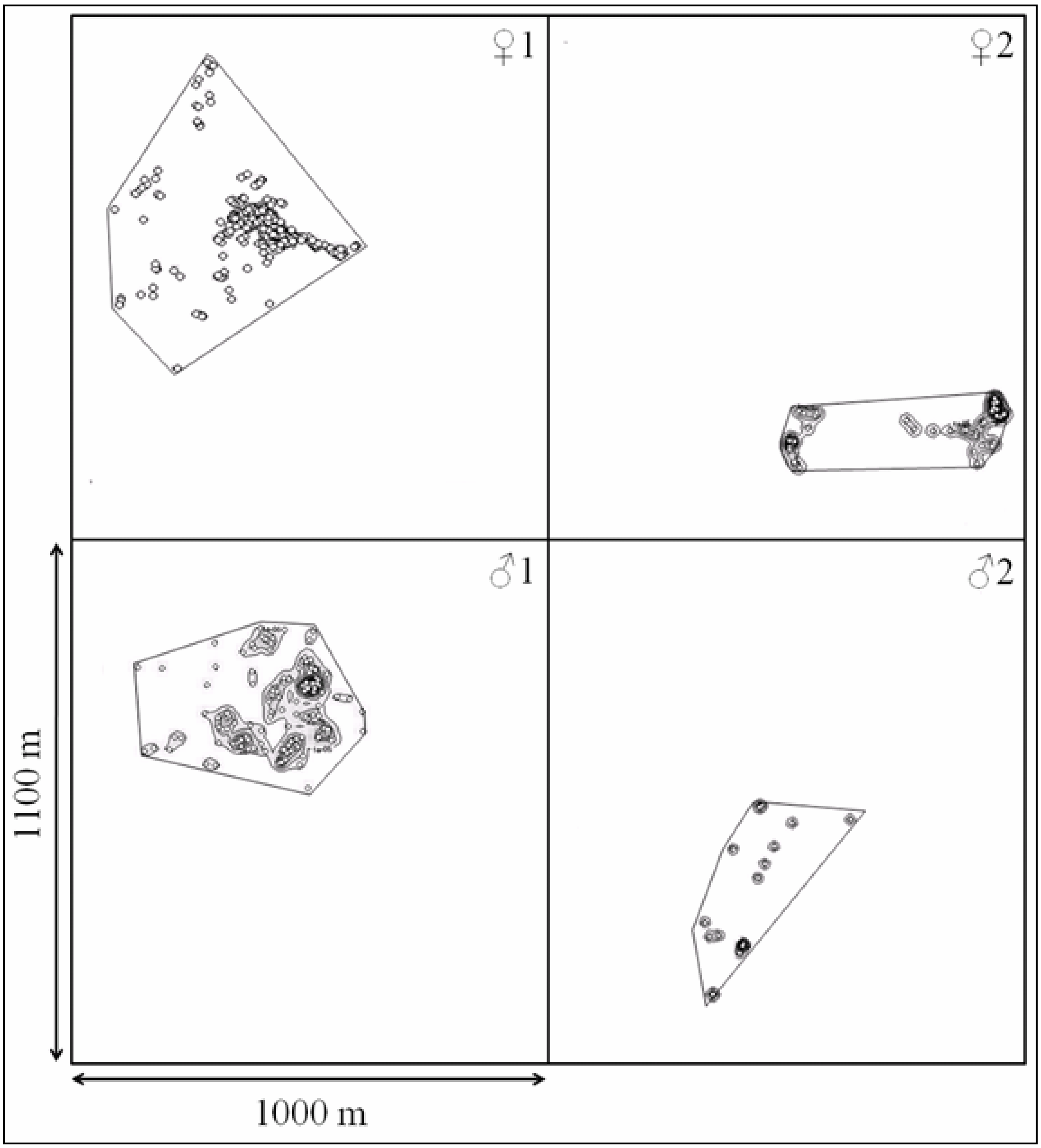
Five individual tortoises (2 ♂ & 3 ♀) were fitted with radio transmitters and tracked on a daily basis. Although five of them were attached with transmitters individual ♀ 3 was tracked only for 15 days after which the transmitter failed. Male # 1 was tracked for 633 days; ♂ 2 was tracked for 215 days; ♀ 1 for 728 days and ♀ 2 for 89 days. A total of 1576 locations were collected between February 2008 and March 2010. The Tortoise (♀ 3) with transmitter that failed could not be traced till the end of the study in March 2010.

5.4.2. Home range

Four out of the five individuals were monitored regularly. Female # 1 had the largest MCP home range 34.7 ha (Fig. 5.4). Male # 1 had 9.3 ha home range followed by ♀ 2 which had 9.0 ha and ♂ 2 had 5.2 ha home range. Female # 1 home range (34.7 ha) encompassed the home range of ♂1 (24.5 %) and ♂ 2 (15 %) and ♀2 did not have any overlap between them, ♂1 & ♂2 had a near complete overlap of their home ranges with that of ♀1. Female # 2 home range was located away from other three individual's home range and did not have any overlap with other three individuals. Female # 1 had a kernel home range of 9.8 ha and it was concentrated in one area but also had small multiple cluster of locations within the MCP (Fig. 5.4). Female # 2 had 3.5 ha kernel home range with two distinct clusters. Male # 1 had 11. 9 ha kernel home range with one distinct cluster of points which was surrounded by small clusters and few independent points. Male # 2 had small kernel home range of 1.0 ha with many small clusters within the MCP (Fig. 5.4).

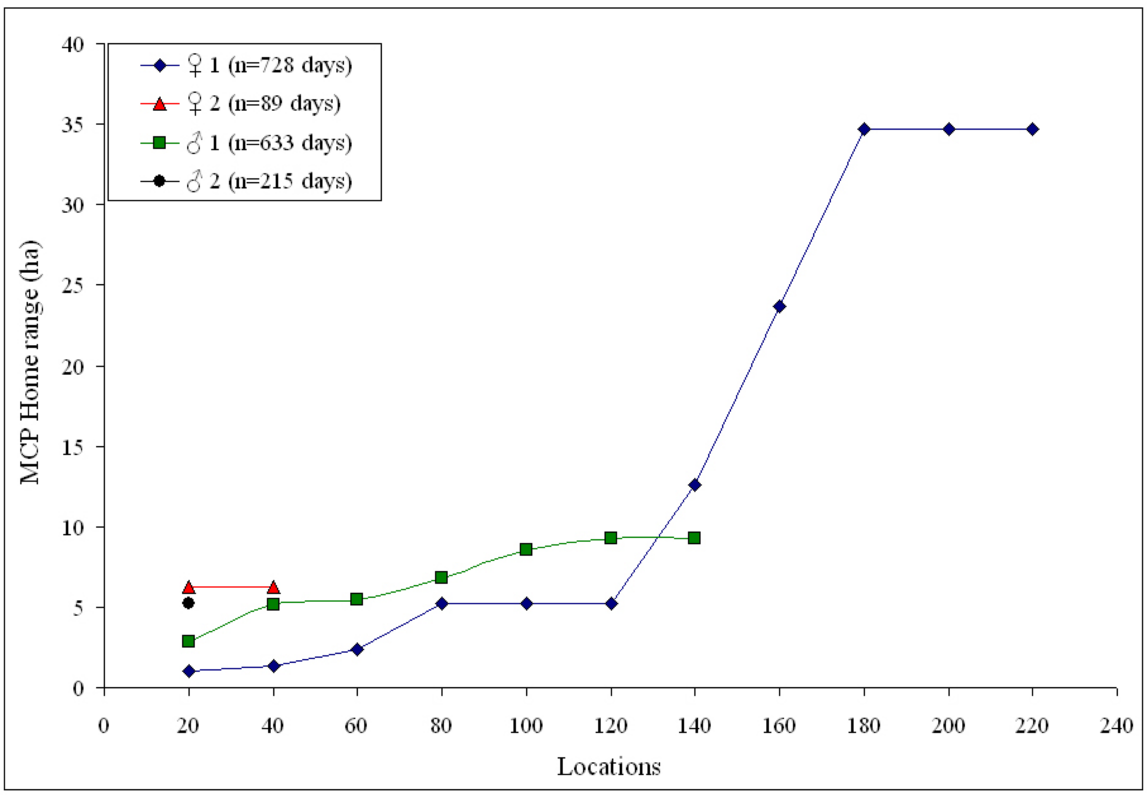
It took 409 days to accumulate 120 different locations for ♀ 1 and it took 485 days to accumulate 120 different locations for ♂ 1. Between 80 and 120 locations, the MCP home range size of an individual started to assymtote (Fig. 5.5). The home range of ♀ 1 increased with increasing number of locations and reached an assymptote at 180 locations. In the case of ♀ 1, it took an additional 85 day to accumulate 180 locations. In all it took 494 days to get 180 locations.

Figure 5.4. Home ranges of four radio-tracked Travancore tortoises from 2006 – 2009, in ATR plotted using 100% MCP and kernel method.



The 12.1 ha of the BLG habitat which is only 11 % of the total study area was differently used intensively by the radio tagged tortoises. Female # 1 used 7.4 ha of the BLG habitat which was 21.5 % of the total MCP home range of the animal. Female # 2 used 0.78 ha of the BLG which was 8.7 % of its total MCP home range. Male # 1 used 3.2 ha of this habitat which is 34.4 % of its MCP home range and ♂ 2 used 1.2 ha of the BLG which is 22.5 % of its MCP home range.

Figure 5.5. 100 % MCP home range of the four radio tracked tortoises with increasing locations.



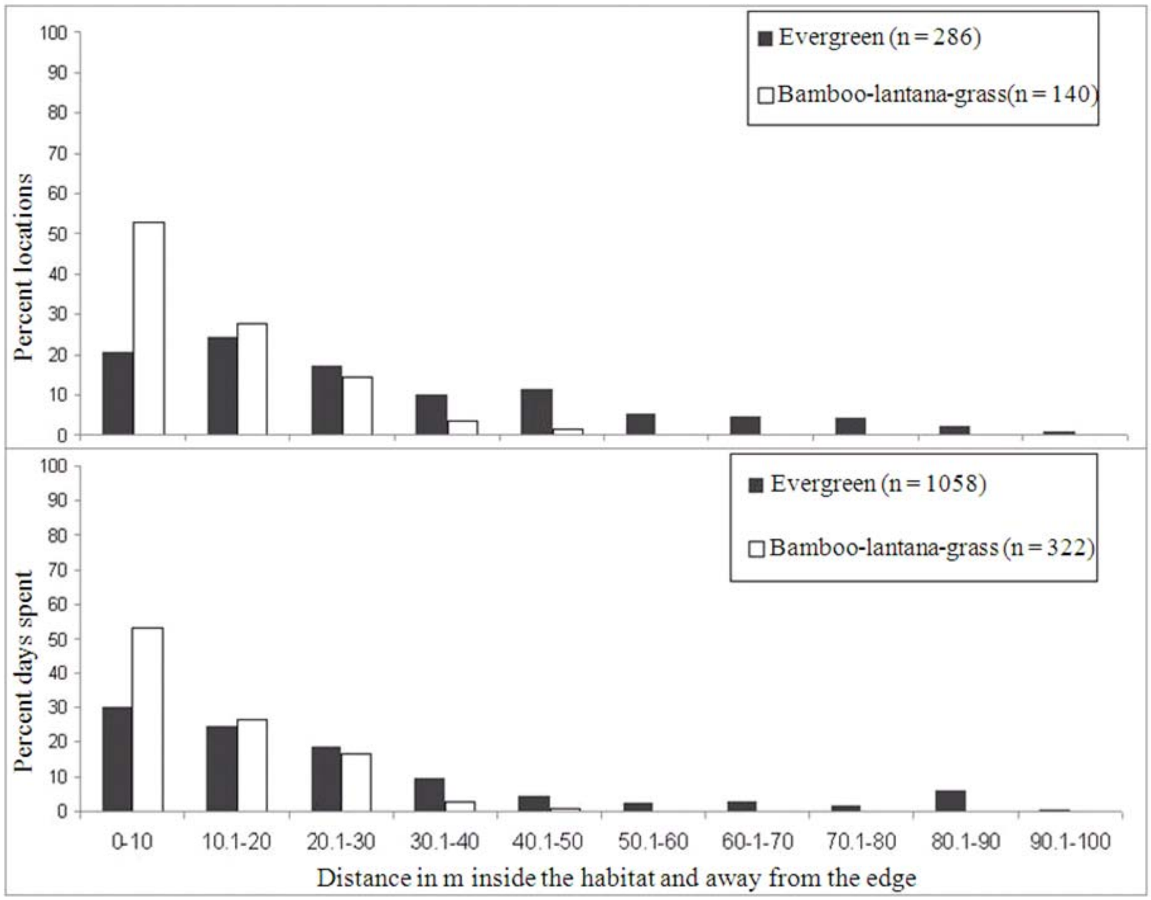
5.4.3. Spatial movement pattern

The total distance travelled by ♂1 was 10.37 km in 633 days; ♀ 1- 31.59 km in 728 days;

♂ 2 - 17.12 km in 215 days and ♀ 2 - 30.74 km in 89 days. The maximum linear distance moved by any radio tracked tortoise was 665 m by ♀ 1. Maximum linear distance moved by TT were: ♂ 1- 454 m, ♂ 2- 412 m and ♀ 2- 245 m. Average linear distance moved by the tortoises were: ♂1- 46.80 m, ♀ 1 - 15.23 m, ♂ 2 - 15.14m and ♀ 2 -19.68m.

Eighty two percent of the TT locations and 87 % of the occassions when they were located they were found >50 m distance from the edge through the evergreen forest. In the BLG habitat where the maximum width of the habitat was > 50 m, 95% of the locations and 96 % of the occassions when located were > 30 from the edge (Fig. 5.6). Female # 1 used a termite hill burrow thrice between 2008-2010. Since its first use it took 455 days for it to return to the burrow in 2009 and after another 114 days it returned to the same burrow in 2010. Male # 1 frequented a rock burrow thrice during the year 2008 and it returned to the same burrow after 249 days in 2009. Canopy cover was correlated with leaf litter cover (Pearson's correlation: $r = 0.56$; p value = <0.01) and number of tree buttress (Pearson's correlation: $r = 0.58$; p value = <0.01) and they were removed from the regression analysis. The VIF values of eight explanatory variables ranged from 1.13 to 2.47 and were well within the threshold of five.

Figure 5.6. Activity levels represented by number of days and percent number of locations of Travancore tortoise at distance class away from edge. "0" the x axis corresponds to the BLG-evergreen edge.



Among the three competing models, a combination of distance to edge and auto-covariate function parsimoniously explained 83 % of the variation in spatial use of the intensive study area by TT (Table 5.2). Distance to the edge influenced TT movement, the grids closer to the edge had a greater probability of being occupied (Table 5.3 & Fig.5.7) than those that were progressively far away from the edge. Movement in space of tortoises was spatially autocorrelated (Table 5.2). Leaf litter cover, number of trees with buttresses, number of fallen logs, number of liana, rockiness, distance to water and elevation did not influence movement in space in models with or without an auto-covariate function.

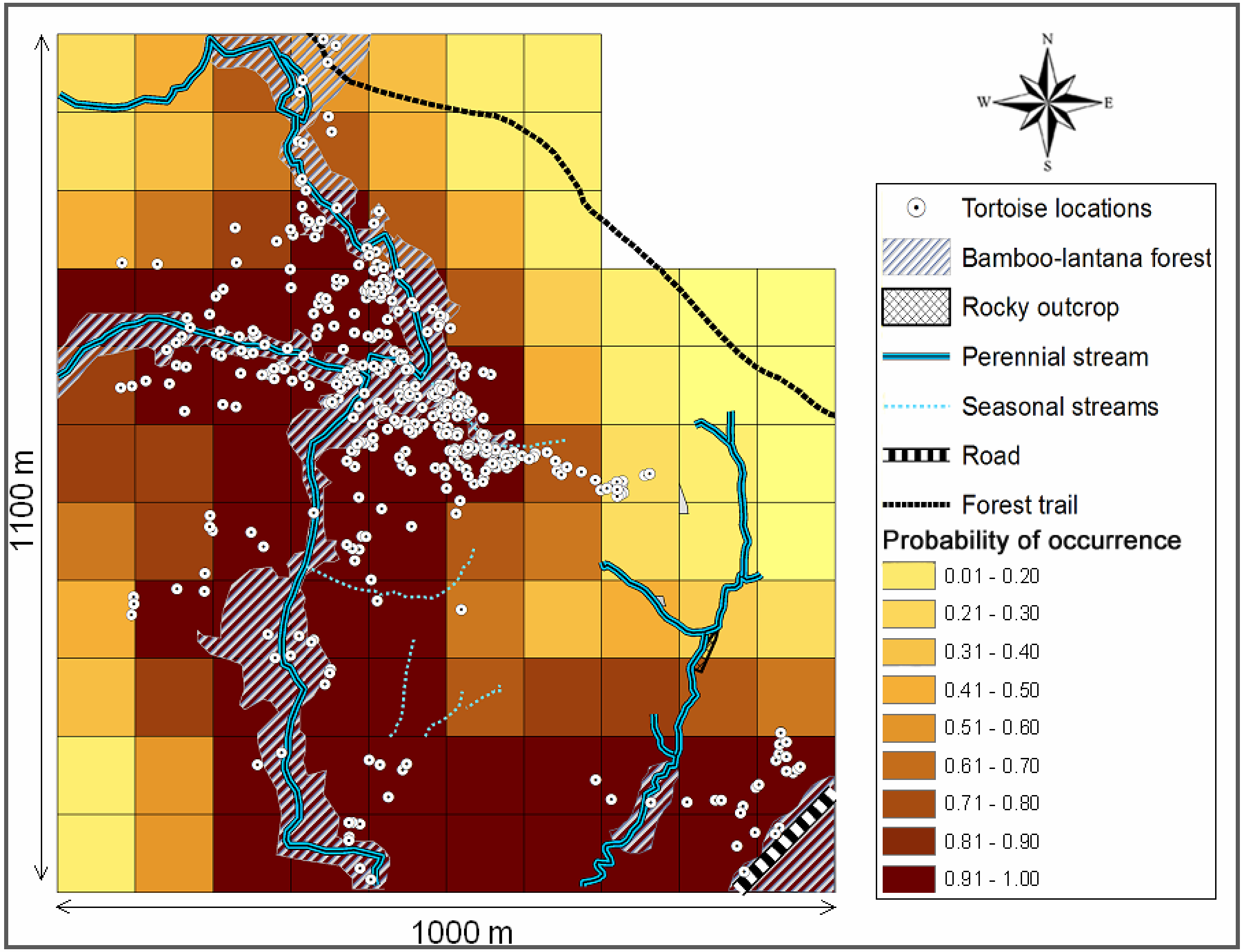
Table 5.2. Models selected based on low AIC value. Overall accuracy is the rate of correctly classified cells. *P <0.0001

S.No	Explanatory variables	Chi square	Degrees of freedom	AIC	Overall model Accuracy
1	Distance to edge + autocovariate	71.28*	1	67.43	0.83
2	No. of logs + no. of liana + no. of trees with buttress + rockiness + leaf litter cover + distance to water + distance to edge + autocovariate	77.64*	8	75.06	0.85
3	No. of logs + no. of liana + no. of trees with buttress + rockiness + leaf litter cover + distance to water + distance to edge	54.73*	7	95.98	0.78

Table 5.3. Coefficients and standard error for model 1 (Distance to edge + autocovariate) showing significant influence on the probability of tortoise movement.

Variables	Coefficients	SE	t	P value
Constant	-14.07	3.9	-3.6	<0.001
Distance to edge	-0.02	0.005	-3.8	<0.001
Autocovariate yW	25.24	6.13	4.1	<0.001

Figure 5.7. Map showing predicted probability of occurrence of Travancore tortoise in the study area based on model 1 (see Table 5.6).



5.4.4. Temporal activity pattern

There were differences in the monthly percent activity of individuals. However, all individuals have similar trends in activity with similar peaks and troughs (Fig. 5.8 & 5.9). Radio-tagged TT's was more active during monsoon compared to post-monsoon and summer (Fig. 5.8 & 5.9). Female # 1 and ♂ 1 was tracked for all the three seasons and they had a similar activity pattern. Female # 2 was tracked only during summer and monsoon, during which, it was more active during monsoon than in summer (Fig. 5.8 & 5.9). Male # 2 was tracked only for six days during monsoon and it was active 50 % of the days and then, it was active for only one day in post-monsoon, remaining 89 days of the post-monsoon it spent inside a burrow.

Factors influencing activity pattern

Minimum temperature and maximum temperatures were correlated for pooled data (Pearson's correlation $r = 0.41$, $P = < 0.001$), ♀ 1 (Pearson's $r = 0.44$, $P = < 0.001$) and ♂ 1 (Pearson's $r = 0.43$, $P = < 0.001$). Only maximum temperature was included in the global model along with rainfall and season as a categorical variable. Rainfall and maximum temperature did not influence the activity for the pooled data for four individuals, ♀ 1 and ♂ 1. Summer and post monsoon had a negative influence on the overall activity of TT (pooled data) and monsoon had a positive influence on the TT (Table 5.6 & Fig. 5.10). Summer season had a negative influence on female # 1 and monsoon had a positive influence on its activity (Table 5.6 & Fig. 5.10). However, post monsoon did not have any influence on ♀ 1's activity. Male #1 activity was negatively influenced by summer and post monsoon and positively influenced during monsoon (Table 5.6 & Fig.5.10). The minimum adequate models were not overdispersed, the overdispersion values for the three different model set were 1.03 (♀

1), 1.05 (♂ 1) and 1.07 (pooled data).

Table 5.4. GLM results based on the best selected (reduced) model examining across season activity of Travancore tortoises to abiotic variables.

Parameter	Coefficient	S.E.	Z value	PR(>|Z|)
♀ 1 (n = 373)				
Intercept (summer)	-1.70	0.25	-6.81	**<0.001**
Post monsoon	-0.07	0.35	-0.91	0.853
monsoon	1.70	0.31	5.50	**<0.001**
♂ 1 (n = 359)				
Intercept (summer)	-1.36	0.26	-5.14	**<0.001**
Post monsoon	-1.66	0.58	-2.89	**0.004**
monsoon	1.11	0.30	3.66	**<0.001**
Pooled 4 individuals (n = 845)				
Intercept (summer)	-1.40	0.15	-9.41	**<0.001**
Post monsoon	-0.73	0.27	-2.76	**0.006**
Monsoon	1.29	0.18	7.20	**<0.001**

Figure 5.8. Percent monthly activity of the four radio tracked Travancore tortoise and monthly rainfall in the study area.

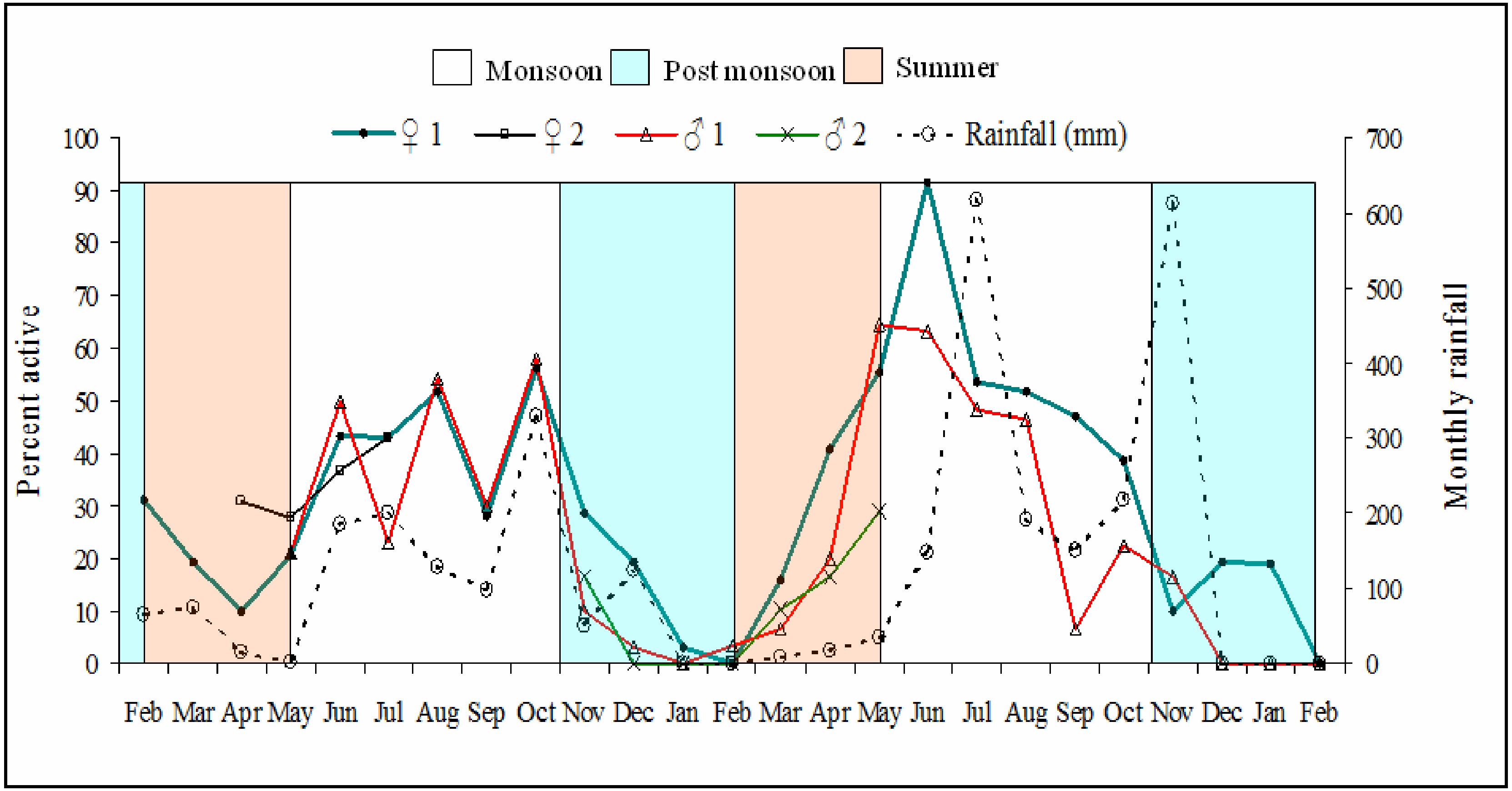


Figure 5.9. Percent monthly activity of the four radio tracked Travancore tortoise and monthly minimum and maximum temperature in the study area.

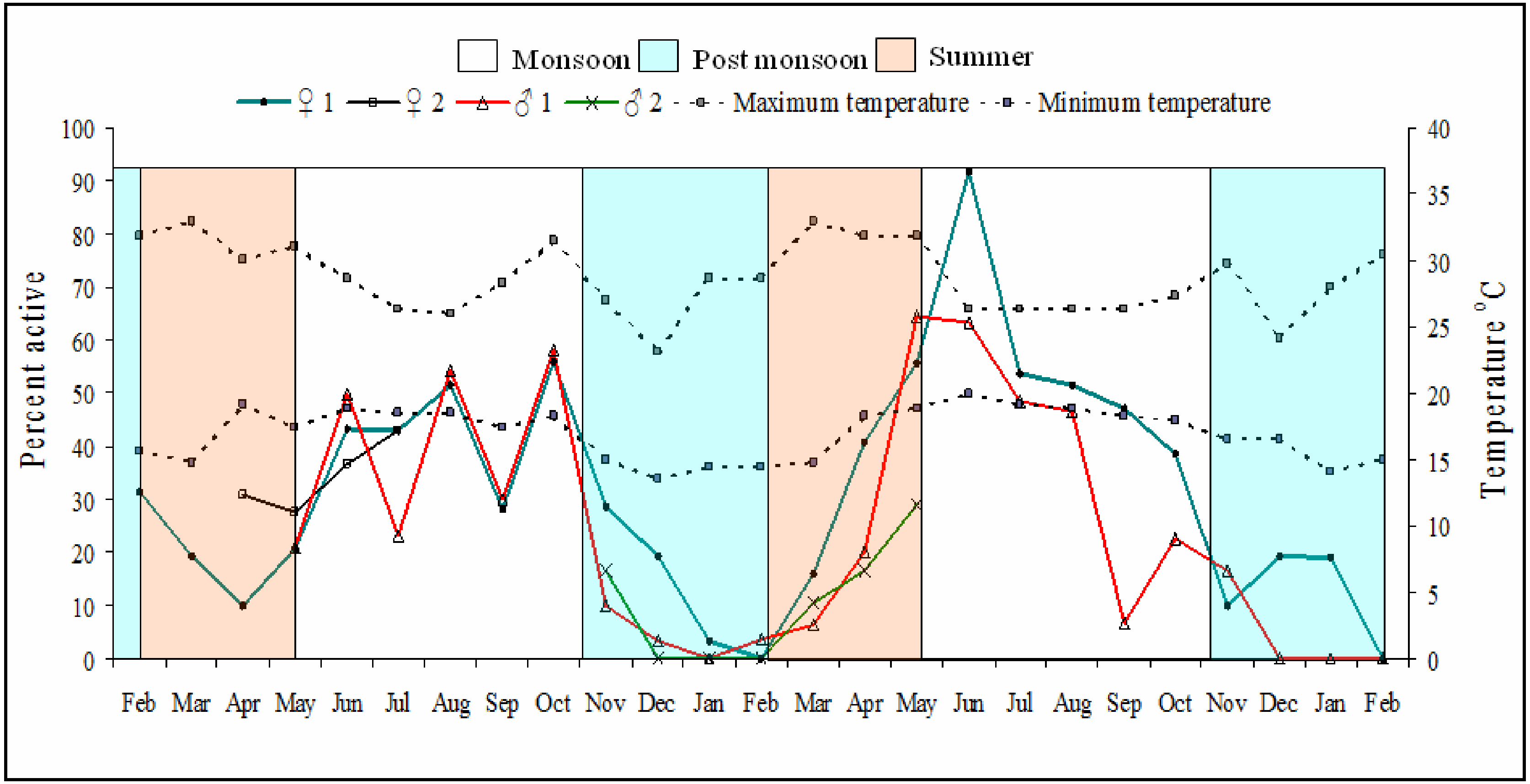
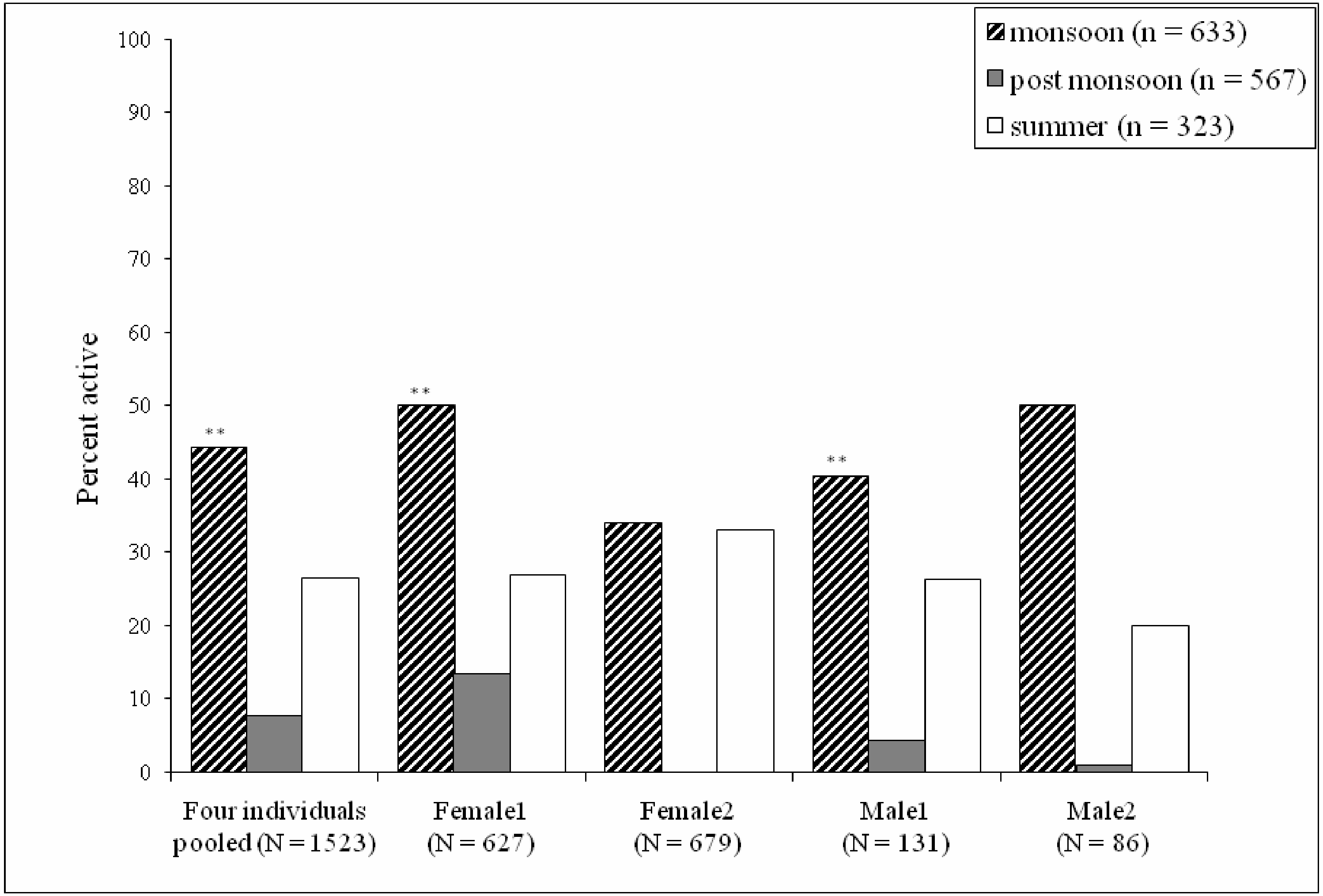


Figure 5.10. Overall and individual differences in seasonal activity of radio tracked Travancore tortoises. * χ2 (P = <0.001)



Percent activity within a season

All the four radio tagged individuals had more than 35 % activity during the monsoon season (Fig. 5.10). The activity of radio tagged TTs (♀ 1, ♂ 1 & ♂ 2) were less during the post monsoon months. The activity of all four radio tagged TTs during summer were comparatively higher than the post monsoon season (Fig. 5.10). The percent activity of ♀ 1, ♂ 1 and for the four individuals pooled data were significantly different among seasons: ♀ 1 ($\chi 2 = 91.0$, df = 2, p-value < 0.001), ♂ 1 ($\chi 2 = 82.6$, df = 2, p-value < 0.001) and pooled data ($\chi 2 = 202.3$, df = 2, p-value < 0.001).

5.4.5. Microhabitat use

All microhabitat types were used by ♀ 1 and ♂ 1 and ♂ 1 was always found using one of the microhabitat type and rarely seen without cover (Table 5.5). ♀ 2 did not use fallen logs, grass cover and lantana bushes during the tracking period (Table 5.5). On most occassions the female tortoises were located buried in leaf litter (Table 5.5). ♂ 1 was found inside lantana scrub on most occassions. Out of the 210 days of tracking, ♂ 2 spent 106 days inside a termite hill burrow (Table 5.5).

Burrow use was not observed in ♀2. ♂ 1, ♂ 2 and ♀ 1 used burrows and the maximum temperature of any given day was significantly different when the tortoise used burrows and when they were outside the burrows (Table 5.6). Minimum and maximum temperature of days when ♀1 spent inside the burrow and the temperatures outside the burrow in two different habitats (BLG & evergreen) is given in Fig (5.11). Minimum temperatures of ♀ 1 were significantly different inside than outside the burrow. In ♂ 2 minimum temperatures was not significantly different when it was inside and outside the burrow (Table 5.6). ♂ 1 minimum and maximum temperatures are not significantly different it was inside and outside the burrow.

Table 5.5. Percentage microhabitat use by the four radio tracked Travancore tortoises. The values represent number of days when direct observations were made.

Microhabitat type	♀ 1		♀ 2		♂ 1		♂ 2	
Buried in leaf litter	320	48.2 %	75	90.4 %	125	23.1 %	28	13.3 %
Inside bamboo thicket	5	0.8 %	4	4.8 %	12	2.2 %	40	19.0 %
Inside lantana scrub	31	4.7 %	0	0.0 %	280	51.9 %	0	0.0 %
Inside pangolin/termite burrow	55	8.3 %	0	0.0 %	19	3.5 %	106	50.5 %
Inside rock boulder	10	1.5 %	0	0.0 %	50	9.3 %	30	14.3 %
Inside tree hollow	70	10.5 %	0	0.0 %	21	3.9 %	4	1.9 %
Under fallen log or liana	71	10.7 %	2	2.4 %	8	1.5 %	0	0.0 %
Under grass	77	11.6 %	0	0.0 %	25	4.6 %	0	0.0 %
Open forest floor	25	3.8 %	2	2.4 %	0	0.0 %	2	1.0 %
Total	664		83		540		210	

Figure 5.11. Temperatures used by ♀1 in burrow compared to temperatures outside burrow in evergreen and bamboo-lantana habitats.

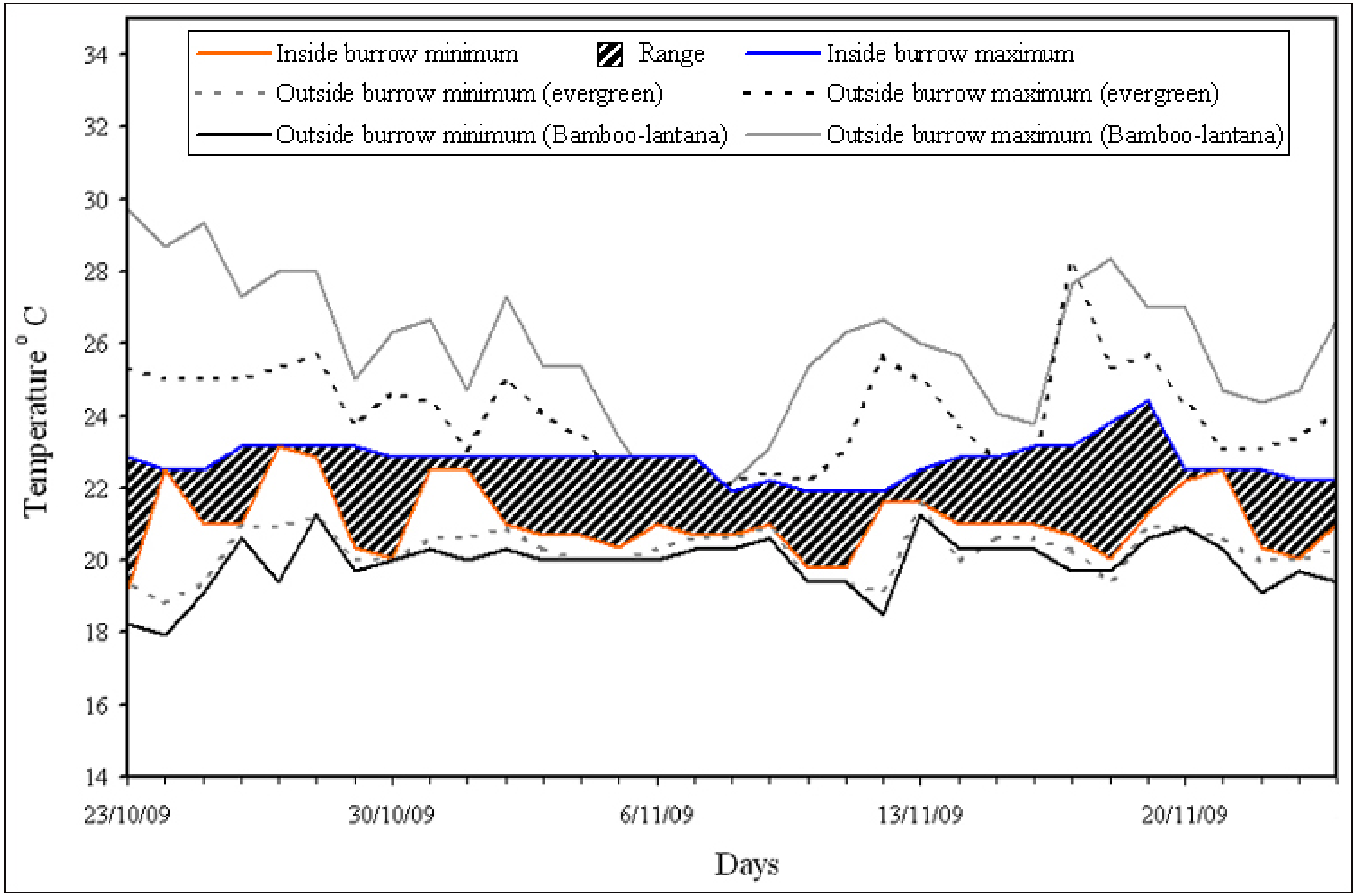


Table 5.6. Minimum and maximum temperature (°C) when the Travancore tortoise was inside and outside the burrow.

Paired variables	N	Average temperature °C	T	Degrees of freedom	P Value
♂ **1**					
Outside minimum + burrow minimum	75	20.45	-0.92	74	0.17
Outside maximum + burrow maximum	75	23.96	1.81	74	0.93
♂ **2**					
Outside minimum + burrow minimum	20	20.97	-1.15	19	0.13
Outside maximum + burrow maximum	20	22.00	-5.67	19	**<0.001**
♀**1**					
Outside minimum + burrow minimum	35	21.13	4.81	34	**< 0.001**
Outside maximum + burrow maximum	35	22.34	-4.28	34	**< 0.0001**

5.5. Discussion

5.5.1. Home range

The MCP & kernel home range size of ♀1 was the largest. Male # 1 had a larger home range compared to ♂ 2. These differences in home ranges of tortoises might be due to incomplete sampling or due to these tortoises having diffuse home ranges. Tracking duration was shorter for ♂ 2 and ♀ 2 compared to ♂1 and ♀ 1, which might also be the reason for smaller home ranges of the former compared to the later. The kernel home ranges also showed a similar trend, ♀1 had the largest home range followed by ♂ 1, ♀ 2, and ♂ 2. In case of ♂ 2 the kernel home ranges did not have any distinct utilization distribution clusters like the other individuals. This might be because ♂ 2 spent most of the time (106 out of 215 tracking days) inside a burrow. Sex, size and reproductive condition also affect the ranging areas of several species of turtles, such as *Gopherus polyphemus* (McRae *et al*., 1981), *Gopherus berlandieri* (Rose and Judd, 1975) and *Trionyx muticus* (Plummer and Shirer, 1975). However in case of *Geochelone carbonaria* home ranges were not related to size, sex nor season; instead it was due to varied idiosyncratically (Moskovits and Kiester, 1987). Individual variation in home range sizes is typical of most terrestrial turtles, such as, *Terrapene carolina carolina* (Stickel, 1950; Schwartz and Schwartz, 1974), *Terrapene ornata ornata* (Legler, 1960), *Gopherus agassizii* (Burge, 1977) and *Gopherus berlandieri* (Judd and Rose, 1983). Idiosyncratic behaviour might be one of the reasons for the variation in home range size observed in *I. travancorica*.

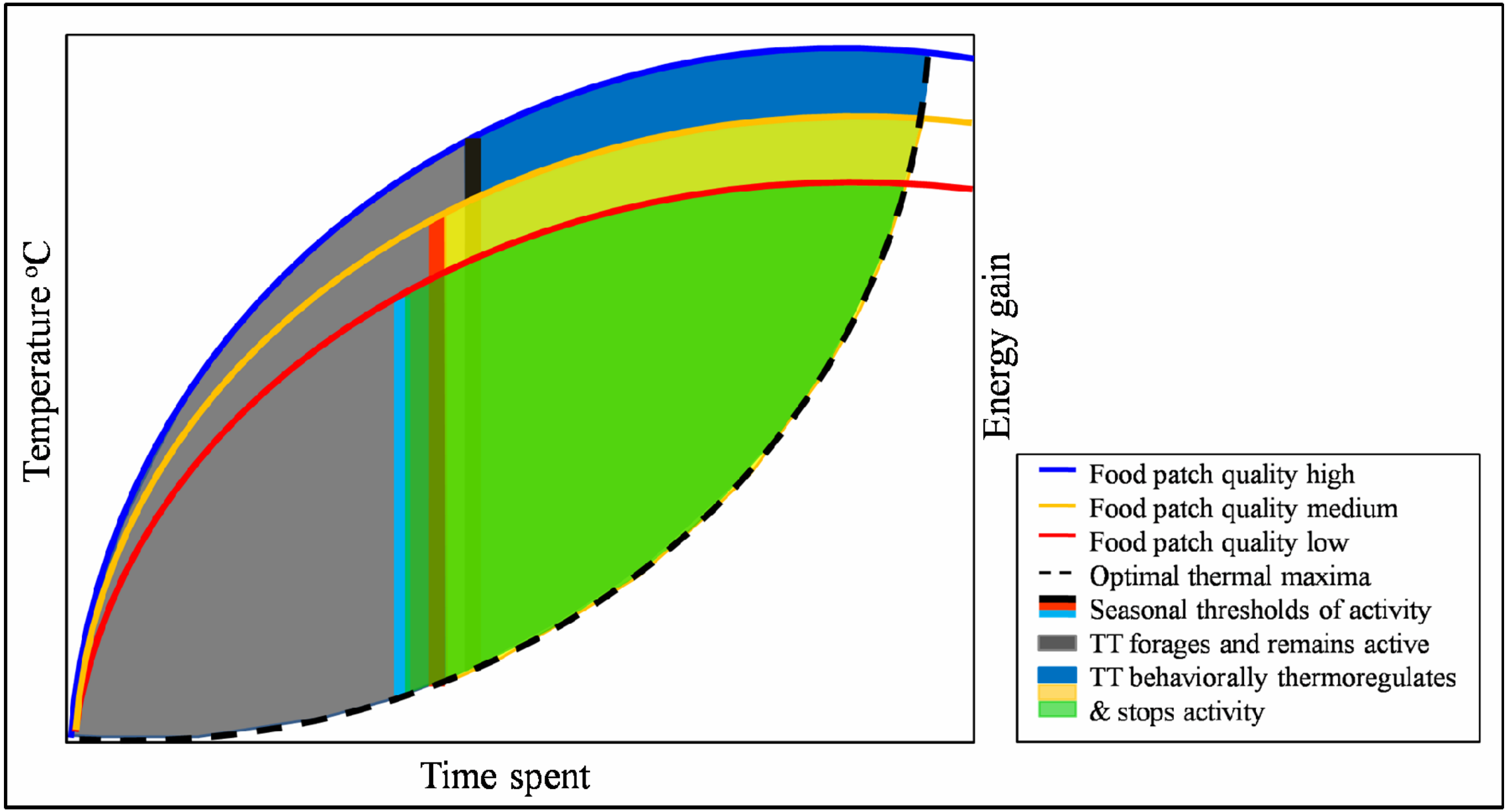
In this study180 locations was required to calculate the 34.7 ha of MCP home range of ♀ 1 and it took 494 days of radio tracking to gather the 180 locations. It highlights the extensive field data collection required to understand the habitat use of the species. Future studies on TT should use > 180 locations to make any inference on their home ranges.

The radio tracked tortoises had overlapping home ranges; ♂1, ♂2 & ♀ 1 had 22 – 34 % of their home ranges covering a large BLG habitat in the study area. Female # 2 had 8.7 % of its home range inside three different patches of BLG habitat. This data suggested that TT was dependent on BLG habitat which are only 12 % of the total study area. These patches of habitat with bamboo, grass and other herbs are important foraging grounds for TT. Dietary differences were speculated to influence the movement pattern of *Clemmys insculpta* and *Terrapane carolina*, particularly with reference to home range size range of habitats utilized (Strang, 1983). Despite differences in sample size, age and size difference the proportion areas used in evergreen and BLG habitats were similar. All the four radio tracked TTs used eight times more BLG than evergreen relative to the habitat that was available for them. TT being primarily herbivorous they probably use these food resource patches in BLG optimally at the same time avoid critical thermal maxima. Critical thermal maxima, the maximum temperature a reptile can tolerate physiologically, is higher than the maximum temperature it will tolerate voluntarily (Cowles and Bogert, 1944). Crepuscular activity in TT is probably a behavioural adaptation for thermoregulation to avoid high temperatures during the day. During the day the TTs take refuge in the evergreen habitats by burying under leaf litter. A hypothetical model of energy gains – optimal thermal maxima and activity of TTs is given in Figure 5.12.

5.5.2. Spatial movement pattern

There was no evidence of movement over long distances from this study. The total distance covered by ♀ 1 was 31.6 km within 34.7 ha MCP home range. Ramesh (2004) reported that a Travancore tortoise marked by J. Vijaya in 1983 in 'Chalakudy' to have traveled 50 km distance in 20 years. Our data suggest that this report is erroneous and TTs have home ranges and do not perform long distance movement. There were also no reports of long distance

Figure 5.12. A conceptual frame work of activity of Travancore tortoise in its habitat.



Within the intensive study area tortoises distributed themselves among the two habitats (evergreen & BLG) with restricted forays away from the BLG habitat (Fig. 5.5). The BLG habitat was usually linear along seasonal and perennial stream. There were some grass marsh openings that had the characteristic vegetation and occupied small proportion of the landscape. These were called locally 'vayal' and because they serve as important feeding grounds for herbivores (Balakrishnan and Easa, 1986) and they might serve as "keystone structures or habitats". The movements of radio tagged TTs were restricted to the edge habitats between evergreen and BLG. Distance to water did not significantly influence the presence of the *I. travancorica* even when the BLG were closer to perennial and seasonal water sources (Fig. 5.1). Number of liana's, fallen logs and trees with buttress were not significantly influencing TT's movement in space. The four radio tagged tortoise did use fallen logs and liana's in the study area but spent comparatively less time in these microhabitats (1.5 – 10.7 %). These logs and liana's used were also few among the many available in the study area, which is the reason why they did not influence the TTs movement in space.

The time they spent near trees with buttress were not recorded during the study, it may also be due to many available trees with buttress and a few which TTs use. Leaf litter cover one of the most used microhabitat (13.3 – 90.4 %) but it did not influence the TTs movement in space. This may be due to more or less uniform leaf litter (mean= 66.8, SE = 1.6) cover in the study area. Rock boulders near rocky out crops were used by TTs (1.5 – 14.3 %). However these were very few outcrops distributed in certain areas in the study area (Fig. 5.1) which is the reason that they were not one of the influencing variables in the spatial analysis. The evergreen and bamboo habitat types had distinct daily minimum and maximum temperatures (Fig 5.7). The intensive use of the edge habitats is an attempt by the tortoises to behaviorally regulate their body temperatures.

5.5.3. Temporal movement

I. elongate is a closely related species to *I. travancorica* and it showed distinct seasonal trend in activity (van Dijk, 1998). They were more active during the daytime, during the wet and cool dry seasons than the hot seasons (van Dijk, 1998). Their activity was limited to brief periods during and after rainfall (van Dijk, 1998). Travancore tortoise also showed a similar behavioral pattern. In summer, when there was sporadic rainfall, they showed brief period of activity and then retreated into their hideouts. Temporal activity pattern of the angulate tortoise (*Chersina angulata*) was strongly influenced by environmental factors, particularly temperature (Ramsay *et al*., 2002). Even among chelonians such as *Terrapene ornate*, the surface level activity in the species was influenced by rainfall and operative temperatures both during seasons and during the day (Plummer, 2003).

The overall data set examining across season revealed that, the activity of TT in the intensive study area was positively influenced by monsoon; negatively influenced by post monsoon and summer seasons. However, neither rainfall nor maximum temperatures had any effect on their activity. While monsoon positively influenced the activity of ♂1 & pooled data, post monsoon and summer was negatively influencing their activity. The effect of monsoon and summer remained the same for ♀1 but there was no influence of post monsoon on the activity of ♀1.

The results explain that there is a strong influence of seasonal changes in the environment on TT. This is also supported by the microhabitat use data. The tortoises spent maximum number of days inside burrows between November to March (♂1 25 days, ♂2 106 days and ♀1 15 days). These coincided with post monsoon and summer seasons in the study area. The ambient temperatures during these months were clearly unfavorable for TT. The percent activity of TTs were significantly different between seasons. During monsoon they showed higher activity than the other two seasons. TTs activity was very low during the post monsoon season and it showed moderate activity during summer. The temperature within monsoon season was not variable. Therefore temperature alone is not enough to explain the bouts of activity during this season. Whereas during certain time period in summer and post monsoon there is extreme fluctuation in temperature and it is evidence from the burrow use of TTs. At the same time the rest of the post monsoon or summer the temperature is not variable and activity during this period cannot be explained by temperature alone. Whereas activity pattern of the TTs closely matches with the rainfall in the study area, rainfall may not have a direct influence on the activity. There are probably other environmental variables like humidity or food resource availability which we did not measure which might be playing a role in the TT activity within these seasons.

5.5.4. Microhabitat use

The density of undergrowth and other cover at the tortoise level may be important than that of canopy cover for *I. elongate* (van Dijk, 1998). Even though they spent more time in the evergreen habitat (Fig. 5.5) they had a close association with the edge between evergreen and

BLG habitats. Within the BLG & evergreen habitats they used a variety of microhabitats which were probably crucial for thermoregulation, such as leaf litter, bamboo thickets, lantana scrub and burrows. *I. elongata* in Thailand was found mostly in mixed-species deciduous forest, they also occurred in open dry deciduous dipterocarp forest and occasionally in streamside galleries of evergreen or open successional vegetation except evergreen. Within these forest types they were found in moderately open forest and they were known to hide in places including small boulder cave, fallen bamboo, an undercut dry stream bed, porcupine burrows, and inside the hollow trunk (van Dijk, 1998).

Desert tortoises (*Gopherus agassizii*) are known to retreat in underground burrows to avoid lethal surface temperatures (Brattstrom, 1965; Voigt, 1975; Ruby *et al*., 1994; Zimmerman *et al*., 1994; Bulovo, 2002). Variation in body temperatures *Gopherus agassizii* was found to be the primary consequence of microhabitat selection, principally the use of burrows (Zimmerman *et al*., 1994). Egyptian tortoises (*Testudo kleinmanni*) retreat into rodent burrows during summer (Geffen and Mendelssohn, 1989). In the case of TT, it is clear that termite burrow/ pangolin burrows are the result of tortoise's preference to temperature profile that has narrow fluctuations. Similarly burying under leaf litter is probably an activity to regulate temperature and avoid high temperatures in the environments.

CHAPTER 6

Conservation Action Plan

6.1. Introduction

Chelonians are by far the most ancient quadruped vertebrates on earth and in India a diverse assemblage of this order survive (Das, 1995; Buhlmann, 2009). There are two species of tortoises in the Peninsular India: Travancore tortoise (*Indotestudo travancorica*) and the India star tortoise (*Geochelone elegans*). The Star tortoise has a wide distribution range in the dry zones of Peninsular India. *I. travancorica* is endemic to the Western Ghats (Iversion *et al.*, 2001). Exploitation for trade of *I. travancorica* is not reported so far. However there are considerable amount of evidence for exploitation by locals in its geographical range (Vijaya, 1983; Frazier, 1989; Bhupathy and Choudhury, 1995).

In the Western Ghats, the human population density is highest compared to any other biodiversity hotspots (Cincotta *et al.,* 2000). Therefore, people live in close proximity to protected areas (PA's) in the region. In many cases, the human enclaves are situated within protected areas in the Western Ghats (Anand *et al.,* 2010). These colonies have remained economically backward and they depend on forest resources for their livelihood. The detection and prevention of crimes in PA’s related to harvesting of species or destruction of habitat are, the duties of protected area managers who are empowered by various laws. The continuous attrition of forest plant resources or small animals are difficult to detect and therefore remain clandestine. This cryptic loss of biodiversity poses an enormous challenge to the already burdened protection force that defend the forest resources from intrusions that come from outside. Nonetheless, the threats faced by populations of thousands of small vertebrates such as the Travancore tortoise are real, and protection has to permeate to the levels where the exploitation of such species could be prevented.

There are three important reasons based on which this species conservation action plan is proposed are: (1) Travancore tortoise populations are sensitive to anthropogenic disturbance and susceptible to population decline (2) There is evidence of exploitation within and outside PA's suggesting that the species is vulnerable to local extinction (3). There is need for a process to be put in place to implement monitoring of the species and train PA management staff on protection and monitoring of TT. These statements have their basis of the findings of a four year study in two tiger Reserves in the Western Ghats. The action plan has been formulated by compiling all available information on the Travancore tortoise and on the results of the previous chapters from this thesis. There is no existing action plan for the species; the present action plan can be used as a model for implementing actions for the conservation of the species. This action plan is prepared following the guidelines on preparation of action plan for conservation of species (Agreement on the Conservation of African-Eurasian Migratory Waterbirds, 2004; Childress *et al.,* 2008; Anonymous, 2009).

6.2. Biological assessment

6.2.1. Systematic Classification & Taxonomy

Phylum : *Chordata*

Class : *Reptilia*

Order : *Testudines*

Family : *Testudinidae*

Genus : *Indotestudo* (Schlegel and Müller, 1844)

Species : *Indotestudo travancorica* (Boulenger, 1907)

Described by Boulenger (1907) as *Testudo travancorica* based on specimens collected by Ferguson from Travancore province in Kerala. Boulenger noted that it bore resemblance to both *Testudo elongata*, from the northern and eastern parts of the Indian subcontinent, and *T. forstenii* [*sic*] from Celebes (now Sulawesi, Indonesia) and the neighbouring Gilolo Island (now Halmahera Island, Maluku, Indonesia). Smith (1931) also considered *T. travancorica* as very closely allied to *T. elongata*. Lindholm (1929) recognized *T. elongata* as a distinct species and assigned it to the subgenus *Indotestudo* (under *Testudo*), but he did not mention the placement of the other two valid names, Williams (1952) included *travancorica* and *forstenii* in this subgenus and partitioned the genus *Testudo,* by placing three species in the subgenus *Indotestudo*. It was in turn placed under the genus *Geochelone* (Williams in Loveridge and Williams, 1957). Bour (1980) elevated *Indotestudo* to a distinct genus, this was supported by cladistic analyses by Crumly (1982, 1984). In an attempt to resolve the disjunct distribution of *I. travancorica* Pritchard (1979: 319) suspected that tortoises from India could have been introduced into Indonesia, giving rise to disjunctive populations. When Hoogmoed and Crumly (1984) examined specimens of the three species of *Indotestudo*, they were unable to distinguish *I. forstenii* from *I. travancorica* and therefore, *I. travancorica* was merged with *I. forstenii*, with the latter name took priority. Since then, the species name *I. forstenii* is associated with many reports of *I. travancorica* (eg: Frazier, 1989; Das, 1991, 1995; Sharath, 1990; Bhupathy and Choudhury, 1995; Radhakrishnan, 1998). Pritchard (2000) examined several specimens of *Indotestudo* from different regions suggested that *I. travancorica* to be resurrected as a distinct species, because it was morphologically different from *I. forstenii*. Evidence through phylogenetic studies supported that there were three distinct species of the genus *Indotestudo*, and also revealed that *I. travancorica* was closer to *I. elongata* than to *I. forstenii* phylogenetically (Iverson *et al*., 2001; Le *et al.,* 2006).

6.2.2. Distribution

Indotestudo travancorica has been reported from three different states Kerala, Tamil Nadu and Karnataka in peninsular India (Boulenger, 1907; Vijaya, 1983; Smith, 1931; Frazier, 1989; Sharath, 1990; Appukuttan, 1991; Das, 1991; Bhupathy and Choudhury, 1995; Radhakrishnan, 1998). Two new locality records were made in Karnataka from Pushpagiri Wildlife Sanctuary and Gersoppa reserve forest (Vasudevan *et al.,* 2010). The species are so far recorded only below 16^{o} N in the Western Ghats (Fig. 6.1). They are reported from 15 different protected areas and seven reserve forests (Table 6.1; Fig. 6.1). They are reported only from the western slopes of the Ghats (Fig. 6.1).

6.2.3. Productivity and Survival

There is no information on their nesting, clutch size and survival in the wild. Captive stocks from MCBT have a clutch size of 2 – 5 eggs. A total of 21 clutches were produced between 1988-1995 (Whitaker and Andrews, 1997) none of these seem to have survived. However three individual born in the years 1999, 2000 and 2002; and four individuals born in 2004 had survived till date and is in the Madras Crocodile Bank Trust (MCBT) captive holding

(MCBT, Taxon information). The captive stock at MCBT had 63.6 % hatching success from eleven clutches. The incubation temperatures averaged 25.5^{o} C for a period of 141.5 days (Whitaker *in press*).

Figure 6.1. Distribution of Travancore tortoise in the Western Ghats of Peninsular India. Numbers correspond to those of Table 1.

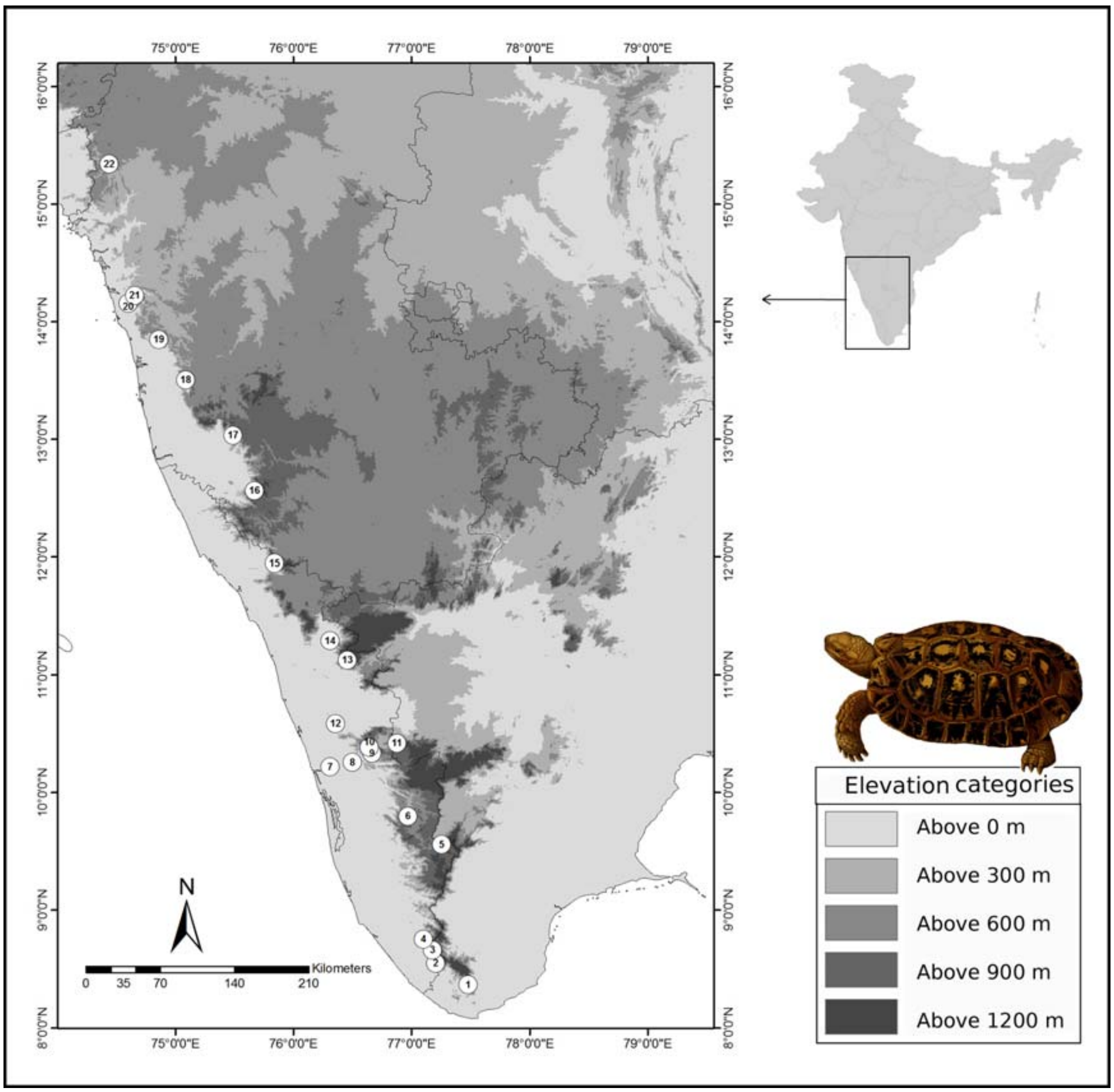


Table 6.1. Details on the localities where *I. travancorica* was reported.

S.no	Location	State	Area in km^2
1	Kanyakumari Forest division	Tamil Nadu	504.9
2	Neyyar Wildlife Sanctuary	Kerala	128.0
3	Peppara Wildlife Sanctuary	Kerala	53.0
4	Shendurney Wildlife Sanctuary	Kerala	171.0
5	Periyar Wildlife Sanctuary	Kerala	427.0
6	Periyar National Park	Kerala	350.0
7	Idukki Wildlife Sanctuary	Kerala	70.0
8	Chimmony Wildlife Sanctuary	Kerala	85.1
9	Chalakudy Reserve Forest	Kerala	279.7
10	Vazhachal Reserve Forest	Kerala	413.9
11	Parambikulam Wildlife Sanctuary	Kerala	285.0
12	Indira Gandhi National Park	Tamil Nadu	117.1
13	Indira Gandhi Wildlife Sanctuary	Tamil Nadu	841.5
14	Peechi-Vazhani Wildlife Sanctuary	Kerala	125.0
15	Silent Valley National Park	Kerala	237.5
16	Nilambur Reserve Forest.	Kerala	325.3
17	Aaralam Wildlife Sanctuary	Kerala	55.0
18	Pushpagiri Wildlife Sanctuary	Karnataka	102.9
19	Agumbae Reserve Forest	Karnataka	56.75
20	Mookambika Wildlife Sanctuary	Karnataka	247.0
21	Sharavathi Wildlife Sanctuary	Karnataka	431.2
22	Gersoppa Reserve Forest	Karnataka	208.2
23	Dandeli Wildlife Sanctuary	Karnataka	475.0

6.2.4. Life history

Breeding

Captive population of Travancore tortoise reveals that it takes approximately 11 years for an individual International Species Information System (ISIS) # 10169) to reach a size of 163mm (Nikhil Whitaker pers. comm.). Age or size at sexual maturity of Travancore tortoise is poorly documented in the past, the above mentioned captive individual female laid a miniature egg measuring 3 mm which is an indication of female sexual maturity. Previous workers necropsied TT in the wild one female measuring 192 mm had one oviductal egg in the right and left oviduct (Nikhil Whitaker pers. comm.). Carapace lengths of two necropsied males were 150 mm and 159 mm respectively. The right testes length averaged 105 mm ± 354 mm, whilst the left testes length was 11.0 mm for both specimens (Nikhil Whitaker pers. comm.). A male having 160 mm SCL had a distinctly concave plastron and hooked tail claw (Ramesh 2008b) indicating probable size of male sexual maturity. Courtship consists of the following stages: 1) sex recognition by olfaction, 2) immobilization of the female by shell-ramming, and 3) mounting and copulation (Auffenberg 1964b). Male combat, consisting of shell-ramming and biting, also occurs (Das 1991; Ramesh 2008a). In adult male tortoises, the pink coloration around the eyes and nares intensifies during the breeding season (Auffenberg 1964a). The breeding season of *I. travancorica* is from November to January (Auffenberg 1964a). But there are reports of breeding in other months of the year; a gravid free-ranging female was found in October (Moll 1989) and in February–March, in captivity (Das 1991). Nesting has not been observed in-situ till date. In captivity, the species excavated small chambers near the roots of trees or shrubs for egg-laying, and the entire process took about 50 minutes. Eggs were 47 x 38 mm and had a mass of 41 g (Ramesh 2007). In captivity, clutch size varied from 1–5 eggs but was often 3 (Vijaya 1983; Sane and Sane 1989; Das 1991, Ramesh 2007); eggs have also been found on the floor of the enclosure (Sane and Sane 1989) or in leaf litter (Das 1991), likely due to a lack of suitable nesting substrates. The incubation period varied from 141–149 days in captivity and a hatchling measured 55 mm (SCL) and had a mass of 35 g (Sane and Sane 1989; Das 1995).

Feeding

Travancore tortoise feeds primarily on a variety of grass and herbs, 45 % of their fecal samples were plant matter. They feed on a variety of herbaceous plants & grass including *Synedrella nudiflora, Desmodium repandum, Senecio scandens, Mimosa pudica, Paspalam sp , Strobilanthus sp* and *Veronica buabaumii* (Ramesh and Parthasarathy, 2006; See chapter 4). They also feed on fruits of *Dillenia pentagyna*, *Grewia tilaefolia, Lantana camera*, *Ficus virens,* Artocarpus *spp* and *Gomphandra sp* (Vijaya, 1983; Ramesh and Parthasarathy, 2006; See chapter 4). They also feed on fungus (Basidomytes). Animal matter consisting of both invertebrates and vertebrates constituted 28 % of Travancore tortoise diet (Deepak *et al*., *in press*; Vasudevan *et al*., 2010). Invertebrates like insects, mollusc, scorpions, crabs and millipedes were part of their diet. Vertebrate remains are reported from the faecal remains in it because they scavenge on carcasses (Deepak *et al*., *in press*; Vasudevan *et al*., 2010)

Ranging pattern

There has been only study on the ranging pattern of TT. This study used radio-tags and fixed them on the five tortoises and monitored their movement for 728 days (Vasudevan *et* al., 2010). The findings from this study were: On an average an adult Travancore tortoise moves between 15.1-47 m in a day. The minimum and maximum distances moved in a day were 0.5 m and 665 m, respectively. They have a home range size of 3.5 – 35 ha. They used *Lantana camara* bushes and bamboo clumps as temporary hide-outs and feed mostly during early morning and late evenings. Their spatial movements have close association with edges of evergreen forest and other forest types (Bamboo mixed, teak plantation and moist deciduous), 79 % of the days the tortoises spent were within 30 m on either side of the forest edge (bamboo and evergreen forest; N = 1380 days).

6.2.5. Habitat and microhabitat requirements

Travancore tortoise inhabits moist forests (evergreen, moist deciduous, riparian and bamboo forests) with streams and grass marshes (Vayals) below 1000 m a.s.l. Rocky outcrops and the burrows in them serve as their thermal refuge during extreme climatic conditions. Radio-tagged tortoises spent up to 106 days inside pangolin/termite hill burrows to escape harsh environmental temperatures (Vasudevan *et al*., 2010). In the same study in 728 tracking days, between February 2008 and March 2010, four tortoises with attached radio transmitters (2 male and 2 females) spent about 37% of the time inactive under leaf litter, 21% inside *Lantana camara* scrub, 12% inside bamboo thicket, 7 % under fallen logs or liana, 6% in rock cavities and 6% in ground level tree hollows, 5% under grass, 4 % inside pangolin or termite burrows and 2 % in the open. Therefore, it forests along with the stream, rocky outcrops and grassland or locally referred as *vayals* serve as essential habitats for their survival.

6.3. Threats

Habitat loss and degradation, introduced invasive species, environmental pollution, disease, unsustainable use and global climate change are considered as significant threats to reptilian species around the world (Gibbons *et al.,* 2000). In the case of *I. travancorica*, hunting and habitat loss and degradation are identified as two important threats. The most important factor that might cause declines in the population of *I. travancorica* is exploitation for subsistence hunting. This species has a long generation time, therefore removal of large breeding adults from the population could significantly reduce their population by impairing reproductive output and subsequently recruitment.

6.3.1. Hunting

Human activity in the Western Ghats, mostly in the form of hunting and gathering, dates back over 12,000 years before present (Chandran, 1997). Hunting and consumption of Travancore tortoise is documented in its entire geographic range. In the Western Ghats, locals belonging to the tribes *Kadar*, *Malai Pandaram, Kani*, *Malasar and Malaimalasar* hunt them using dogs or by following their tracks (Vijaya, 1983; Frazier, 1989; Moll, 1989; Choudhury and Bhupathy, 1993; Deepak and Vasudevan, 2010). It also known that the locals during their forays in the forests, opportunistically capture and consume the tortoises (Chandi, 2008). The behaviour and ranging pattern of the species make them cryptic for human detection, but they are exposed to detection by domestic dogs that rely on olfactory cues. In Anamalai hills and other parts of Western Ghats people are known to use domestic dogs to hunt tortoises (Vijaya, 1983; Frazier, 1989; Moll, 1989; Choudhury and Bhupathy, 1993; Deepak *et al., in press*); in nine out of the 25 trails sampled during the course of this study we noticed domestic dogs accompanying people and one occasion, they were found with a captured tortoise. Sometimes, hatchling tortoises are also reared as pets by the locals till they attain a size suitable for consumption. *Kani* tribe members in the southern Western Ghats, also use charred shell mixed with oil as a cure for external injuries and skin rashes (Bhupathy and Choudhury, 1995). There are no records of this species in trade (Choudhury and Bhupathy, 1993).

6.3.2. Habitat loss

In the Anamalais alteration of forests and fragmentation is a well documented scenario (Raman and Mudappa, 2003; Sekar and Ganesan, 2003). In other areas in Western Ghats deforestation and alteration of habitat is rampant (Buchy, 1996; Jha *et al.,* 2000; Anand *et al*., 2010). These factors have strong influence on the survival of TT in its geographic range. Habitat alteration and fragmentation of forest due to hydroelectric reservoirs is known from almost all areas where the tortoise occurs (Bhupathy and Choudhury, 1995). There are 24 operational and 12 proposed hydroelectric projects to be implemented in the state of Kerala. This state also has the western slopes of the Western Ghats that has habitat for the species, which would severely impact the biodiversity of this region (Sreekumar and Balakrishnan, 1998). Submergence of vast tract of forests will fragment the habitat for *I. travancorica* resulting in fragmentation of the population. Additionally these projects also bring in settlers, who in turn pose a threat to the species by disturbing the habitat and hunting them.

6.4. Treaties, legislation and policies relevant for conservation of *Indotestudo travancorica*

Indotestudo travancorica is listed as 'Vulnerable' in the IUCN Red List (IUCN, 2010). There are no records of this species in trade. However it is listed in Appendix II of Convention on International Trade in Endangered species of Wild Flora and Fauna (CITES), probably because it was earlier considered synonymous with the commercially exploited *Indotestudo forstenii* (Jenkins, 1995). The threat due to trade on the species requires further verification and revision of listing of the species in CITES. It is protected under Schedule IV of the Indian Wildlife (Protection) Act (1972).

6.5. Protected Areas

The areas where the Travancore tortoises are distributed come under 5a and 5b biogeographic classification (Rodgers and Pawar, 1988). These biogeographic zones together have 67 protected areas (PA network cell, WII). Many of the small PAs, some National Parks, Sanctuaries, are within another larger conservation units (Tiger Reserves). Earlier, Travancore tortoise has been reported from 10 Wildlife Sanctuaries, one Tiger Reserve and five Reserved forests (Bhupathy and Choudhury 1995). Currently Travancore tortoises are known from 17 protected areas in the Western Ghats covering an area of 4201.3 Km^2 (Table 6.1). These PAs are of great significance to the Travancore tortoise population in the Western Ghats. The reserves have a mean area of 247 Km^2 with 23.5% of them <100 km^2. These limitations expose several populations to exploitation and insularization in remnant habitats.

6.6. Travancore tortoise protection and conservation status

I. travancorica is a protected species and it is illegal to deliberately kill, or harvest them in India. Possession of derived body parts of the tortoise is an offence according to the Wildlife

(Protection) Act (1972). The penalties for the act are not less than ₹25,000 or minimum of three years sentence in a prison. Conservation authorities in many range states are aware of the species status. However *I. travancorica* occurs in the areas where other large charismatic species are found, so the priority of conservation is focused more on charismatic species. Local people living in these regions hunt the *I. travancorica* and other turtles without the knowledge of the conservation authorities.

6.7. Habitat status

The central and southern Western Ghats have undergone 40 % decline in the forest cover in the past 70 years (Menon and Bawa, 1997). Natural habitats cover close to one-third of the over 160,000 km^2 extent of the Western Ghats. The protected area comprises 67 parks spanning 11,222.47 km^2 (source: PA network, WII). The remaining land area is subjected to diverse land uses including human inhabitations, artificial reservoirs, agriculture: vegetables, paddy (*Oryza* spp); Plantations: coffee (*Coffea* spp), tea (*Camellia sinensis*), rubber (*Hevea brasiliensis*) and cardamom (*Elettaria cardomomum*) interspersed with a variety of other cash crops (Daniels *et al*., 1990). In many areas the human enclaves are enveloped by protected areas (Anand *et al*., 2010). There is ongoing dependence on forest resources by these human enclaves. Scheduled Tribes and Forest Dwellers (Recognition of Forest Rights) Act , 2006 states that a scheduled tribe or other traditional forest dwellers have the right to hold and live in the forest land under the individual or common occupation for habitation or for self-cultivation for livelihood by a member or members of a forest dwelling scheduled tribe or other traditional forest dwellers; Right of ownership, access to collect, use and dispose of minor forest produce which has been traditionally collected within or outside village boundaries (The Gazette of India, 2006). Because many PA have human enclaves and the notification of the PAs have not delineated them as areas outside PAs, resolving the rights of the people as per the Recognition of forest Rights Act is a prolonged process. Therefore, ensuring strict protection within Pas is undermined. It has been proposed that PA notify an area as CWH and exclude this area from FRA. Critical Wildlife Habitat as per the definition, 'Critical Wildlife Habitat' means such areas of National Parks and Sanctuaries that are required to be kept as inviolate for the purposes of wildlife conservation as determined and notified by the Ministry of Environment and Forests (MOEF), after open process of consultation by an expert committee.

6.8. Captive breeding

The only known captive breeding group of this species in the country is from Madras Crocodile Bank Trust (MCBT). The group consists of four males, 12 females and five juveniles and five hatchlings which are housed in enclosures (MCBT database, Nikhil Whitaker, pers. comm.). Source of the captive population (twelve females and four males) are from Kerala state between 1980 to 1985. Some observations on the hole nesting and feeding of captive group have been published over the years (Vijaya, 1983; Das, 1991, Ramesh, 2007). It has been recommended by the Central Zoo Authority (CZA) that MCBT should be considered as a coordinating zoo for Travancore tortoise captive breeding and Mysore Zoo and Trivandrum Zoo to be considered as the participating Zoo (Vijayaraghvan *et al*., 2008).

6.9 Cryo banking

Systematic banking of genomic resources using cryopreserved germplasm offers the oppurtunity to further conservation strategies of endangered species by assisting in the effective genetic management of captive populations (Johnston and Lacy, 1995). Cryopreserved germ plasm will allow indefinite preservation of the presently available gene diversity represented in either captive or wild populations (Johnston and Lacy, 1995).

6.9. Recommended plan of Action

1. *I. travancorica* is vulnerable and populations are subject to exploitation. Removal of adults from the populations might affect the long-term survival of the species. Ensuring protection of populations and implementing a monitoring program by the protection staff involving the local people will enable conservation of the species. A *pro forma* of sampling strategies and the budget required to carry out the survey is given in Table .6.2 (Section 1). A fact sheet of the species is also appended (Appendix 7).

   Line agencies- State forest department of Tamil Nadu, Kerala and Karnataka; Institutions: Kerala Forest Research Institute, A.V.C college, Mayiladuthurai, Kerala Agriculture University, Salim Ali Centre for Ornithology and Natural History (SACON) and Wildlife Institute of India.

2. Grass marshes or locally know as "*Vayals*" or "*Kans*" are crucial microhabitats and forage for the species. These are also areas where there is high detection and thereby increases the possibility of exploitation of the species. Mapping and protection of

grass marshes will provide good foraging grounds for the species. Only one percent ($3.7\ Km^2$) of the potential area contains grass marshes (*vayals*) in the Anamalai and Parambikulam Tiger Reserves. The protection and monitoring these 'keystone structures' should be of importance in the PA management and persistence of the tortoise population in the PAs.

Line agencies- MOEF, State forest department of Tamil Nadu, Kerala and Karnataka.

3. There is scanty information on the breeding biology and *in situ* nesting ecology of the species. Studies on their breeding biology are important in order to understand their reproductive ecology and other breeding habitat requirement of the species. Budgetary requirements to carry out studies on the breeding biology of the species is given in Table .6.2 (Section 2 & 4).

   Line agencies- Kerala Forest Research Institute, A.V.C college, Mayiladuthurai, Kerala Agriculture University, and Wildlife Institute of India, SACON, MCBT; Laboratory for Conservation of Endangered Species (LACONES)

4. *Ex-situ* conservation breeding programs should be strengthened by encouraging more Zoos to participate in coordinated breeding of the species. Participating Zoos should undergo training on captive management of Travancore tortoise before involving in the breeding program. Budgetary requirements to establish a conservation breeding program is given in Table 6.2 (Section 3). Budgetary requirement for Cryo-preservation of germplasm is given in Table 6.2 (Section 5).

Line agencies- MCBT, Trivandrum Zoo, and Mysore Zoo; LACONES

Table 6.2. *Pro forma* of annual work plan and budget for Travancore tortoises.

<table>
<tr><td colspan="3">Section 1: Survey and monitoring</td></tr>
<tr><td colspan="3">Based on the surveys in the Anamalai hills and other places in the Western Ghats. It is recommended that the surveys should be carried out during the month of June (Radio tracked tortoises (N=4) showed highest activity (58%) during this month. These surveys have to be carried out for six days, the schedule for six days are as follows:</td></tr>
<tr><td colspan="3">Day 1: In each range three forest trails of 1.5 km lengths should be surveyed in the forest with three persons (one tracker, one watcher and one volunteer) in each trail. Each survey should take about one hour to complete. The persons walking in front will record the signs and tracks and also detect the species. The other two persons will record the data and verify it. Other relevant habitat data will be collected by them. All surveys are to be carried out in the evening only (Appendix 5).</td></tr>
<tr><td colspan="3">Day 2: The same exercise will be repeated.</td></tr>
<tr><td colspan="3">Day 3: The same exercise will be repeated. One biologist will compile all the data.</td></tr>
<tr><td colspan="3">Day 4: The same exercise to be repeated again followed by a questionnaire survey of opportunistic records (Appendix 6)</td></tr>
<tr><td colspan="3">Day 5: Same exercise to be repeated.</td></tr>
<tr><td colspan="3">Day 6: A presentation of results of the survey. On this day there will also be an awareness programme with tribals and staff followed by a feast.</td></tr>
<tr><td colspan="3">Budget: For each Protected Area (List as given in Table 6.1)</td></tr>
<tr><td>S.No</td><td>Head of expenditure</td><td>Cost</td></tr>
<tr><td rowspan="2">1</td><td>Hire of data entry computer assistant @ ₹300 /- per day x 6 days</td><td>1800</td></tr>
<tr><td align="right">Total</td><td>1800</td></tr>
<tr><td colspan="3">Budget: For each Range in a Protected Area</td></tr>
<tr><td>S.no</td><td>Head of expenditure</td><td>Cost</td></tr>
</table>

1. 2. 3. 4.	One volunteer & one tracker staff wages @ ₹ 120/person per day x 6 days Food expense for volunteer & staff @ ₹ 120/person per day x 6 days Torch Batteries Stationary and other consumables	720/- 720/- 100/- 200/-
	Total	1740/-
Section 2: Breeding biology studies		
Budget for field studies		
S.No	Head of expenditure	cost
1	*In situ* studies and feacal/salaivary sample collection @ 2,00,000/- per year x 4 years	8,00,000
	Total	8,00,000
Section 3: Captive breeding program		
Budget		
S.No	Head of expenditure	cost
1 2	One time infrastructure and development 1,50,000 x 2 Zoo's (excluding MCBT) Annual maintenance of tortoises @ 50, 000 /- x 3 Zoo's (including MCBT)	3,00,000 1,50,000
	Total	4,50,000
Section 4: Hormonal studies		
Budget		
S.No	Head of expenditure	Cost
1	Laboratory analysis using hormonal assays (roughly 200 samples in 2 years) @ ₹ 1000/- per sample	20,00,000
	Total	20,00,000
Section 5: Cryopreservation		
Budget		
S.No	Head of expenditure	Cost
1	Collection of tissue and culture of fibroblast cells and cryo preservation	5,00,000
	Total	5,00,000

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Appendix 1. All models analyzed in model set 1: investigating relationships between site covariates and detection probability of *Indotestudo travancorica.* Water = no. of water bodies; Grass = extent of grass marsh; veg.type = vegetation type; K= no. of parameters; -2Log*L* = Log likelihood; ΔAIC = Delta AIC; AIC *wt* = AIC model weight.

S. no	Models	K	-2Log*L*	ΔAIC	AIC*wt*
1	ψ(.) γ (.) *p* (Water + Grass+ Year + effort)	12	310.52	0.00	0.54
2	ψ(.) γ (.) *p* (Water + Grass)	5	326.24	1.72	0.23
3	ψ(.) γ (.) *p* (Water)	4	330.19	3.67	0.09
4	ψ(.) γ (.) *p* (Water + Year + effort)	11	317.24	4.72	0.05
5	ψ(.) γ (.) *p* (Grass)	4	331.54	5.02	0.04
6	ψ(.) γ (.) *p* (.)	3	334.68	6.16	0.02
7	ψ(.) γ (.) *p* (Grass+ Year + effort)	11	319.15	6.63	0.02
8	ψ(.) γ (.) *p* (Water + Year)	7	329.25	8.73	0.01
9	ψ(.) γ (.) *p* (Year + Effort)	10	323.88	9.36	0.00
10	ψ(.) γ (.) *p* (Grass +Year)	7	330.60	10.08	0.00
11	ψ(.) γ (.) *p* (Year + effort + veg. type)	14	316.86	10.34	0.00
12	ψ(.) γ (.) *p* (Year)	6	333.23	10.71	0.00
13	ψ(.) γ (.) *p* (veg.type)	7	331.65	11.13	0.00
14	ψ(.) γ (.) *p* (Year + veg. type)	10	330.48	15.95	0.00
15	ψ(.) γ (.) *p* (survey)	20	311.17	16.65	0.00

Appendix 2. All models analyzed in model set 2: investigating relationships between site covariates and detection probability. K= no. of parameters; -2Log*L* = Log likelihood; ΔAIC = Delta AIC; AIC *wt* = AIC model weight; * model with numerical convergence error.

S. no	Models	K	-2Log likelihoo	ΔAIC	AIC *wt*
1	ψ (Dist) γ (.) *p* (Water + Grass)	6	319.77	0.00	0.46
2	ψ (Dist) γ (.) *p* (Water + Grass+ Year + effort)	13	307.86	1.91	0.18
3	ψ (Water) γ (.) *p* (Water+ Grass + Year +	13	309.21	3.44	0.08
4	effort)	6	323.59	3.82	0.07
5	ψ (Water) γ (.) *p* (Water+ Grass)	4	327.86	4.09	0.06
6	ψ (Dist) γ (.) *p* (.)	13	310.47	4.70	0.04
7	ψ (Grass) γ (.) *p* (Water+ Grass + Year +	4	328.52	4.75	0.04
8	effort)	6	325.42	5.65	0.03
9	ψ (Water) γ (.) *p* (.)	7	324.58	6.77	0.01
10	ψ (Grass) γ (.) *p* (Water+ Grass)	4	332.57	8.80	0.00
11	ψ (Dist + Year) γ (.) *p* (.)	3	334.68	8.91	0.00
12	ψ (Grass) γ (.) *p* (.)	8	325.81	10.04	0.00
13	ψ (.) γ (.) *p* (.)	11	323.42	13.65	0.00
14	ψ (Dist) γ (.) *p* (veg.type)	7	333.47	15.97	0.00
15	ψ (Year) γ (Year) *p* (Year)				
16	ψ (veg.type) γ (.) *p* (.)				
17	ψ (Dist) γ (year) *p* (Water + Grass)*				
	ψ (Dist) ε (year) *p* (Water + Grass)*				
	ψ (year) ε (year) *p* (year)*				

Appendix 3. Model averaged estimates of model coefficients for model set 1 detection probability (*p*) models. Water bodies = no. of water bodies; Grass marsh = extent of grass marsh.

Parameter	Site covariates		Year				Effort			
	Water bodies	Grass marsh	2006	2007	2008	2009	2006	2007	2008	2009
Coefficient	0.07	0.07	-1.06	-0.68	-0.99	-1.44	0.12	-0.56	0.20	1.14
Standard error	0.13	0.10	0.40	1.38	0.41	0.58	0.13	1.85	0.20	0.50
Cumulative weight	0.91	0.83	0.62	0.62	0.62	0.62	0.61	0.61	0.61	0.61

Appendix 4. Model averaged estimates of model coefficients for occupancy (ψ) and detection probability (*p*) models. Water bodies = no. of water bodies; Grass marsh = extent of grass marsh.

Parameter	Site covariates			Year			
	Water bodies	Grass marsh	Disturbance level	2006	2007	2008	2009
Detection probability							
Coefficient	0.26	0.26	_	0.26	-0.08	-0.23	-0.36
Standard error	0.28	0.19	_	0.12	0.41	0.11	0.17
Cumulative weight	0.88	0.88	_	0.31	0.31	0.31	0.31
Occupancy							
Coefficient	0.04	0.01	-0.28	_	_	_	_
Standard error	0.01	0.02	0.20	_	_	_	_
Cumulative weight	0.20	0.07	0.73	_	_	_	_

Appendix 5. Sample data sheet for field surveys of Travancore tortoises.

<table>
<tr><td>Date:</td><td>Location name:</td><td></td><td>Protected Area:</td></tr>
<tr><td rowspan="4">Start time:

End time:</td><td rowspan="2">Start GPS location:</td><td>N:</td><td rowspan="2">Range:</td></tr>
<tr><td>E:</td></tr>
<tr><td rowspan="2">End GPS location:</td><td>N:</td><td rowspan="2">Habitat type:</td></tr>
<tr><td>E:</td></tr>
<tr><td>Surveyors name:</td><td colspan="3"></td></tr>
</table>

S.No	Time	Microhabitat	Signs	individuals	GPS location		Remarks
					N	E	

Appendix 6. Sample questionnaire sheet for Travancore tortoise occurrence survey.

Date:	**Location name:**	**Settlement or village name:**	**Protected Area:**
Surveyors name:		**GPS location:** **N:** **E:**	**Range:**

S.No	Name of the villager	Age	Sex	No of individuals sighted	Date & time of sighting	Location

Appendix 7. Fact sheet for Travancore tortoise in four different languages (Tamil, Malayalam, Kannada and English)

இந்தியாவில் மட்டும் காணப்படும் ஆமைகள்

ಭಾರತಕ್ಕೆ ಸೀಮಿತವಾದ ಆಮೆಗಳು

ഇന്ത്യയിൽ മാത്രം ജീവിക്കുന്ന ആമകൾ

India's Endemic Turtles

Locality records

திருவாங்கூர் ஆமை (Travancore tortoise) ஒரு பெரிய காட்டு ஆமை. அது 330 மி.மீ வரை வளரக் கூடியது. அது அதிகளவில் மலைக்காடுகளில் 450-850 மீ கடல் மட்ட உயரத்தில் காணப்படும். ஆண் ஆமைகள் இனச்சேர்க்கையின் போது ஒன்றோடு ஒன்று மோதிக்கொள்ளும். பெண் ஆமைகள் மண்ணில் ஒரு சிறிய குழி தோண்டி அதில் முட்டையிடும், ஒன்று முதல் ஐந்து முட்டைகள் வரை இடும். ஆமைகுஞ்சுகள் 55-60 மி.மீ நீளம் வரை இருக்கும். இவ்வகை ஆமைகள் அதிகளவில் வேட்டையாடப்படுகின்றன. அது மட்டுமில்லாமல் காட்டுத்தீ, வாழிடம் நாசக்கேடு மற்றும் வாழிடம் துண்டாதல்' மூலமாக இவ்வினம் அழியும் அபாயத்தில் உள்ளது.

இனம் கண்டறிதல்: தலையின் பின் முதுகோட்டில் சிறிய செதில் இருக்காது ஓட்டின் முதுகெலும்பு பாகத்தில் இரண்டாவதாக வரும் ஓடுதான் ஆமையின் உயரமான பகுதி ஆகும்.

தகுதி : ஐ.யு.சி.என் (IUCN) ரெட் லிஸ்ட் - வல்ணரபல். இந்திய வனவிலங்கு (பாதுகாப்பு) சட்டம் - செட்யூல் IV.

பரவியிருத்தல் : தமிழகம், கேரளம் மற்றும் கர்நாடகா மாநிலங்களில் மேற்கு தொடர்ச்சி மலைப்பகுதியில் மட்டும் காணப்படுபகிறது.

அவரவர் மொழிகள் : தமிழ் : பெரிய ஆமை, கல் ஆமை, காடர் : வெங்கல ஆமை, கன்னடம்: பெட்ட ஆமே, குட்டே ஆமே, காடு ஆமே. மலையாளம் : சூரல் ஆமா.

இவ்வின ஆமையை உங்கள் பகுதியில் பார்த்தாலோ, கேள்விப்பட்டாலோ தயவு செய்து கீழ்க்கண்ட முகவரிக்கு தெரிவிக்கவும். நாங்கள் கண்டிப்பாக உங்களை தொடர்புக் கொள்வோம்.

ಟ್ರಾವಂಕೋರ್ ಆಮೆ (Travancore tortoise): ಕಾಡಿನಲ್ಲಿ ಜೀವಿಸುವ ಒಂದು ಅತಿದೊಡ್ಡ ಆಮೆ. ಇದು 330 ಮಿಮೀ.ನಷ್ಟು ಬೆಳೆಯುತ್ತದೆ. ಇದು ಮುಖ್ಯವಾಗಿ ಹುಲ್ಲು ಮತ್ತು ಸಣ್ಣಗಿಡಗಳನ್ನು ತಿನ್ನುತ್ತದೆ. ಇದು ಮೃದ್ವಂಗಿಗಳು, ಕೀಟಗಳು, ಸತ್ತು ಕೊಳೆಯುತ್ತಿರುವ ಪ್ರಾಣಿಗಳು, ಶಿಲೀಂದ್ರಗಳು ಮತ್ತು ಹಣ್ಣುಗಳನ್ನೂ ಸಹ ತಿನ್ನುತ್ತದೆ. ಇದು 450–850 ಮೀ. ಸಮುದ್ರಮಟ್ಟದಿಂದ ಎತ್ತರದಲ್ಲಿರುವ ಗುಡ್ಡ ಪರ್ವತದ ಕಾಡುಗಳಲ್ಲಿ ಕಂಡು ಬರುತ್ತದೆ. ಸಂತಾನೋತ್ಪತ್ತಿಯ ಸಮಯದಲ್ಲಿ ಅಂದರೆ ನವೆಂಬರ್‌ನಿಂದ ಮಾರ್ಚ್‌ನಲ್ಲಿ ಗಂಡು ಆಮೆಗಳು ತಮ್ಮ ಹೊರ ಮೇಲ್ಮೈ ಚಿಪ್ಪಿನಿಂದ ಗುದ್ದಿ ಹೋರಾಡುತ್ತವೆ. ಇವುಗಳು ನೆಲದಲ್ಲಿ ಸಣ್ಣದಾದ ಗುಂಡಿಯನ್ನು ಮಾಡಿಕೊಂಡು ಅಲ್ಲಿ 50–60 ಮಿಮೀ. ಗಾತ್ರದ ಮೊಟ್ಟೆಗಳನ್ನು ಇಡುತ್ತದೆ. ಇದನ್ನು ಬೇಟೆಯಾಡುತ್ತಾರೆ, ಹಾಗೂ ಕಾಡ್ಗಿಚ್ಚು, ಆವಾಸಸ್ಥಾನದ ನಾಶ ಮತ್ತು ಆವಾಸಸ್ಥಾನದ ಛಿದ್ರೀಕರಣದಿಂದಾಗಿ ಈ ಪ್ರಾಣಿಯು ಅವನತಿಯ ಹಂತ ತಲುಪುವ ಭೀತಿ ಇದೆ.

ಗುರುತಿಸುವಿಕೆ : ಈ ಆಮೆಯಲ್ಲಿ ನೆತ್ತಿಯ (ತಲೆ) ಮೇಲಿನ ಸ್ಕ್ಯೂಟ್ ಇರುವುದಿಲ್ಲ ಮತ್ತು ಬೆನ್ನುಹುರಿಯ ಜೊತೆ ಇರುವ ಎರಡನೇ ಸ್ಕ್ಯೂಟ್ ಮೇಲ್ಮೈ ಚಿಪ್ಪಿನ ತುದಿಯಲ್ಲಿರುತ್ತದೆ.

ಸ್ಥಾನಮಾನ : IUCN ಕೆಂಪು ಪಟ್ಟಿಯ ಪ್ರಕಾರ ಇದು 'ವಲ್ನರ್‌ಬಲ್' (Vulnerable) ಎಂದು ಗುರುತಿಸಲ್ಪಟ್ಟಿದೆ. ಭಾರತದ ವನ್ಯಜೀವಿ ಸಂರಕ್ಷಣಾ ಕಾಯಿದೆಯ ಪ್ರಕಾರ ಇದು ಶೆಡ್ಯೂಲ್ IVಗಿ ರಲ್ಲಿರುವ ಪ್ರಾಣಿ.

ಹಂಚಿಕೆ: ಈ ಆಮೆಗಳು ಕೇರಳ, ಕರ್ನಾಟಕ ಹಾಗು ತಮಿಳುನಾಡು ರಾಜ್ಯಗಳಲ್ಲಿರುವ ಪಶ್ಚಿಮ ಘಟ್ಟದ ಕಾಡುಗಳಿಗೆ ಸೀಮಿತವಾಗಿದೆ.

ಸ್ಥಳೀಯ ಹೆಸರುಗಳು : ಕನ್ನಡ – ಬೆಟ್ಟ ಆಮೆ, ಗುಡ್ಡೆ ಆಮೆ, ಕಾಡು ಆಮೆ. ಮಲಯಾಳಂ – ಚುರ್ರೆಲ್ ಆಮ. ತಮಿಳು– ಪೆರಿಯ ಆಮೈ, ಕಲ್ ಆಮೈ, ಕಾಡಾರ್ – ವೆಂಗಲ ಆಮೈ.

ಈ ಆಮೆಯನ್ನು ನೋಡಿದರೆ ಅಥವಾ ಅದು ಇರುವ ಬಗ್ಗೆ ನಿಮ್ಮ ಸ್ಥಳದಲ್ಲಿ ಮಾಹಿತಿ ದೊರೆತರೆ, ದಯವಿಟ್ಟು ಈ ಕೆಳಗೆ ಕೊಟ್ಟಿರುವ ವಿಳಾಸಕ್ಕೆ ಬರೆದು ಅಥವಾ ದೂರವಾಣಿಯ ಮೂಲಕ ಕರೆಮಾಡಿ ತಿಳಿಸಿ. ನಂತರ ನಾವು ನಿಮ್ಮೊಂದಿಗೆ ಇದರ ಬಗ್ಗೆ ಮಾಹಿತಿ ಪಡೆಯಲು ಬಹುಬೇಗ ಸಂಪರ್ಕಿಸುತ್ತೇವೆ.

തിരുവിതാംകൂർ ആമ: (Travancore tortoise) 330 മില്ലി മീറ്ററോളം വലുപ്പമുള്ള കാട്ടാമകളാണ് തിരുവിതാംകൂർ ആമകൾ. നത്തക്കക്ക, പ്രാണികൾ, കൂണുകൾ, പഴങ്ങൾ തുടങ്ങിയവയെ എല്ലാം ഭക്ഷണമാക്കുമെങ്കിലും, ഇവയുടെ പ്രധാനയാഹാരം കുറ്റിച്ചെടികളും, പുല്ലുകളുമാണ്. 450 മുതൽ 850 മീറ്റർ വരെ ഉയരമുള്ള മലമ്പ്രദേശങ്ങളിലാണ് ഇവയെ സാധാരണയായി കാണുന്നത്.

മണ്ണിൽ ചെറിയ കുഴികൾ ഉണ്ടാക്കി അതിലാണിവ മുട്ടയിടുന്നത്. ഒരേസമയം 1 മുതൽ 5 വരെ മുട്ടകൾ ഇടാറുണ്ട്. മുട്ട വിരിഞ്ഞുവന്ന ആമക്കുഞ്ഞുങ്ങൾക്ക് ഏതാണ്ട് 55-60 മി.മീറ്ററോളം വലുപ്പമുണ്ടാകും. വേട്ടയാടൽ കൂടാതെ കാട്ടുതീ, ആവാസവ്യവസ്ഥയുടെ നശീകരണം, വിഘടനം, എന്നിവയെല്ലാം ഇവയുടെ നിലനിൽപ്പിന് ഭീഷണിയാകുന്നു.

തിരിച്ചറിയൽ: തവിട്ട് നിറത്തിലുള്ള പുറംതോടിൽ കറുപ്പോ, കടും കാപ്പിനിറത്തോടു കൂടിയതോ ആയ ചെറിയ ദീർഘചതുരാകൃതിയിലുള്ള അടയാളങ്ങൾ ഇവയെ തിരിച്ചറിയാൻ സഹായിക്കും.

IUCN റെഡ് ലിസ്റ്റിൽ വംശനാശഭീഷിണി നേരിടുന്ന ഗണത്തിലാണ് ഇവയെ ഉൾപ്പെടുത്തിയിരിക്കുന്നത്. കൂടാതെ ഇന്ത്യൻ വന്യജീവി സംരക്ഷണനിയമത്തിന്റെ നാലാം പട്ടികയിൽ പെടുത്തിയിരിക്കുന്നു.

പ്രാദേശിക നാമങ്ങൾ: തമിഴ് - പെരിയ ആമൈ, കാടാർ-വെങ്കലാമ, കന്നട - ബെട്ട ആമേ, ഗുഡ ആമേ, കാട് ആമേ

നിങ്ങൾ ഇതിനെ കാണുകയോ ഇതിനെപ്പറ്റി കേൾക്കുകയോ ചെയ്തിട്ടുണ്ടെങ്കിൽ ദയവായി താഴെക്കൊടുത്തിരിക്കുന്ന മേൽവിലാസത്തിൽ ബന്ധപ്പെടുക. ഞങ്ങൾ ഉടൻതന്നെ നിങ്ങളുമായി ബന്ധപ്പെടുന്നതാണ്.

Travancore tortoise (*Indotestudo travancorica*) is a large forest tortoise growing up to 330 mm. It primarily feeds on grasses and herbs. It also feeds on molluscs, insects, animal carcass, fungi and fruits. It occurs in hill forests at 450-850 m above sea level. Males combat by ramming their shell during their breeding season between November and March. It makes a shallow nest in the ground and lay 1-5 eggs. Hatchlings are 55-60 mm in size. The tortoise is hunted and it is threatened due to forest fires, habitat destruction and fragmentation. Identification: a scute right behind the head is absent and the second scute along the vertebral column is located at the highest point of the shell. Status: IUCN Red list - Vulnerable; India's Wildlife (Protection) Act: Schedule IV. Distribution: restricted to the Western Ghats, in the states of Kerala, Karnataka and Tamil Nadu. Vernacular names: Tamil: Periya amai, Kal amai, Kadas: Vengala amai. Kannada: Betta aame, Gudde aame, Kadu aame. Malayalam: Churrel aama.

If you have seen or heard about this tortoise anywhere in your area, please write or contact us at the address given below and we will get in touch with you soon

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