การใช้วิทยุติดตามในการศึกษาขนาดของเขตอาศัยและกิจกรรมของเต่าหกดำ

*Manouria emys phayrei* (Blyth, 1853)

นาย ปรัชญาพร วันชัย



วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

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ปีการศึกษา 2550

# RADIO-TELEMETRY STUDY OF HOME RANGE SIZE AND ACTIVITIES OF THE BLACK ASIAN GIANT TORTOISE *Manouria emys phayrei* (Blyth, 1853)

Mr. Pratyaporn Wanchai



A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Zoology
Department of Biology
Faculty of Science
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| Thesis Title | RADIO-TELEMETRY STUDY OF HOME RANGE SIZE AND ACTIVITIES OF THE BLACK ASIAN GIANT TORTOISE *Manouria emys phayrei* (Blyth, 1853) |
| By | Mr. Pratyaporn Wanchai |
| Field of Study | Zoology |
| Thesis Advisor | Associate Professor Kumthorn Thirakhupt, Ph.D. |
| Thesis Co-advisor | Professor Craig B. Stanford, Ph.D. |

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ปรัชญาพร วันชัย: การใช้วิทยุติดตามในการศึกษาขนาดของเขตอาศัยและกิจกรรมของเต่าหกดำ *Manouria emys phayrei* (Blyth, 1853). (RADIO-TELEMETRY STUDY OF HOME RANGE SIZE AND ACTIVITIES OF THE BLACK ASIAN GIANT TORTOISE *Manouria emys phayrei* (Blyth, 1853)) อ. ที่ปรึกษา: รศ. ดร. กำธร ธีรคุปต์, อ.ที่ปรึกษาร่วม: ศ.ดร. Craig Stanford, 84 หน้า.

การศึกษาอาณาเขตที่อยู่อาศัยและกิจกรรมการดำรงชีวิตของเต่าหกดำที่อุทยานแห่งชาติแก่งกระจาน จังหวัดเพชรบุรี ได้ดำเนินการ ตั้งแต่เดือน พฤศจิกายน 2548 – มิถุนายน 2550โดยใช้วิทยุติดตาม เต่าหกดำตัวเต็มวัยจำนวน 11 ตัว (ตัวผู้ 7 ตัว และตัวเมีย 4 ตัว) และตัวที่ยังเจริญไม่เต็มวัย 3 ตัว จากบริเวณเขาพะเนินทุ่งถูกนำมาติดเครื่องส่งสัญญาณวิทยุ เพื่อทำการติดตามเก็บข้อมูลในภาคสนาม พบว่าค่ามัธยฐานของเขตอาศัยตลอดทั้งปีของเต่าหกดำเพศผู้ คือ 0.60 ± 0.33 ตารางกิโลเมตร เพศเมีย คือ 0.56 ± 0.07 ตารางกิโลเมตร และตัวที่ยังไม่เต็มวัย คือ 0.08 ± 0.06 ตารางกิโลเมตร ขนาดของเขตอาศัยตลอดทั้งปีของเพศผู้และเพศเมียไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ แต่มีขนาดของเขตอาศัยมากกว่าตัวที่ยังไม่เต็มวัยอย่างมีนัยสำคัญทางสถิติ เมื่อศึกษาเป็นฤดูกาลพบว่า ขนาดของเขตอาศัยในฤดูฝนของเพศผู้และเพศเมีย มีขนาดกว้างกว่าในฤดูแล้งอย่างมีนัยสำคัญทางสถิติ แต่ในตัวที่ยังไม่เต็มวัยพบว่าขนาดของเขตอาศัยในฤดูฝนและฤดูแล้งไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ จากการศึกษา สามารถจำแนกถิ่นอาศัยของเต่าหกดำได้ 5 ประเภท ได้แก่ ป่าไผ่ ป่าดิบแล้ง ป่าดิบแล้งผสมป่าไผ่ ลำธารตื้นๆ และพื้นที่ชุ่มน้ำ โดยในช่วงฤดูฝน เต่าหกดำตัวเต็มวัยเลือกที่จะอยู่ในบริเวณป่าไผ่ซึ่งเป็นบริเวณที่มีแหล่งอาหารคือหน่อไม้ขึ้นอยู่ทั่วไป ส่วนตัวที่ยังไม่เต็มวัย มักจะพบแช่โคลนอยู่บริเวณพื้นที่ชุ่มน้ำ ในฤดูแล้งหนาว (พฤศจิกายน -กุมภาพันธ์) พบว่าเต่าหกดำทั้งตัวเต็มวัยและยังไม่เต็มวัย ส่วนใหญ่จะมีพฤติกรรมการซุกซ่อนตัวโดยเต่าหกจะซุกตัวใต้ใบไม้หรือกองไม้แห้ง และในฤดูแล้งร้อน (มีนาคม-เมษายน) พบว่าเต่าหกดำทั้งตัวเต็มวัยและยังไม่เต็มวัย เลือกที่จะอาศัยอยู่ใกล้ๆกับลำธารและมักจะพบว่าลงไปแช่น้ำในลำธารตื้นๆ สำหรับการศึกษาปัจจัยทางกายภาพในถิ่นที่อยู่อาศัยของเต่าหกดำพบว่ามีอุณหภูมิอากาศและความชื้นสัมพัทธ์เฉลี่ยตลอดปีในบริเวณที่พบ เต่าหกดำเพศผู้ เพศเมีย และตัวที่ยังเจริญไม่เต็มวัย ไม่แตกต่างอย่างมีนัยสำคัญทางสถิติ (ANOVA, $p<0.05$) และ จากข้อมูลการศึกษาด้านอาหารพบว่า เต่าหกดำกินพืชหลายชนิดเป็นอาหารเช่น *Lasia spinosa*, *Zingiber* sp., *Amorphophallus paeoniifolius*, *Musa* sp., *Marantha* sp., *Bambusa* sp. และเห็ดที่ไม่สามารถจำแนกชนิดได้ 2 ชนิด อาหารหลักของเต่าหกดำตัวเต็มวัย คือ หน่อไม้ *Bambusa* sp. และอาหารหลักสำหรับเต่าหกดำตัวยังเจริญไม่เต็มวัย คือ *Lasia spinosa*

ภาควิชา......ชีววิทยา...... ลายมือชื่อนิสิต......ปรัชญาพร วันชัย......
สาขาวิชา......สัตววิทยา...... ลายมือชื่ออาจารย์ที่ปรึกษา......กำธร ธีรคุปต์......
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PRATYAPORN WANCHAI : RADIO-TELEMETRY STUDY OF HOME RANGE SIZE AND ACTIVITIES OF THE BLACK ASIAN GIANT TORTOISE *Manouria emys phayrei* (Blyth, 1853). THESIS ADVISOR: ASSOC. PROF. KUMTHORN THIRAKHUPT, Ph.D., THESIS CO ADVISOR: PROF. CRAIG STANFORD, Ph.D., 84 pp.

Home range sizes and activities of *Manouria emys phayrei* were studied at Kaeng Krachan National Park, Phetchaburi Province, Thailand from November 2005 - June 2007. A total of fourteen *M. emys phayrei*, consisting of eleven adults (seven males and four females) and three juveniles was radio-tracked. The median annual home ranges (95% minimum convex polygon) were $0.60 \pm 0.33$, $0.56 \pm 0.07$ and $0.08 \pm 0.06$ $km^2$ for adult males, adult females and juveniles, respectively. The median home range sizes of males and females were not significantly different but were significantly larger than the home range sizes of juveniles (Mann-Whitney U-test). The median home range sizes in the wet season (May – October) were larger than in the dry season (November – April) for most individuals. *M.e.phayrei* utilized 5 types of habitats; bamboo forest, dry evergreen forest, dry evergreen forest mixed with bamboo, stream and mud-swamp. In the rainy season (May - October), most adult tortoises were found foraging in the bamboo forest whereas juvenile tortoises were generally located in the mud-swamp. In the cold dry season (November-February), few tortoises were active and they were often found beneath fallen branches or leaf litter whereas in the hot-dry season (March - April) they were frequently found soaking in the shallow stream. The year-round averages for air temperature and relative humidity where the males, females and juveniles were found were not significantly different (ANOVA, $p<0.05$). Furthermore, the results showed that these tortoises are generalist herbivores, consuming at least 10 species of plants such as *Lasia spinosa*, *Zingiber* sp., *Amorphophallus paeoniifolius*, *Musa* sp., *Marantha* sp. and *Bambusa* sp.. *Bambusa* sp. and *Lasia spinosa* were main diets of adults and juveniles, respectively.

Department.......Biology....... Student's signature.......P. Wanchai.......
Field of study.....Zoology....... Advisor's signature.......K. Thirakhupt.......
Academic year....2007........... Co-advisor's signature.......[signature].......

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Finally, I would like to dedicate my work to my family for their love and support for everything. Finally, I would like to thank and express my deepest gratitude to all my teachers at all levels.

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# CHAPTER I

# INTRODUCTION

Thailand is one of the world's leading nations in chelonian biodiversity, with at least 26 species, or more than 10% of the world's total chelonian species diversity (Thirakhupt and van Dijk, 1994). At present, many turtle and tortoise species in Thailand are under intensive human threat by hunting for food and pet trade. Most recent works on turtles and tortoises in Thailand were on their taxonomy, distribution and status (Nutaphand, 1979; Chan-ard and Nabhitabhata, 1986; Nabhitabhata, 1989 and Thirakhupt and van Dijk, 1997) but there are few studies on biology and ecology such as home range size and activity pattern in the wild.

The black giant tortoise, *Manouria emys phayrei* is the largest tortoise of mainland Asia (Smith, 1973). *M.e. phayrei* is classified as an endangered species by IUCN 2007 whereas CITES 2007 places it in Appendix II. The major human threats to *M.e. phayrei* are habitat destruction, hunting for food and pet trade. Although it has been maintained and bred in captivity, little is known of its home range, habits, diet, reproduction and activities in the wild.

Several methods are available to determine activity areas and home ranges of tortoises such as mark-recapture and thread trailing techniques, However, the best method to obtain detailed information on movement is through radiotelemetry (Pough *et al*., 2001). Advances in the field of wildlife telemetry have made it possible to acquire detailed data on many aspects of wildlife biology, including habitat use, home range size, mortality, survivorship, and migration timing and routes. Since many wildlife species are secretive and difficult to observe, radiotelemetry has provided a valuable tool to learn more about their respective life histories, even when dense vegetation precludes effective visual searching. (Palomares and Delibes, 1991). An important consideration for using radio telemetry techniques is assuring that they do not affect significantly the behavior, physiology, reproductive success, and survival of the animals (Boardman *et al*., 1998).

The purpose of this project is to study the home range size, activities and morphology of *M.e. phayrei* in the wild. The benefit of this study is to provide new and useful basic information on its home range size, ecology and behavior which could be used for determining reserve areas and future management for the black giant tortoise.

The objectives of this study were;

1. To determine the home range size of the black Asian giant tortoise, *M.e.phayrei*
2. To describe activities and some environmental conditions which affect the activities of the black Asian giant tortoise

# CHAPTER II

# LITERATURE REVIEW

## 2.1 Description and taxonomy of *Manouria emys phayrei*

This species is classified in:

Phylum: Chordata

Class: Reptilia

Order: Testudines

Family: Testudinidae

Genus: *Manouria*

Species: *Manouria emys*

Subspecies: *Manouria emys phayrei*

*Manouria emys* is one of the two tortoise species in the genus *Manouria*. It is the largest Asian terrestrial chelonian. Specimens attaining a length of over 60 mm and a weight of 37 kg have been recorded (Moll, 1989).

*M. emys* is divided into two subspecies by the shape and the arrangement of pectoral plastral scutes (Aranyavalai, 1996), *M. emys phayrei* (Blyth, 1853) and *M. emys emys*. The common name of *M.e.phayrei* is widely known as the black giant tortoise, other common names include the Asian brown tortoise, Burmese mountain tortoise, Burmese brown tortoise, Burmese black tortoise and black Asian giant tortoise.

The species was originally described as *Testudo emys* by Schlegel and Müller in 1844. Since then, their taxonomy has been altered. The subspecies *phayrei* was first described by Blyth in 1853. Today they are classified in the genus '*Manouria*'. The Burmese brown tortoise is classified by the species name *'emys'* and is further broken down into two subspecies, '*e. emys'* and '*e. phayrei'*. In 1979, Nutaphand, in his book

Turtle of Thailand, referred to *M.e.phayrei* as *'Geochelone nutapundi'*. However, the older name for the subspecies should still be valid.

*Manouria* is believed to be the most primitive genus of living tortoises, based on a lack of many derived morphological features of other tortoises, such as mental glands, carpal bone alignment (Auffenberg, 1966), and primitive gular scute structure (Crumly, 1982, 1984; Highfield, 1990), and preference for a wet rather than arid habitat (Crumly, 1982). *Manouria emys* engages in behaviors, such as nest-building and nest-guarding, which occurs in no other species of the tortoise (Schaeffer and Morgan, 2002; Ruby and Senneke, 2003).

## 2.2 Distribution

*M.e.phayrei* ranges from Assam, India to Myanma, Bangladesh and western Thailand, while *M.e.emys* ranges from Peninsula Malaysia, Sumatra to Borneo. For Thailand, *M.e.payrei* can be found from Tak Province (northern Thailand) as far south as Ranong and western Surat Thani Province, and may extend into northern Phang-nga Province, while *M.e.emys* ranges from Southern Thailand (Ranong and Nakorn Sri Thammarat Province) to northern Malaysia (Ernst and Barbour , 2001; Fritz and Havas, 2007; Moll, 1989; Morgan and Schaffer, 2001; Nutaphand, 1979).

## 2.3 Morphology

*Manouria emys phayrei* is the largest Asian tortoise. It grows to 60 centimeters in carapace length and weighs up to 37 kilograms (Moll, 1989). The plain brown carapace is highly domed. The extremities are broad and plump. The anterior and posterior marginal scutes are upturned and slightly serrate. A rather broad cervical scute is present. Vertebrals are wider then long; $5^{th}$ is expanded. It has well-defined growth annuli surround the flat areolae of the vertebrals and pleural. Eleven marginals lie on each side, and the supracaudals are divided both dorsally and ventrally. The carapace varies from olive or brown to black; vertebral and pleural areolae may be tan in young individuals. The plastron is well developed and has both an anterior and posterior notch. Plastral lobes are almost equal in length and width. The gulars are thickened and extend beyond the carapacial rim. The bridge is wide; the two or more inguinal scales are larger than the single axillary. The plastron is yellow with black shading, usually around the periphery. The head is moderate to large with a nonprojecting snout and a slightly hooked upper jaw. Its prefrontal is divided longitudinally, and followed by a single large frontal scale; other head scales are small. The head is black with some pink, bronze, or brown pigment. Limbs and tail are black. The anterior surface of each forelimb is covered with large, pointed, overlapping scales. Several very large pointed tubercles (spurs) occur on each thigh, giving rise to the colloquial name of "six footed" tortoise, for the Thai name "tao hook dum". The tail ends in a horny scale (Ernst and Barbour, 2001) (Figure 3).

The two subspecies can be distinguished by the arrangement of the pectoral plastral scutes (Aranyavalai, 1996). These meet medially in *M.e.phayrei*, but do not meet in *M.e.emys* (Figure 1). *M.e.phayrei* is on average larger and lay larger egg clutches, and its carapace color tends to be darker brown at maturity (Schaeffer and Morgan, 2002).

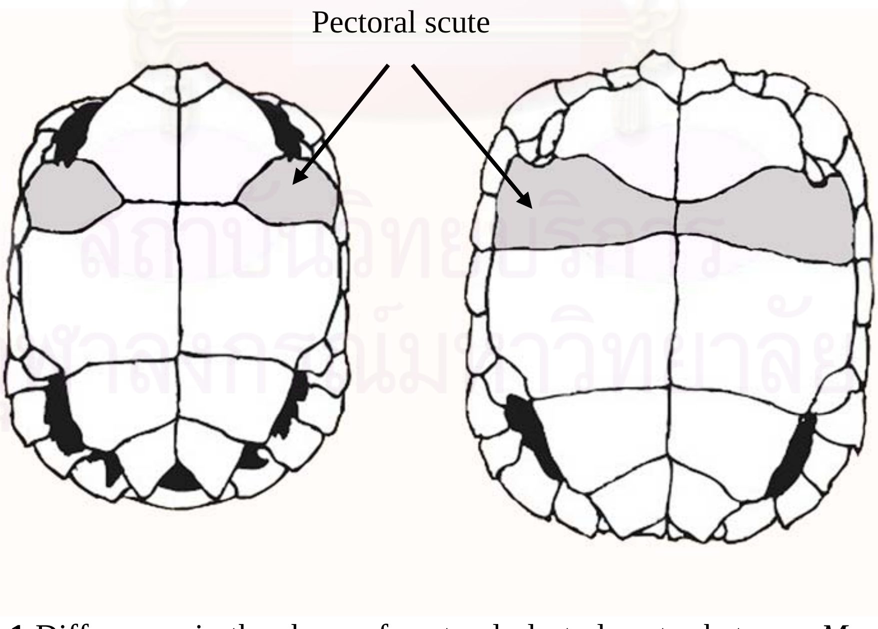


**Figure 1** Differences in the shape of pectoral plastral scutes between *M.e.emys* (left) and *M.e.phayrei* (right).

## 2.4 Sexual dimorphism

*M.e.phayrei* showed litter sexual dimorphism. Tail length is usually considered the most distinct character for determining sex in most tortoise species, males having longer and wider tails than females (Auffenberg and Iverson, 1979; Ernst and Babour, 1989; Schaffer and Morgan, 2002). However, this does not apply to *M. e. emys* (Cox *et al*., 1998). Other suggested male characteristics are concavity of plastron (Ernst and Babour, 1989), bulging of the fifth central scute and narrower carapace (Morgan and Schaffer, 2001; Schaffer and Morgan, 2002).

Aranyavalai (1996) reported that five different morphological characters were found to distinguish males from females in *M. e. phayrei*. These were; 5th central scute length and width, 4th lateral scute length, abdominal scute width and tail length.

## 2.5 Natural habitat

*M.e.phayrei* is usually found in highland tropical evergreen forest of Southeast Asia and prefers moist situations. During the warmer parts of the day, these tortoises prefer to soak in pools or to remain in the shade, out of the sun's rays. It some times forages in shallow mountain streams. Much time is spent under the moist soil or under leaf litter (Nutaphand, 1979).

Mortensen (2004) conducted a six month study, with thirteen telemetry-tagged animals, in Tabin Wildlife Sanctuary in southeastern Sabah, East Malaysia. He reported that *M.e.emys* were observed in deep gullies, on the steep sides of ravines, near the top of the hills and shade seemed to be essential for suitable tortoise habitat. Humidity measurements at the forest floor during the daytime rarely fell below 90% and temperatures range between 25.8°C and 34.6°C. The lack of tortoises in the palm monocultures surrounding the reserve suggests that the clear-cut forestry practice leads to extinction in the affected areas.

## 2.6 Diet

Nutaphand (1979) reported that *M.e.phayrei* feeds mainly on variety of vegetations, including bamboo shoots, lotus and banana trunk. However, little is recorded about the diet of this species in the wild.

Lambert and Howes (1994) found that one *M. e. emys* female in Danum Valley Conservation Area, Sabah, East Malaysia fed on small seedlings, herbs and fallen fruits. Five were indentified as *Polyporus grammocephaus*, *Laetiporus sulphreus*, *Lentinus polychrous* and two species of *Russula* and at least seven species of fungi were eaten by tortoise.

Mortensen (2004) reported that the main diet of *M. emys emys* in Tabin Wildlife Reserve Sabah, Borneo is *Alocasia* sp. In addition, plants from the families Begoniaceae, Melostomataceae, Marantaceae, Woodsiaceae, Zingiberaceae and mushroom were eaten.

## 2.7 Status

*Manouria emys* is listed in the International Union for the Conservation of Nature and Natural Resources (IUCN) Red List 2007 as endangered, as defined by:

• population reduction in the form of an observed, estimated, inferred or suspected reduction of at least 50% over the last 10 years or three generations, whichever is the longer, based on (and specifying) a decline in area of occupancy, and extent of occurrence and/or quality of habitat actual or potential levels of exploitation;

• population reduction of at least 50%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer, based on (and specifying) a decline in area of occupancy, and extent of occurrence and/or quality of habitat actual or potential levels of exploitation.

*Manouria emys* is also listed on Appendix II of CITES 2007 and in Thai Wildlife Protection Law 1992.

## 2.8 Home range and activity pattern

The home range of an animal was first defined by Burt (1943) as the area traversed by the individual in its normal activities of food gathering, mating, and caring for young.

Variations in home range size are associated with the species, sex and age of animal, with the season, and with such ecological condition as available food and intraspecific strife (Smith, 1974). In poor habitat, the home range would be larger than in more adequate habitat (Dice, 1952). Overall size of the home range varies with the available food resources, mode of food gathering, body size, and metabolic needs. Among mammal species, the home range size is related to body size, reflecting the link between body size and energy requirement (food resources). In general, carnivores require a larger home range than herbivores and omnivores of the same size. Males and adults usually have larger home ranges than females and juveniles (Smith and Smith, 2006).

In terrestrial turtle, the yearly activity pattern is often affected by the necessity of a period of hibernation or estivation. In temperate areas, most terrestrial turtles have the highest activity peak in spring, but in xeric habitats the highest peak occurs during rainy periods. The daily activity cycle is in large part a response to temperature and moisture condition rather than to light. The mean daily movement of individual tortoise, regardless of species, seems to be greatest in populations where the shelter is apart from the feeding ground, or where food plants are scarce or widely scattered (Auffenberg and Iverson, 1979).

The only field data available for *Manouria emys* are from two field studies of *M. e. emys*. Lambert and Howes (1994) found that one *M. e. emys* female used a 0.6 $km^2$ area of forest, traveling less than 200 m during the course of the study.

Mortensen (2004) conducted a six month study, with thirteen telemetry-tagged animals, in Tabin Wildlife Sanctuary in southeastern Sabah, East Malaysia. He found wide individual variation in ranging patterns. Tortoises traveled from 0 to almost 400 m per day, and occupied home ranges from 0.01 $km^2$ to 1.81 $km^2$ (n=8). Tortoises were found to prefer activities like walking and foraging at ambient temperatures between 25.8°C and 34.6°C. When nighttime temperatures dropped, and when daytime temperatures increased, the tortoises hid under debris or tree falls for insulation.

McKeown *et al* (1991) studied on management and breeding of four separate captive *M. emys* consisting of two large adults *M.e.phayrei*, an adult female *M. e. emys* and a young adult *M. e. emys* in Captivity at Honolulu Zoo, California. They reported that *M.e.phayrei* female constructed a large leaf-litter mound by back sweeping ground litter for up to 4 m from the nest site; nested occurred in April, May and September and female usually laid two clutches a year. Clutch sizes in captivity were 23 to 51 eggs larger than that reported by Nutaphand (1979), who reported that the clutch sizes for *M. e. emys* were 5-8 eggs. The nesting female assumed nest guarding behavior against potential predators for a period of 3-6 days and 6-20 days for the *M. e. phayrei* and *M. e. emys*, respectively. When incubated artificially at temperatures ranging between 25.6-28.9 °C the egg incubation period was relatively short varying from 63-84 days.

Auffenberg and Weaver (1969) suggested that the home range size of the Texas tortoise, *Gopherus berlandieri* in southeastern Texas was related to food availability and shelter sites (burrows), i.e., home range size was larger where food plants were scarce or widely scattered and where pallets instead of burrows are constructed.

Rose and Judd (1975) studied on activity and home range size of the Texas tortoise, *Gopherus berlandieri*, in southern Texas, the results indicated that males had larger home ranges than females and that some of the home ranges were stable for at least 2 years. More tortoises were active in the evening than in the morning.

Barrett (1990) reported that the average home range size of 14 desert tortoises, *Xerobates agassizi* in the Picacho Mountains of Arizona was 19 ha (range 3-53 ha). Home range size was not significantly different between sexes and was not correlated with carapace length or number of observations. Tortoises used an average of eight dens each and reused previously occupied dens. Tortoises occupied larger dens in summer than in other seasons and moved to steeper rocky slopes in winter.

Pike (2006) reported that hatchling gopher tortoises, *Gopherus polyphemus* moved infrequently and over very short distances through their first winter, a period during which they are presumably receiving energy from yolk stores. With the onset of warm spring weather, hatchling tortoises began to move more, most likely to obtain energy after depleting yolk stores. Home range size varied from 0.0001-4.8 ha. Hatchlings moved infrequently, spent large amounts of time in burrows and under tall vegetation, and moved short distances while changing refugia.

## 2.9 Radio-telemetry

Radio telemetry was designed to track animals remotely in their natural environments in order to conduct studies on animal numbers, habitat use, behavior, survival, movement, and distribution patterns, among others. The technology has been developed drastically over the 40 years (Millspaugh and Marzluff, 2001).

Radio-telemetry has become widely used for studying turtle migration, dispersal, home range, habitat use, physiology, and the effectiveness of relocation efforts, such as *Gopherus berlandieri* (Rose and Judd, 1975), *Testudo kleinmanni* (Geffen and Mendelsson, 1988), *Xerobates agassizi* (Barrett, 1990), *Gopherus agassizii* (Barrett, 1990), *Gopherus Polyphemus* (Butler *et al.*, 1995) and *Testudo graeca* (Anadón *et al*., 2006). An important consideration for using radio transmitter techniques is assuring that they do not affect significantly the behavior, physiology, reproductive success, and survival of the animals (Boardman *et al*, 1998).

In Thailand, the radio-tracking technique was used in studying wildlife for the first time by Tsuji, Poonswad and Jirawatkavi in 1987, in a study of hornbills at Khao Yai National Park. The only study for tortoise in Thailand has been used in studying elongated tortoise, *Indotestudo elongata* at Khao Nang Rum Wildlife Research Station, Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province by Tharapoom (1996).

**Figure 2** Distribution of *Manouria emys* (Vetter and van Dijk, 2006)


Red = *Manouria emys emys*

Blue = *Manouria emys phayrei*

Pink = Area of intergradation


A

B

C

**Figure 3** A = Carapace of *M.e.phayrei* adult

B = Plastron of *M.e.phayrei* adult

C = Red circle shows large pointed tubercles (spurs) of *M.e.phayrei* adult

# CHAPTER III

# METHODOLOGY

## 3.1 Study area

Kaeng Krachan National Park was established in 1981, the 28 th National Park in Thailand. It is the largest national park in Thailand with 2,914.70 sq.km. of forest in the watersheds of the Phetchaburi and Pranburi rivers. It includes portions of Nong Ya Plong, and Kaeng Krachan Districts in Phetchaburi Province and of Hua Hin District in Prachuap Khiri Khan Province.

The National Park was designated on June 12, 1981 ; its original borders encompassed 2,478 sq.km. Later, the park area was extended, as proposed by the Hua Hin Environmental Conservation Group, to cover the boundary between Phetchaburi and Prachuap Khiri Khan Provinces.

### Topography

The area, about 45 squares kilometers, consists of both ground and water in reservoir. The vastly forest upper the Kaeng Krachan Dam is on complicated mountain ranges. The average height is 500 meters above mean sea level with the highest peak at 1,200 meters above mean sea level. Most of the mountains are granite mountain, few are limestone mountains, and many are full of fluoride. Most of the area is covered by rain forest so that it is the source of water of Phet Buri River and Pran Buri River.

### Watersheds and Climate

The park is composed of two major watersheds. About half of the area drains to the Phetchaburi River, which flows to Kaeng Krachan dam at the eastern edge of the park and then down through farmland to the provincial capital of Phetchaburi. The southern haft of the park drains to the Pranburi River, which flows south to the Pranburi dam and then on to the town of Pranburi in Prachuab Khiri Khan Province.

Because of the abundant rainfall and undisturbed forest cover in these watersheds, the streams, waterfalls and river of Keang Krachan flow year round.

The park is covered largely by evergreen forest. Humidity remains high throughout the year (Figure 5), with heavy rain during the rainy season (Figure 6) and cool weather, average temperature below 30 ºC for much of the year. The steep forest areas of the park are even more humid than the young forest and clear land in the lower elevation.

**Flora and Fauna**

Kaeng Krachan is located on the eastern slope of the Tenasserim Mountain Range at the border of Myanmar. It occupies the western half of Phetchaburi Province (Kaeng Krachan and Nong Ya Plong Districts) and a portion of northern Prachuap Khiri Khan Province (Hua Hin District).

Most of the park is steep forest. Over three-quarters of the area has slopes greater than 30 %, 85 % of the terrain is evergreen rainforest, another 10 % is mixed deciduous forest. The forest is rich and complex, with hanging lianas, ferns and orchids, and an abundance of fruiting trees and vines. The forest of Kaeng Krachan is unusually diverse because of its location at the juncture of continental Asia and the Malaysian Peninsula. Continental species such as oaks, chestnuts, and maples are found here, as are peninsula palms and fruiting trees. Some of the valuable trees of Kaeng Krachan include makhamong (Afzelia), takhian (Hopea), chanthana (Tarena), yang (Dipterocarpus), taback (Lagerstroemia), pradu (Pterocarpus), kritsana (Aquilaria), and many more.

Like the plant community, the animals of Kaeng Krachan represent both Asiatic and Malaysian species. Over 400 species of birds are known to occur within the Park’s boundaries, and 57 mammals. Larger mammals include elephant, gaur, sambar deer, banteng, serow, and bear, indo-chinese tiger, leopard, both common and Fea’s muntjac, Malayan tapir, white-handed gibbon, dusky and banded langurs, Asian

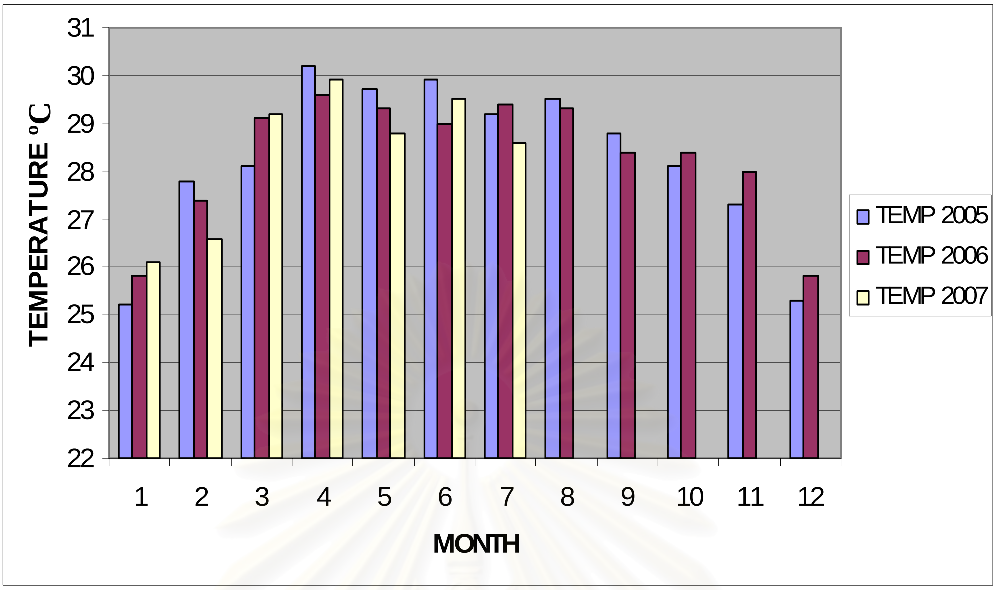


**Figure 4** Average Temperature at Kaeng Krachan National Park in 2005, 2006 and 2007 (January-July).

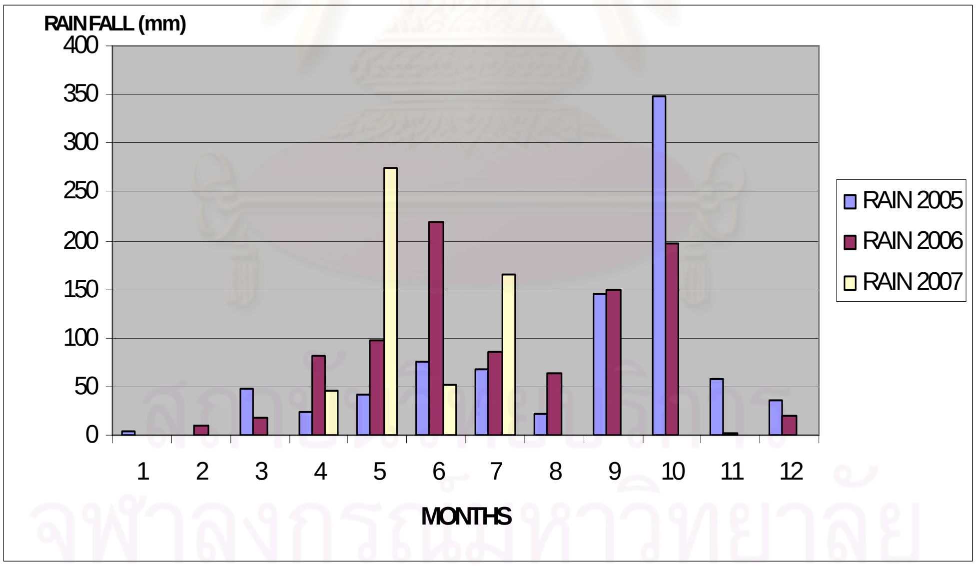


**Figure 5** Total rainfall at Kaeng Krachan National Park in 2005 (January-December), 2006 (January-December) and 2007(January-July).

wild dog, otter, and wild boar. Among the birds recorded in the park are six species of hornbills, red junglefowl, both Kalij pheasant and grey peacock-pheasant, woolly-necked stork, black eagle, and many species of songbirds, woodpeckers and other forest birds.

This study was conducted at Khao Phanoen Thung Substation. The study area is approximately 18 $km^2$, located between the elevations from 750 – 1200 m. Major habitat type in this area classified in to 5 types such as bamboo forest, dry evergreen forest, dry evergreen forest mixed with bamboo, stream and mud swamp.

## 3.2 Equipment

### 3.2.1 Radio-telemetry equipment

1. Transmitters used in this study; (Figure 10)

- Model 1, transmitter dimention: depth 1 cm., width 2.7 cm., length 4.4 cm., used 20 cm. antennas, mass 25 g. for adult.

- Model 2, transmitter dimention: depth 1 cm., width 2 cm., length 3 cm., used 20 cm. antennas, mass 15 g. for juvenile.

2. Advanced Telemetry Systems (ATS) receiver (Model FM16) (Figure 8).

3. Handheld ATS 3 element Folding Yagi Antenna (Figure 9)

4. GPS model Garmin GPS V

5. Thermo-Hygrometer

6. Infrared temperature gun

7. Spring balance, 30 kg.

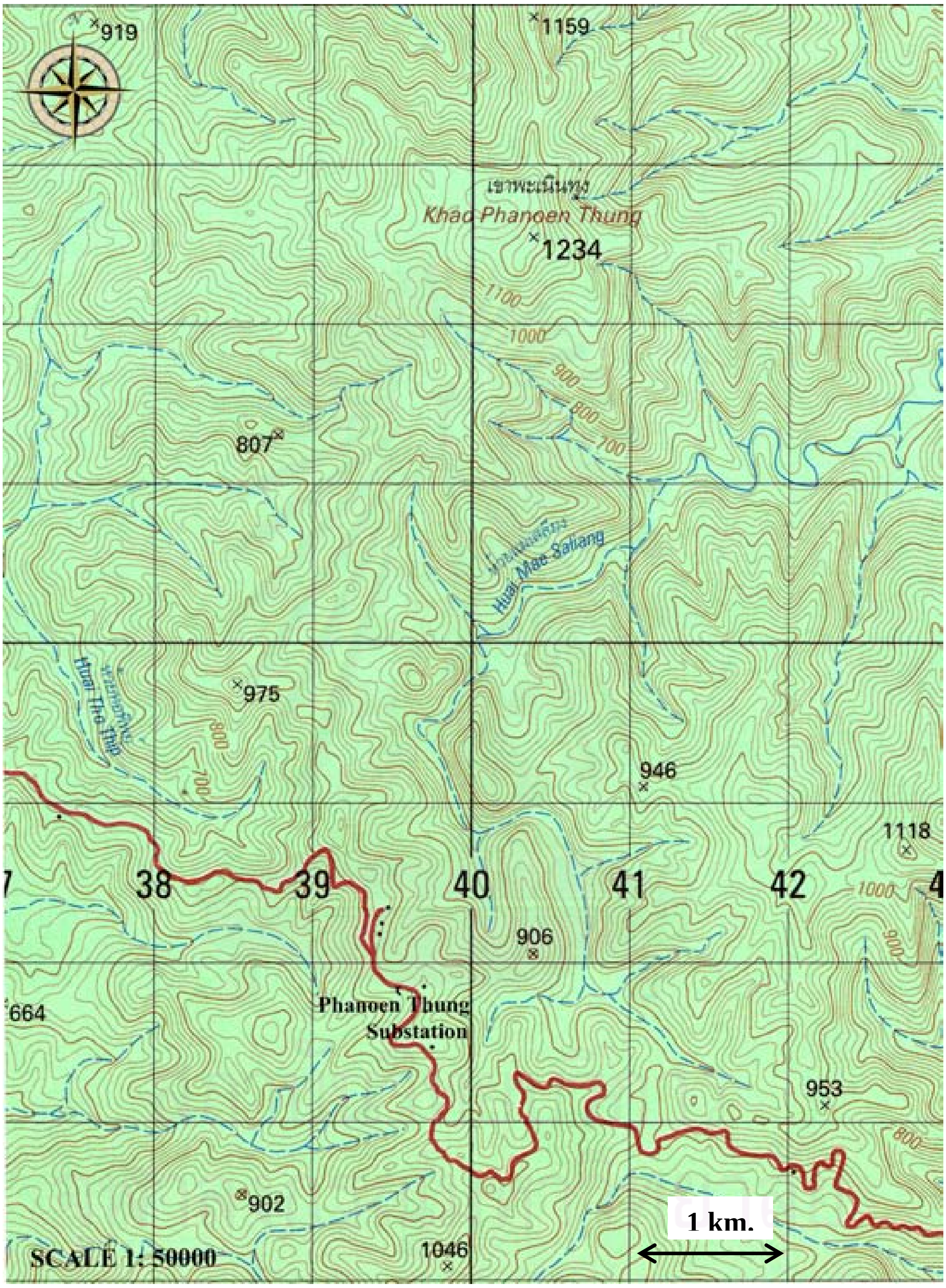


**Figure 6** Study area around Phanoen Thung Substation.


**Figure 7** ATS receiver (Model FM16)

**Figure 8** Handheld ATS 3 element Folding Yagi Antenna

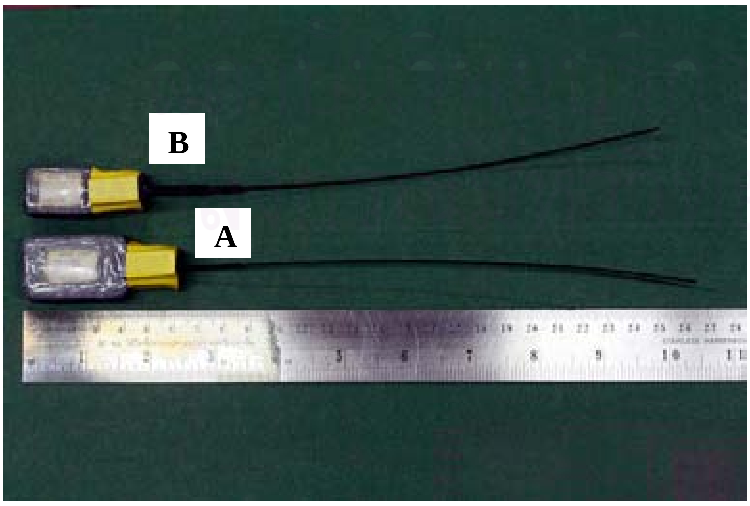


**Figure 9** 148 mhz Radiotransmitters

**A** = Model 1

**B** = Model 2

## 3.3 Study methods

### 3.3.1 Radio-telemetry technique

Each Tortoise was equipped with a 148 mhz radiotransmitter. The total amount of time for radio attachment was about 30 minutes. Post-attachment transmitter weight was 35 g. and 25 g. for adult and juvenile, respectively and did not exceed the recommended 5% of body weight guidelines (Schubauer, 1981). Transmitter life was approximately 18 months. Each tortoise was assigned a unique frequency.

Tortoises were located using a ATS receiver (Model FM16) and either a handheld ATS 3 element Folding Yagi Antenna.

### 3.3.2 Attachment of transmitters

After a tortoise was found in the forest, a transmitter was attached to the lower posterior part of the carapace using two-component epoxy which is waterproof and long-lasting but harmless to the animal (Boarman *et al.*, 1998) (Figure 11). Attachment of transmitters on females was anterior to the highpoint to avoid interference with mating (Figure 12). Sex was determined based on Aranyavalai (1996). The antenna was attached with epoxy around marginal scutes. Transmitters will be replaced if indications are that they are failing to function properly.

### 3.3.3 Collection of data

Field work was conducted from November 2005 -June 2007 in order to collect field data for two seasons (wet and dry season). Every tortoise was located 1-3 times per month, depending on the condition of the weather.


**Figure 10** Attachment of a transmitter on male.


**Figure 11** Attachment of a transmitter on female.

### 3.3.4 Home range

When the tortoise was found, the location was obtained by GPS. All point used a minimum accuracy of 20 meters. Positions were given in Universal Transverse Meercator (UTM).

### 3.3.5 Temperature and relative humidity

Temperature and relative humidity at the tortoise site were measured using a thermo-hygrometer at 1 m. above the forest floor. Carapace and surface temperature was measured using an infrared temperature gun at 2 m. from tortoise. All temperatures were given in degrees Celsius (°C) and humidity in percentage relative humidity (%RH).

### 3.3.6 Diet

When the tortoise was located, diet items eaten at the time or shortly before were recorded. All food items were photographed and some were brought back to Cholalongkorn University for identification.

### 3.3.7 Activity

When the tortoise was located, its activity was noted. Activity states were classified into six categories: (1) walking; (2) eating; (3) basking (staying on the forest floor, fully exposed to the sun, usually with limbs spread wide and necks stretched out); (4) resting (plastrons touching the ground rather than supported on limbs, necks mostly retracted) (5) soaking (staying in shallow stream or mud swamp) and (6) hiding (staying under leaf litter or fallen branches with limbs and necks retracted).

### 3.3.8 Habitat used

When tortoises were found, the type of habitat, canopy cover, distance to nearest water resource and slope were noted.

Habitats were classified into 5 types (1) bamboo forest, (2) dry evergreen forest, (3) dry evergreen forest mixed with bamboo, (4) stream and (5) mud swamp (Figure 7).

Canopy cover was divided into three categories: full cover, semi cover and open. A location was noted as full cover if the canopy was dense enough to shade out the majority (>50%) of sunlight. Semi cover was noted if the canopy was broken and sunlight penetrated to the forest floor and open was noted if no canopy existed at all.

Slope was evaluated within low slope (0-20degree), medium slope (20-45 degree) and high slope >45 degree categories.

### 3.3.9 Morphometry

Tortoises were measured when first encountered. Morphometry of tortoises were measured for 56 characters based on Aranyavalai (1996). Scutes, tail length, anal gap were measured, using vernier calliper. Carapace length, plastron length and plastron width were measured using flexible measuring tape. Weight was measured using a 30 kg spring balance.

### 3.3.10 Analysis of data

The home range size of each individual was estimated by Minimum Convex Polygon Method (MCP) using ArcView GIS 3.2 and the Home Range Extension for ArcView 3.x. (Rodgers and Carr, 1998). All measurements for home range were reported in $km^2$.

MCP was chosen, because it is the most commonly and widely used home range estimators. The advantages of MCP are simplicity, flexibility of shape and ease of calculation (White and Garrott, 1990) and should be accurately represent the maximum home range area for most herpetofauna (Row and Demers, 2006).

In this study, small sample size of the tortoise was studied, so nonparametric statistics was used to analysis the data.

The difference in median home range size between sexes, adults and juveniles and between dry and wet season were analyzed using man-Whitney U-test at confidence level of 95 %.

The difference in mean air temperature, surface temperature, carapace temperature and relative humidity between adults and juveniles and between wet season, cold-dry season and hot-dry season were analyzed using ANOVA at confidence level of 95 %.

A

B

C

**Figure 12** A = bamboo forest, B = dry evergreen forest, C = dry evergreen forest mixed with bamboo at Kaeng Krachan National Park (photographed on June – October 2006)

D

E



**Figure 12** (cont.) D = stream and E = mud swamp at Khao Phanoen Thung, Kaeng Krachan National Park. (photographed on June – October 2006)

# CHAPTER IV

# RESULTS AND DISCUSSION

In this study, 14 *M.e.phayrei* of different sex and age classes, consisting of eleven adults (seven males and four females) and three juveniles were attached with radio-transmitters and tracked at Kaeng Krachan National Park, Phetchaburi Province. All of them were found in the forest area around Phanoen Thung Substation between October 2005 – June 2007. Data on home range sizes and activities among adult males, females and juveniles were compared in order to see the differences between sexes and age classes. Morphometry data on all *M.e.phayrei* encountered during study were shown in Table 1.

## 4.1 Home range size

The home range size of each individual was estimated by Minimum Convex Polygon Method using ArcView GIS 3.2 and the Home Range Extension for ArcView 3.x (Rodgers and Carr, 1998). In this study, the tortoise sample size was small, so median and nonparametric statistics were used to analyze the data. Size of the home range was estimated year round and also separated into wet season (June-October) and dry season (November-April).

For the annual home range, three of those (MEP2,4,5) were lost before one year due to transmitter failure. Therefore, 8 adult tortoises were used for home range analysis. Jennrich and Turner (1969) suggested that for a stable home range estimation, 12 months locations of each individual should be used for analysis to avoid the bias from unequal numbers of relocation points.

Home range sizes of 14 tortoises are shown in Table 2. The results showed that the size of home ranges varied greatly among individuals. Among adults, they were 0.238 $km^2$ to 1.050 $km^2$, 0.079 $km^2$ to 0.786 $km^2$ and 0.003 $km^2$ to 0.154 $km^2$ during year round, in wet season and dry season, respectively. For juveniles, they

**Table 1** Mophometry data of *M.e.phayrei* at Khao Phanoen Thung, Kaeng Krachan National Park.

| **Animal Code** | **Mass (kg.)** | **Carapace Length (cm.)** | **Plastron Length (cm.)** | **Plastron Width (cm.)** | **Tail Length (cm.)** | **Sex** |
|---|---|---|---|---|---|---|
| JMEP1 | 4.1 | 26.4 | 27.5 | 21.35 | 3.9 | Unknown |
| JMEP2 | 4 | 26.2 | 27.5 | 20.5 | 4.2 | Unknown |
| JMEP3 | 3 | 24 | 24.3 | 18.5 | 4.5 | Unknown |
| MEP2 | 20 | 48 | 49 | 32.5 | 8 | Male |
| MEP3 | 24.5 | 53 | 50 | 39 | 9 | Male |
| MEP4 | 13 | 41.5 | 41 | 31.5 | 8 | Male |
| MEP5 | 15 | 44 | 42.7 | 33.5 | 8 | Male |
| MEP6 | 24 | 51 | 51 | 39 | 8 | Female |
| MEP7 | 15.2 | 46.5 | 46 | 37 | 7 | Male |
| MEP8 | 21.5 | 49 | 49.5 | 35 | 7.5 | Female |
| MEP9 | 14.5 | 42 | 45.5 | 34 | 7.0 | Female |
| MEP10 | 14 | 40 | 39 | 39 | 8.5 | Male |
| MEP11 | 15 | 46.5 | 45 | 34 | 7.2 | Female |
| MEP12 | 14 | 44 | 42 | 32 | 9.4 | Male |

JMEP = Juvenile *Manouria emys phayrei*     MEP = *Manouria emys phayrei*



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**Table 2** Home range sizes of *M.e. phayrei* at Khao Phanoen Thung, Kaeng Krachan National Park.

| **Tortoises** | **Home Range (km²)** | | | | | | **Sex** |
|---|---|---|---|---|---|---|---|
| | **Wet Season (Month) / No. of Fixes** | | **Dry Season (Month) / No. of Fixes** | | **Year round (Month) / No. of Fixes** | | |
| MEP2 | 0.123 | (May-June 06)/4 | 0.157 | (Feb-April 06)/6 | 0.269 | (Feb-June 06)/10 | Male |
| MEP3 | 0.079* | (June-Oct 06)/5 | 0.044* | (Nov 06-Apr 07)/6 | 0.238* | (June 06-May 07)/12 | Male |
| MEP4 | 0.166 | (May-June 06)/7 | 0.025 | (March-April 06)/3 | 0.313 | (March –June 06)/10 | Male |
| MEP5 | 0.786* | (June-Oct 06)/8 | 0.047 | (Feb-April 06)/6 | 0.977 | (Feb-Oct 06)/15 | Male |
| MEP6 | 0.429* | (June-Oct 06)/11 | 0.034* | (Nov 06-April 07)/7 | 0.483* | (June 06-May 07)/20 | Female |
| MEP7 | 0.174* | (June-Oct 06)/12 | 0.095* | (Nov 06-April 07)/9 | 0.660* | (June 06-May 07)/23 | Male |
| MEP8 | 0.205* | (June-Oct 06)/9 | 0.154* | (Nov 06-April 07)/8 | 0.631* | (June 06-May 07)/17 | Female |
| MEP9 | 0.143* | (June-Oct 06)/5 | 0.097* | (Nov 06-April 07)/6 | 0.473* | (June 06-May 07)/12 | Female |
| MEP10 | 0.337* | (June-Oct 06)/5 | 0.003* | (Nov 06-April 07)/6 | 0.647* | (June 06-May 07)/12 | Male |
| MEP11 | 0.221 | (July-Oct 06)/6 | 0.021* | (Nov 06-April 07)/8 | 0.607* | (July 06-June 07)/17 | Female |
| MEP12 | 0.337 | (July-Oct 06)/4 | 0.034* | (Nov 06-April 07)/8 | 1.050* | (July 06-June 07)/15 | Male |
| JMEP1 | 0.043* | (May-Oct 06)/14 | 0.04* | (Nov 06-April 07)/11 | 0.085 * | (June 06-May 07)/19 | Unknown |
| JMEP2 | 0.002* | (May-Oct 06)/11 | 0.009* | (Nov 06-April 07)/8 | 0.020* | (June 06-May 07)/19 | Unknown |
| JMEP3 | 0.042 | (May-June 06)/3 | 0.009* | (Dec 06-April 07)/6 | 0.148 | (Dec 06-June 07)/9 | Unknown |

**Note: * =** Data for home range analysis JMEP = Juvenile *Manouria emys phayrei* MEP = *Manouria emys phayrei*

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were 0.02 $km^2$ to 0.148 $km^2$, 0.002 $km^2$ to 0.043 $km^2$ and 0.04 $km^2$ to 0.009 $km^2$ during year round, in wet season and dry season, respectively. Year round home range diagrams of tortoises are shown in Figures 13, 14 and 15. This result is concordant with the previous study of home range sizes of *M.e.emys* (Mortensen, 2004) who reported that the home range sizes of *M. emys emys* in Tabin Wildlife Reserve, Sabah, Borneo were between 0.002 $km^2$- 0.51 $km^2$ estimated by Minimum Convex Polygon Method. Lambert and Howes (1994) found that one *M. e. emys* female used 0.6 $km^2$ over a period of 53 days. However, the method used to estimate the ranging of this animal was not reported.

The median home range sizes within season and year-round between adult male and female tortoises were not significantly different but were significantly larger than the home range sizes of juveniles (Table 3).

The median home range sizes of adult males and females in wet season were significantly larger than in dry season. However, for juveniles, the median home range sizes were not significantly different between wet and dry season.

There was no significant difference in sizes of home ranges within season and year-round between adult males and adult females in this study. This result was opposite to those of other turtle species, both terrestrial and aquatic males tend to have a wider home range than females in general (Auffenberg and Weaver, 1969; Rose and Judd, 1975; Schubauer *et al*., 1990; Smith, 2006). However, this result was similar to Tharapoom (1996) who studied home range sizes and activity of the yellow tortoise, *Indotestudo elongata* at Khao Nang Rum Wildlife Research Station, Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province, Thailand. He reported that the home range sizes of males and females were not significantly different both in the dry and the wet season. Similar result was also reported by Geffen and Mendelssohn (1988) on Egyptian Tortoise, *Testudo kleinmanni* in the Northwestern Negev, Israel.

**Table 3** Median home range sizes of adult male, adult female and juveniles *M.e. phayrei* in wet season, dry season and year-round.

| **Tortoises** | **Home Range (km$^2$)** | | |
|---|---|---|---|
| | **Wet Season (May-Oct) / No. of individual** | **Dry Season (Nov-Apr) / No. of individual** | **Year round (May-Apr) / No. of individual** |
| Adult Males | 0.174 / 4 | 0.034 / 4 | 0.647 / 4 |
| Adult Females | 0.226 / 3 | 0.066 / 4 | 0.558 / 4 |
| Juveniles | 0.042 / 2 | 0.009 / 3 | 0.085 / 2 |



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The lack of a significant difference between the median home range size of males and females and the high variation among individuals are probably due to the small sample size because the bias of the Minimum Convex Polygon Method is greater for small sample size (Boulanger and White, 1990).

Body size and energy requirement may also influence the difference in home range of adults and juveniles. Larger body size would mean a greater energy requirement and a greater area travelled to acquire resources, resulting in larger movements and a larger home range (Hailey and Coulson 1996; Gaston and Blackburn 1996).

The median home range sizes of adult tortoises in wet season were significantly larger than in dry season. This may be due to adaptation to the lack of resources in dry season because dry season is associated with unfavourable environmental conditions such as low humidity, low rainfall and a limited availability of food plants. Many tortoises are inactive or stay under fallen branches or leaf litter at least 1 month during coldest months (November-January). This may help support this hypothesis because inactive period is usually interpreted as a mechanism for energy conservation that reduces metabolic rate when little food is available (Gregory, 1982).

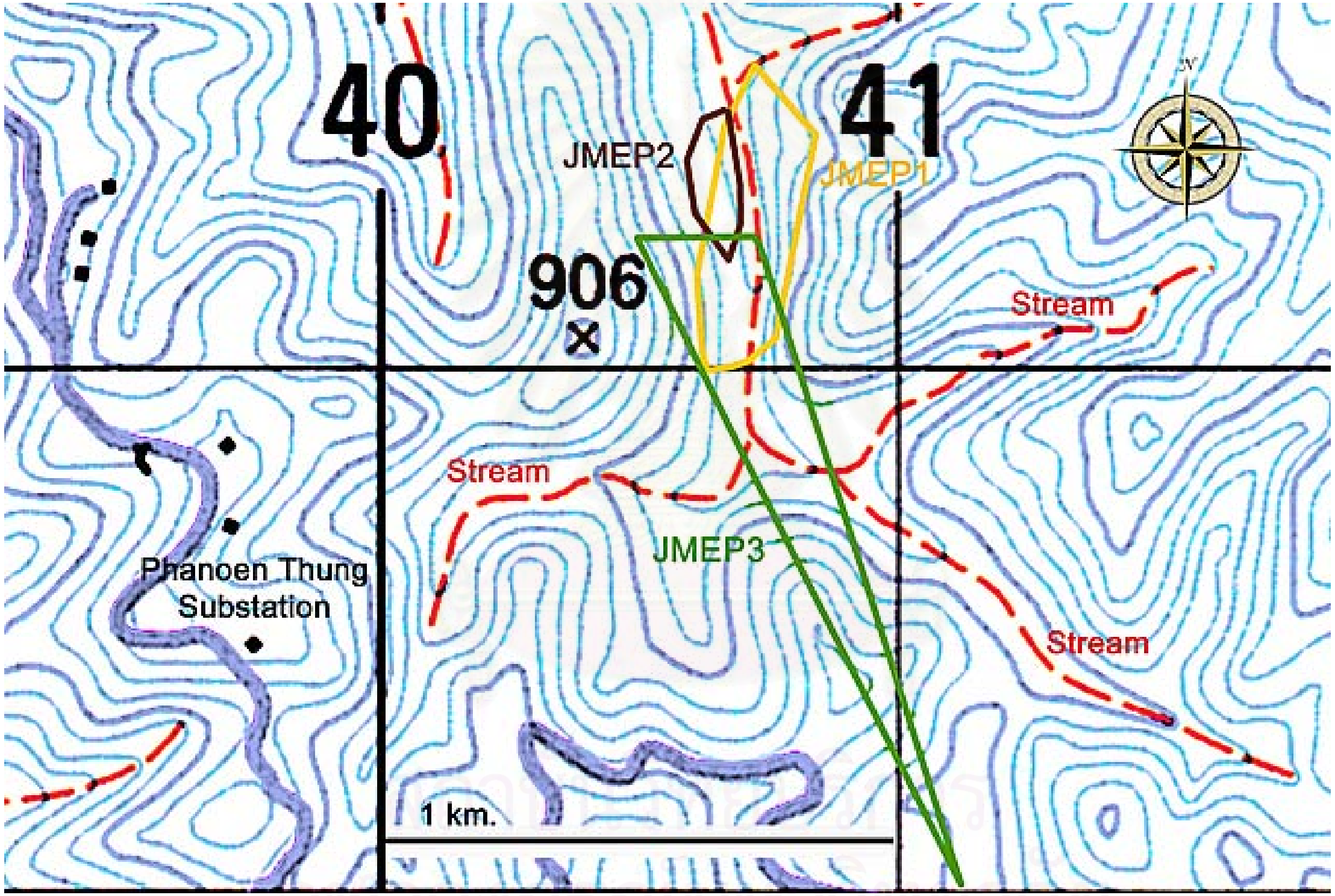


**Figure 13** Home range sizes of *M.e. phayrei* juveniles (year-round), located around Phanoen Thung Substation.

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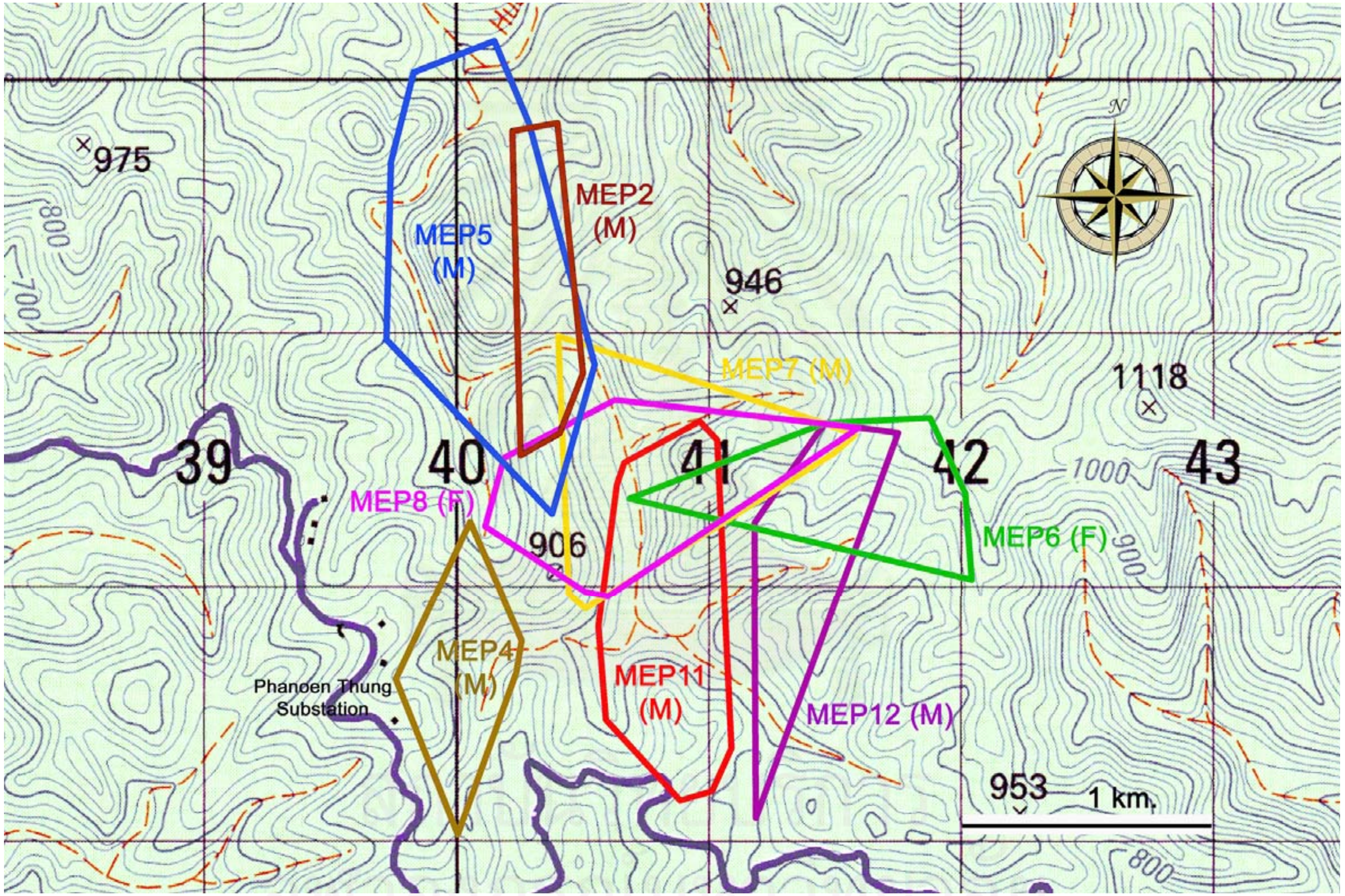


**Figure 14** Home range sizes of adult males (M) and females (F) (year-round), located around Phanoen Thung Substation.

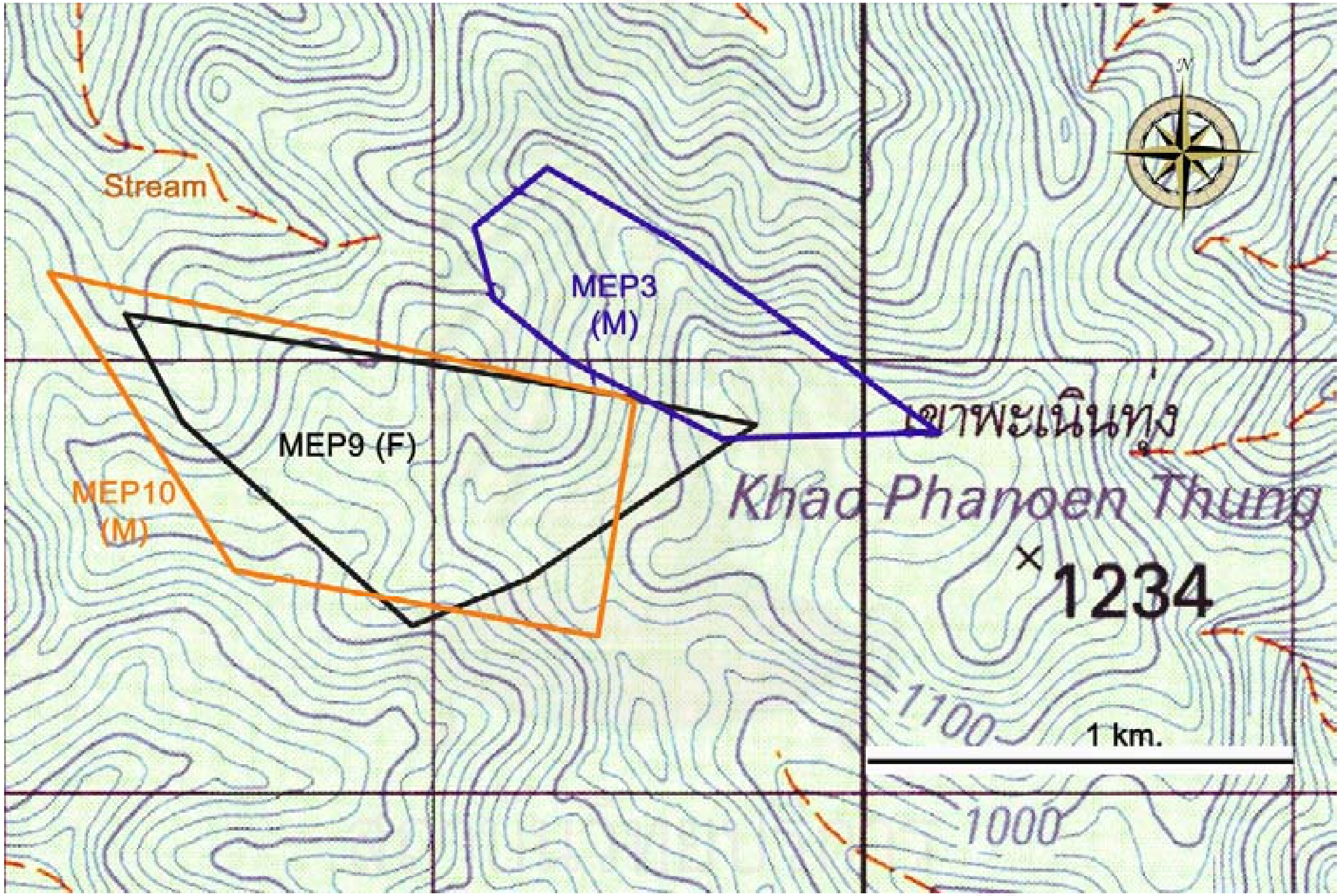


**Figure 15** Home range sizes of adult males (M) and females (F) (year-round), located near to the highest peak of Khao Phanoen Thung, north of Phanoen Thung Substation.

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## 4.2 Seasonal activity

In this study, tortoises activities were classified into basking, eating, hiding, resting, soaking and walking (Table 4 and Table 5).

During wet season (May-October), adult tortoises were mostly found eating (33.33 %) followed by resting (26.88 %), basking (19.35 %), hiding (10.75 %), soaking (5.38 %) and walking (4.30 %), respectively. For juvenile tortoises, they were mostly found soaking (38.89 %) followed by eating (22.22 %), hiding (16.67 %), resting (11.11 %), basking (5.56 %), and walking (5.56 %), respectively.

During the cold dry season (November-February), a few tortoises were active. They spent most of their time hiding, 53.06 % and 61.54 % for adults and juveniles, respectively. Most of them were commonly found under the fallen branches or leaf litter. Basking, eating, resting, soaking and walking constituted less than 16 % of observation.

During hot dry season (March-April), both adults and juveniles spent the majority of their time soaking (51.61 %). Basking did not appear during this season.

Although most activities occurred in every season there were seasonal differences in the relative frequencies of activities. For adult tortoises, feeding occurred more frequently in wet season than dry season. This difference presumably reflects the availability of food. Seasonal change may affect on some food plants of tortoises. Many kinds of food plants were easily found in the forest, especially bamboo shoot in wet season. In contrast, during the dry season, there is little edible food plant available. Another possibility that a peak of feeding is in wet season may be because the tortoises need to storage energy for inactive period. Smith and Smith (2006) noted that before entering hibernation or inactive peroid, most species eat a large amount of food and store energy as fat deposits in order to survive during inactive period. In contrast, the result showed that the majority of activity of juvenile in wet season is soaking, followed by feeding. This difference may be explained by

**Table 4** Activities of *M.e.phayrei* adults in different seasons.

| Season | Activity Percentage of observation (n) | | | | | | No. of Fixs |
|---|---|---|---|---|---|---|---|
| | **Basking** | **Eating** | **Hiding** | **Resting** | **Soaking** | **Walking** | |
| **Wet** | 19.35 (18) | 33.33 (31) | 10.75 (10) | 26.88 (25) | 4.3 (4) | 5.38 (5) | 93 |
| **Cold_Dry** | 2.04 (1) | 10.2 (5) | 53.06 (26) | 14.29 (7) | 6.12 (3) | 14.29 (7) | 49 |
| **Hot_Dry** | 0 | 16.13 (5) | 6.45 (2) | 19.35 (6) | 51.61 (16) | 6.45 (2) | 31 |

**Table 5** Activities of *M.e.phayrei* juveniles in different seasons.

| Season | Activity Percentage of observation (n) | | | | | | No of Fix |
|---|---|---|---|---|---|---|---|
| | **Basking** | **Eating** | **Hiding** | **Resting** | **Soaking** | **Walking** | |
| **Wet** | 5.56 (2) | 22.22 (8) | 16.67 (6) | 11.11 (4) | 38.89 (14) | 5.56 (2) | 36 |
| **Cold_Dry** | 3.85 (1) | 0 | 61.54 (16) | 11.54 (3) | 15.38 (4) | 11.54 (3) | 26 |
| **Hot_Dry** | 0 | 20 (2) | 10 (1) | 20 (2) | 40 (4) | 10 (1) | 10 |



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the trade-off between feeding and predator avoidance, causing juvenile tortoises to be able to forage for a shorter time because of predation. Mushinsky et al. (2003) reported that gopher tortoise, *Gopherus polyphemus* juveniles foraged only for a brief time and traveled for short distances during a foraging bout because they are vulnerable to predation. The broad - headed skink, *Eumeces laticeps*, alters several aspects of feeding behavior in ways suggesting tradeoffs between predation risk and feeding. When the food (cricket) was closer to the predator, the lizards more frequently did not attack it, and often retreated to safety before consuming it, reducing the duration of exposure to predation (Cooper, 2004).

During cold-dry season, both adult and juvenile tortoises spent the majority of their time hiding. This may be due to adaptation to the lack of resources in dry season. Inactive period is usually interpreted as a mechanism for energy conservation that reduces metabolic rate when little food is available (Gregory, 1982). The environmental change such as low temperature, low humidity and lack of rain may also influence on body function of tortoises. Activity patterns of turtles and tortoises influenced by seasonal change and other environmental factors have been reported by several authors. Ruby *et a.l* (1994) suggested that when stressed by lack of water and food resources, desert tortoises reduced the length of above-ground activity time. In cold months, the yellow-margined box Turtle, *Coura flmmarginata* is less active and reduces foraging (Lue and Chen, 1999). The extreme continental climate of central Asia (hot and dry summer followed by a very cold winter) limits steppe tortoise activity to the spring only (Lagarde *et al.*, 2003). Duda *et al*., 1999 suggested that the strategy of desert tortoises, *Gopherus agmsizii* during lean years may be to minimize energy expenditures and wait for conditions to improve. Using this behavioral plasticity, desert tortoises can adapt to a harsh environment with unpredictable resources.

In hot dry season, adult and juvenile tortoises spent the majority of their time soaking. Tortoises chose soaking frequently during this period because they can avoid the extreme heat. Activity at high temperature enhances evaporative water loss (Naege, 1976). The highest air temperature recorded in this study was 32.5 Cº, during hot-dry season. Under this condition, this activity pattern will offer a distinct advantage to lower evaporative water loss and help them to maintain its water balance (Ramsay *et al.,* 2002).

Thompson (1971 in Litzgus and Brooks, 2000) suggested that reptiles achieve body temperatures only a few degrees below their critical maxima by selecting temperatures in the upper parts of their normal ranges of activity. At high body temperature, turtles lost some of their ability to function, including a righting reflex that is a normal response to being turned on their backs (Orenstein, 2001).

Behavioral thermoregulation includes restriction of activity periods and microhabitat selection can function in reducing water loss. Use of burrows and shelters has been demonstrated experimentally to reduce evaporative water loss in many reptiles (Bulova, 2002) such as desert tortoise, *Gopherus agassizii,* retreats into underground burrow for immediate refuge from high surface temperature (Zimmerman *et al.,* 1994). Adult *M.e.phayrei* may be too large to hide under the rock and they do not have burrow like those of desert tortoises. Therefore, shallow stream could be useful for thermoregulation.

This study is apparently the first record of basking activity in *M. emys***.** Eggenschwiler (2003) suggested that this species do not really bask and Mortensen (2004) suggested that *M. e. emys* exhibits a non-heliotherm lifestyle (heliotherm – poikilotherm that depend primarily on radiant energy for their body heat). For both adults and juveniles, basking occurred in wet and cold dry season but did not appear during hot dry season which may be due to the avoidance from extreme heat.

Basking is present in many turtle and tortoise groups. Boyer (1965) suggested that basking serves a variety of needs in these animals, including thermoregulation, conditioning of the skin and shell, reducing the incidence of plant and animal parasites and retarding the development of epizootic and epiphytic infestations.

Thomas (1999) suggested that basking increases body temperature and such increases in turtles are associated with the increase of (1) ingestion rate, (2) intestinal motility rate, (3) digestive turnover time, (4) metabolic rate, and (5) activity levels.

**Mating**

Only one mating behavior was observed during this study on May 21 2007. Mating occurred in the bamboo forest and under a full canopy cover (Figure 19). Temperature was measured to 22.8 ºC and relative humidity was 85%.

This behavior was found while a male attempting to mount a female. The male stayed behind the female in copulatory-ready position. Male raising the front legs onto the female's back with his neck fully extended. Female tried to walk away but the male followed and continued headbobing with increased frequency while attempting to catch up the female. Eventually, when the female was stationary, the male caught up the female and attempted to mount again. A male continued this activity, with its head stretched out over the female's carapace. During this activity, the male repeated grunting and moaning. After copulation, the female stayed at the same position while the male walked away. A total of the time for mating behavior was about 30 minutes.

In the wet season (June 2006), a male (MEP 7) and a female (MEP 8) were found staying together. However, there was no interaction between them during observation.


**Figure 16** Bamboo shoot was eaten by *M.e.phayrei* adult.


**Figure 17** *Amorphophallus paeoniifolius* was eaten by *M.e.phayrei* adult.


**Figure 18** Adult *M.e.phayrei* soaked in shallow stream.


**Figure 19** Juvenile *M.e.phayrei* soaked in mud swamp.


**Figure 20** Basking behavior of *M.e.phayrei* adult.


**Figure 21** Basking behavior of *M.e.phayrei* juvenile.


**Figure 22** Mating behavior of *M.e.phayrei*.

**4.3 Habitat temperature and relative humidity**

The air temperature, ground surface temperature, carapace temperature and relative humidity were recorded at the position where tortoises were located. Averages are shown in Table 6 and Table 7.

The air temperature at the position where tortoises were located ranged from 19.5-32.5 ºC. The averages of temperature during wet season, cold-dry season and hot-dry season were 24.26±0.13ºC, 23.40±0.21 ºC and 27.0±0.19 ºC, respectively. The average air temperature during hot dry season was significantly higher than in wet season and cold-dry season.

The ground surface temperature at the position where tortoises were located ranged from 15.3-30.20 ºC. The averages of ground surface temperature during wet season, cold-dry season and hot-dry season were 20.91±0.27 ºC, 20.60±0.24 ºC and 21.57±0.21 ºC, respectively. The averages ground surface temperature were not significantly different between wet season, cold-dry season and hot dry season.

The carapace temperature at the position where tortoises were located ranged from 15.3-30.0 ºC. The averages of carapace temperature during wet season, cold-dry season and hot-dry season were 21.31±0.30 ºC, 21.14±0.30 ºC and 22.20±0.24 ºC, respectively. The averages carapace temperature were not significantly different between wet season, cold-dry season and hot dry season.



The relative humidity at the position where tortoises were located ranged from 68-100%. The averages of relative humidity in wet season, cold-dry season and hot-dry season were 85.23±0.44%, 75.19±0.41% and 77.34±0.60%, respectively. The averages relative humidity during cold-dry season was significantly lower than in wet season and hot-dry season (ANOVA, $p \leq 0.05$).

**Table 6** Means and ranges of year-round air temperature, ground surface temperature, carapace temperature and relative humidity.

| Tortoise | Temperature (ºC) | | | RH ± SE (%) (Min-Max) |
|---|---|---|---|---|
| | Air ± SE (Min-Max) | Ground surface ± SE (Min-Max) | Carapace ± SE (Min-Max) | |
| Male | $24.67\pm0.21^{A,II}$ (19.5-32.5) | $21.09\pm0.25^{B,I}$ (15.4-28.1) | $21.64\pm0.30^{B,I}$ (15.4-27.5) | $80.92\pm0.60^{A}$ (71 -100) |
| Female | $24.24\pm0.23^{A,II}$ (19.5-27.8) | $21.39\pm0.31^{B,I}$ (16.2-29.7) | $22.04\pm0.36^{B,I}$ (15.4-30.0) | $80.94\pm0.72^{A}$ (70-100) |
| Juvenile | $24.89\pm0.22^{A,II}$ (19.5-28.5) | $20.13\pm0.42^{A,I}$ (15.3-30.2) | $20.68\pm0.34^{A,I}$ (15.3-27.7) | $80.53\pm0.86^{A}$ (68-100) |

Note: • Significant difference (ANOVA, p<0.05) between columns is indicated by different Roman number.
• Significant difference (ANOVA, p<0.05) between rows is indicated by different superscript letter.

**Table 7** Means and ranges of temperature and relative humidity in at the study site in wet season, cold-dry season and hot-dry season.

| Season | Temperature (ºC) | | | RH ± SE (%) (Min-Max) |
|---|---|---|---|---|
| | Air ± SE (Min-Max) | Ground surface ± SE (Min-Max) | Carapace ± SE (Min-Max) | |
| Wet | 24.26±0.13 $^{B,II}$ (20.5-30.2) | 20.91±0.27 $^{A,I}$ (15.3-30.2) | 21.31±0.30 $^{A,I}$ (15.3-30.0) | 85.23±0.44$^{C}$ (78-100) |
| Cold_Dry | 23.40±0.21 $^{A,II}$ (19.5-27.5) | 20.60±0.24 $^{A,I}$ (16.2-26.8) | 21.14±0.30 $^{A,I}$ (16.2-29.5) | 75.19±0.41$^{A}$ (68-83) |
| Hot_Dry | 27.00±0.19 $^{C, II}$ (24.8-32.5) | 21.57±0.24 $^{A,I}$ (18.3-24.2) | 22.20±0.21 $^{A, I}$ (18.2-24.6) | 77.34±0.60 $^{B}$ (73 -92) |

Note: • Significant difference (ANOVA, p<0.05) between columns is indicated by different Roman number.
• Significant difference (ANOVA, p<0.05) between rows is indicated by different superscript letter.

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The ranges of air temperature and relative humidity at the position where tortoises were located during various activities are shown in Table 8 to Table 11.

The averages of air temperature when adult tortoises were basking = 25.21±0.38 ºC, eating = 23.93±0.26 ºC, hiding = 23.71±0.29 ºC, resting = 24.24±0.27 ºC, soaking = 26.37±0.45 ºC and walking = 24.05±0.64 ºC. The average air temperature during soaking activity was significantly higher than basking, eating, resting and walking (ANOVA, $P < 0.05$).

The averages of humidity while adult tortoises were basking = 82.71±0.65%, eating = 84.60±0.83%, hiding = 75.85±0.71%, resting = 81.78±0.82%, soaking = 78.77±0.83% and walking = 80.47±1.02%. Humidity during hiding activity was significantly lower than basking, eating, resting soaking and walking (ANOVA, $P < 0.05$).

The averages of air temperature when juvenile tortoises were basking = 24.80±1.10 ºC, eating = 25.48±0.44 ºC, hiding = 24.25±0.37 ºC, resting = 25.43±0.52 ºC, soaking = 24.59±0.47 ºC and walking = 24.17±0.81 ºC. The average air temperature during soaking activity was significantly higher than basking, eating, resting and walking (ANOVA, $P < 0.05$). There was no significant difference between the mean temperature of each activity.

The averages of humidity when juveniles tortoises were basking = 83.50±0.50%, eating = 84.70±1.83%, hiding = 75.74±1.25%, resting = 80.15±1.42%, soaking = 81.56±1.23% and walking = 80.47±1.02%. Humidity during hiding activity was significantly lower than basking, eating, resting soaking and walking (ANOVA, $P< 0.05$).

The averages air year-round temperature, surface temperature, carapace temperature and relative humidity between male and female tortoises were not significant different (ANOVA, $p<0.05$) (Table 6).

**Table 8** Means and ranges of air temperature at different activities of *M.e.phayrei* adults.

| Activity | Air Temperature (°C) | | | N |
|---|---|---|---|---|
| | Mean ± SE | Min | Max | |
| Eating | 23.93 ±0.26$^{A}$ | 21 | 27 | 38 |
| Hinding | 23.71±0.29$^{A}$ | 19.5 | 27.5 | 41 |
| Resting | 24.24 ±0.27$^{AB}$ | 20.5 | 27.1 | 36 |
| Soaking | 26.37 ±0.45$^{C}$ | 23.1 | 32.5 | 22 |
| Walking | 24.05 ±0.64$^{AB}$ | 19.7 | 27 | 15 |
| Basking | 25.21 ±0.38$^{B}$ | 22.5 | 27.8 | 18 |

Note: N = Number of observations
Significant difference (ANOVA, $p<0.05$) between rows is indicated by different superscript letter.

**Table 9** Mean and ranges of relative humidity at different activities of *M.e.phayrei* adults.

| Activity | Relative Humidity (%) | | | N |
|---|---|---|---|---|
| | Mean ± SE | Min | Max | |
| Eating | 84.60±0.83$^{D}$ | 74 | 93 | 38 |
| Hinding | 75.85± 0.71$^{A}$ | 70 | 84 | 41 |
| Resting | 81.78 ±0.82$^{C}$ | 71 | 91 | 36 |
| Soaking | 78.77 ±0.83$^{B}$ | 73 | 87 | 22 |
| Walking | 80.46 ±1.02$^{BC}$ | 75 | 90 | 15 |
| Basking | 82.72 ±0.61$^{CD}$ | 78 | 87 | 18 |

Note: N = Number of observations
Significant difference (ANOVA, $p<0.05$) between rows is indicated by different superscript letter.

**Table 10** Means and ranges of air temperature at different activities of *M.e.phayrei* juveniles.

| Activity | Temperature (ºC) | | | |
|---|---|---|---|---|
| | **Mean ± SE** | **Min** | **Max** | **N** |
| Eating | $25.48\pm0.44^{A}$ | 24.1 | 28.2 | 10 |
| Hiding | $24.25\pm0.37^{A}$ | 19.5 | 26.5 | 23 |
| Resting | $25.43\pm0.58^{A}$ | 20.7 | 28.5 | 13 |
| Soaking | $24.59\pm0.47^{A}$ | 20.6 | 28.2 | 16 |
| Walking | $24.17\pm0.81^{A}$ | 22 | 27.2 | 6 |
| Basking | $24.80\pm1.10^{A}$ | 23.7 | 25.9 | 2 |

Note: • N = Number of observations
• Significant difference (ANOVA, $p<0.05$) between rows is indicated by different superscript letter.

**Table 11** Means and ranges of relative humidity at different activities of *M.e.phayrei* juveniles.

| Activity | Relative Humidity (%) | | | |
|---|---|---|---|---|
| | **Mean ± SE** | **Min** | **Max** | **N** |
| Eating | $84.7\pm1.83^{C}$ | 75 | 93 | 10 |
| Hiding | $75.30\pm1.03^{A}$ | 68 | 86 | 23 |
| Resting | $80.15\pm1.42^{B}$ | 74 | 89 | 13 |
| Soaking | $81.56\pm1.23^{BC}$ | 73 | 93 | 16 |
| Walking | $82.17\pm2.76^{BC}$ | 73 | 93 | 6 |
| Basking | $83.50\pm0.50^{BC}$ | 83 | 84 | 2 |

Note: • N = Number of observations
• Significant difference (ANOVA, $p<0.05$) between rows is indicated by different superscript letter.

There was no significant difference in the air temperature and relative humidity between adult and juvenile tortoises (Table 6). However, the ground surface and carapace temperature of juveniles tortoises were significantly lower than adult male and female tortoises (ANOVA, $p<0.05$).

Although there was significant difference in the means of temperature between seasons, there was no significant difference in the means of carapace temperature comparing among seasons (Table 7). This indicated that tortoises are able to maintain their optimal body temperature throughout the year. Reagan (1974) reported that a mean activity temperature of the three-toed box turtle, *Terrapene carolina triunguisof* is 25.90C° and constancy with which this temperature is maintained throughout the annual period of activity. Texas Tortoise, *Gopherus berlandieri*, showed little variation in body temperature during annual activity (Judd and Rose, 1977).

There was no significant difference between the means of carapace and ground surface temperature. This may be because of the physical requirements for maintain equilibrium between body and surface temperatures. This result is concordant with Zimmerman *et. at*. (1994) who reported that during activity period, the mean body temperature of the desert tortoise, *Gopherus agassizii* did not differ from ground surface and burrow temperature.

The result showed that when temperature was high, adult tortoises used damp area for soaking. This indicates that tortoises can select appropriate thermal habitat to avoid temperature extremes.

Both adult and juvenile tortoises had hinding activity when the relative humidity was low. This condition can directly affect on the body function of tortoises and inactive activity will give more benefit to the tortoises.

## 4.4 Habitat Use

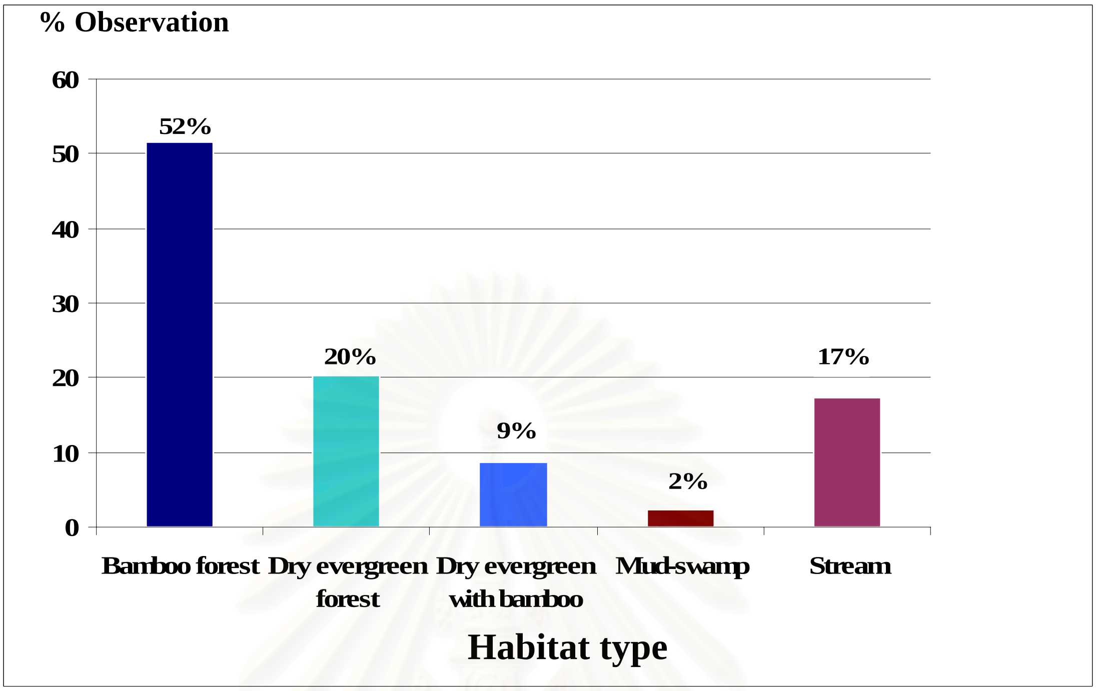
The results demonstrated that *M.e.phayrei* exhibits seasonal variations in habitat use (Figure 20 and Figure 21). In wet season and cold-dry season, adult tortoises were frequently observed on slopes of up to 45 degrees (Table 20) in bamboo forest and dry evergreen forest. In hot-dry season, they spent most of the time in stream (Figure 21(A)).

Juvenile tortoises were frequently encountered on plain area and near to the stream or water resources (Table 25 and Table 26). They mostly spent their time in mud-swamp in wet season. During the cold-dry season, juveniles spent their time in dry evergreen forest and mud-swamp whereas in hot-dry season they spent their time in dry ever green forest, mud-swamp and the stream (Figure 21(B)).

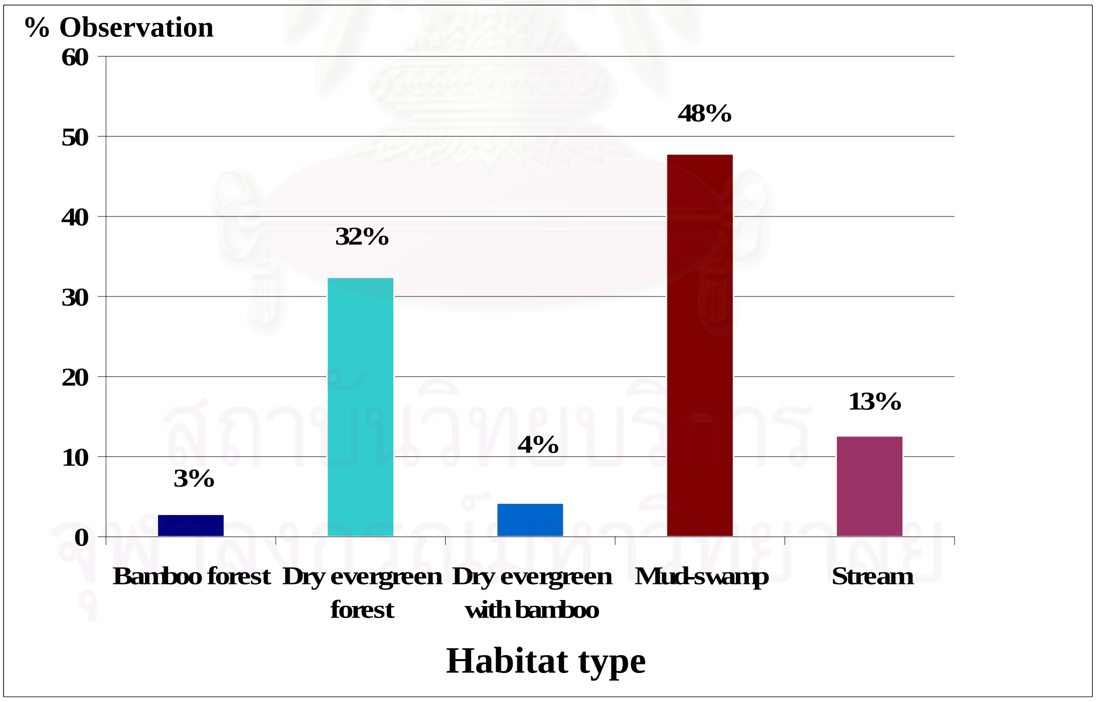
Most adult tortoises were found in bamboo forest in wet season (May-October). This may be because of a reflection of seasonality and plant abundance because bamboo shoot normally occurs during this period.

In cold dry season, a few tortoises were active and were often found beneath fallen branches or leaf litter in bamboo forest and dry evergreen forest (Figure 22). Both habitats may provide a shelter for tortoises with suitable temperature and moisture during the inactive period.

In hot dry season (March-April), they were frequently found near to the stream. This habitat may supply enough food and water for tortoises because finding the tortoises in this habitat was often associated with feeding on *Alocasia* and submerging in the stream. This indicate that shallow steam is used in hot-dry season for feeding and thermoregulation. Numerous studies on habitat selection by turtles have confirmed the importance of habitat structure in thermoregulation (e.g. Barrett, 1990; Litzgus and Brooks, 2000, Bryant *et al.*, 2002 and Anadón *et al*, 2006).

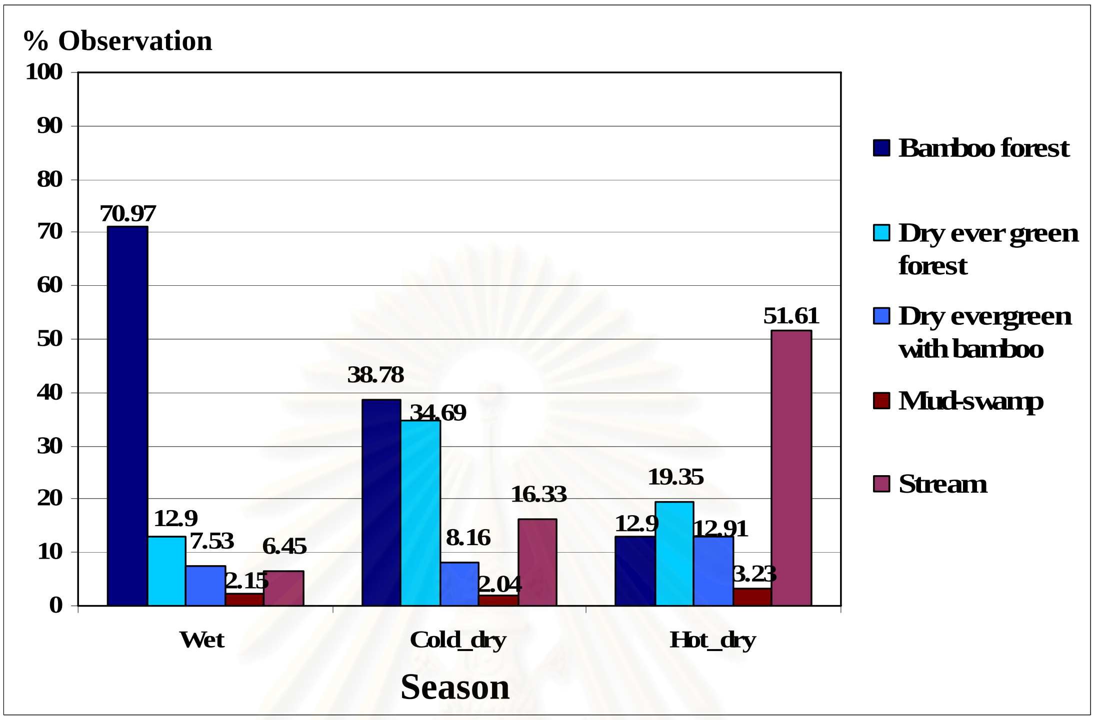



**A**

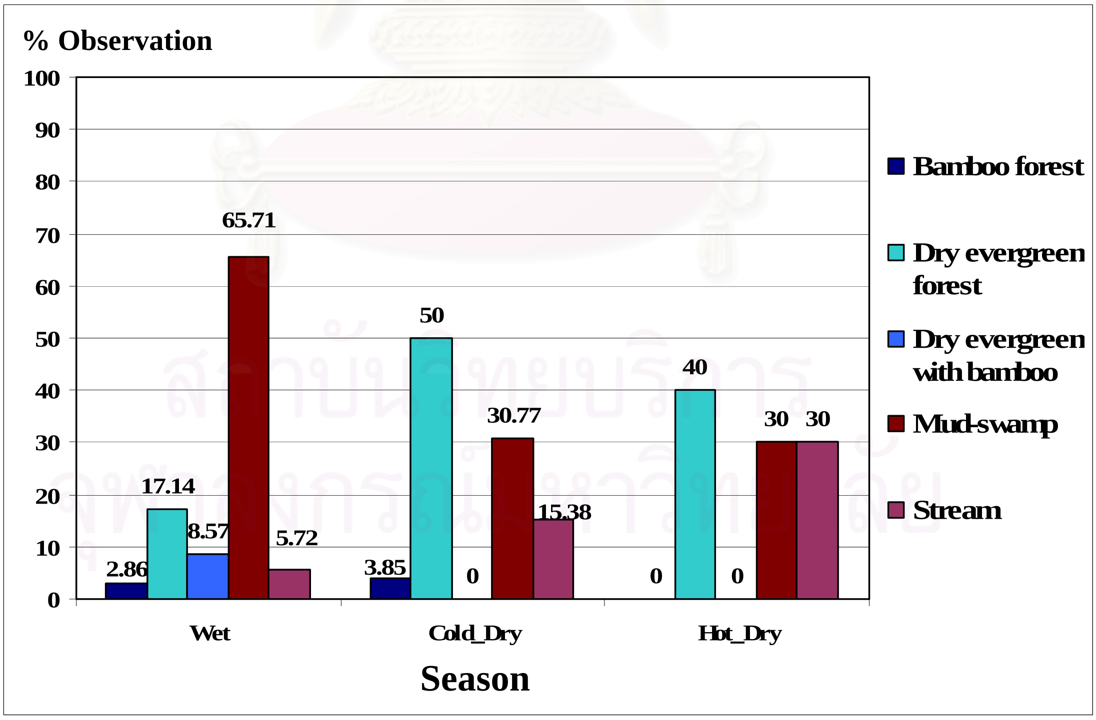



**B**

**Figure 23** Percentages of year-round habitat use by *M. e. phayrei*
**A** = Adult  **B** = Juvenile




**A**




**B**

**Figure 24** Percentages of habitat use of *M. e. phayrei* in different seasons
**A** = Adult **B** = Juvenile

**Table 12** Percentages of canopy cover used by *M.e.phayrei* adults.

| Season | Canopy cover (%) Percent of observation (n) | | |
|---|---|---|---|
| | Full cover | Semi cover | Open |
| Wet | 72.05 (67) | 15.05(14) | 12.9 (12) |
| Cold_Dry | 79.6 (39) | 10.2 (5) | 10.2(5) |
| Hot_Dry | 61.29 (19) | 3.23 (1) | 35.48 (11) |

**Note:** n = Number of observation

**Table 13** Distances from nearest water source of *M.e.phayrei* adults.

| Individuals | Distance from nearest water source (m) Percent of observation (n) | |
|---|---|---|
| | <50 m | >50 m |
| Wet | 26.88 (25) | 73.12 (68) |
| Cold_Dry | 42.86 (21) | 57.14 (28) |
| Hot_Dry | 90.32 (28) | 9.68 (3) |

**Note:** n = Number of observations

**Table 14** Percentages of slope where *M.e.phayrei* adults were found.

| Individual | Slope ( $^{o}$ ) Percent of observation (n) | | |
|---|---|---|---|
| | 0-20 | 21-45 | >45 |
| Wet | 21.51 (20) | 8.6 (8) | 69.89 (65) |
| Cold_Dry | 20.41 (10) | 2.04 (1) | 77.55 (38) |
| Hot_Dry | 61.29 (19) | 3.23 (1) | 35.48 (11) |

**Note:** n = Number of observations

**Table 15** Percentages of canopy cover used by *M.e.phayrei* juveniles.

| **Season** | **Canopy cover (%)** | | |
|---|---|---|---|
| | **Percent of observation (n)** | | |
| | **Full cover** | **Semi cover** | **Open** |
| **Wet** | 80.56 (29) | 11.11 (4) | 8.33 (3) |
| **Cold_Dry** | 80.77 (21) | 11.54 (3) | 7.69 (2) |
| **Hot_Dry** | 50 (5) | 30 (3) | 20 (2) |

**Note:** n = Number of observations

**Table 16** Distances from nearest water source of *M.e.phayrei* juveniles.

| **Individuals** | **Distance from nearest water source (m)** | |
|---|---|---|
| | **Percent of observation (n)** | |
| | **<50 m** | **>50 m** |
| **Wet** | 97.22 (35) | 2.78 (1) |
| **Cold_Dry** | 92.31 (24) | 7.69 (2) |
| **Hot_Dry** | 100 (10) | 0 |

**Note:** n = Number of observations

**Table 17** Percentages of slope where *M.e.phayrei* juveniles were found.

| **Individual** | **Slope (Subadult)** | | |
|---|---|---|---|
| | **Percent of observation (n)** | | |
| | **0** | **<45** | **>45** |
| **Wet** | 94.44 (34) | 0 | 5.56 (2) |
| **Cold_Dry** | 53.85 (14) | 0 | 46.15 (12) |
| **Hot_Dry** | 80 (8) | 0 | 20 (2) |

**Note:** n = Number of observation

Juveniles mostly spent their time in mud-swamp during wet season. This habitat type may supply enough food and shelter for hiding. The swamp is abundantly vegetated with *Phrynium pubinerve* (Figure 23). Using dense vegetation may allow juveniles to take advantage of their cryptic coloration. When they submerge in the mud, it is difficult to distinguish them from the surrounding (Figure 24). Therefore, it makes them difficult to find by predators. The swamp is also abundantly with *Lasia spinosa* that juveniles consume mostly during wet season.

In cold dry season, during inactive period, JMEP2 remained in mud-swamp whereas JMEP1 shifted its habitat use. JMEP1 was found beneath fallen branches or leaf litter in dry ever green forest because the water level in swamp was very low and when the water level rose in wet season, it returned to the same area. For JMEP3, it was found inside the hollow near to the stream (Figure 25). In hot-dry season, juveniles used 3 different habitats almost equally but not far from the stream or water resources.

Results from Table 21 and Table 24 suggested that both adults and juveniles mostly spent their time under full cover canopy. This result was similar to Mortensen (2004) who reported that *M.e.emys* preferred places with full cover canopy for 66% of the observations. Johns (1997 in Montensen, 2004) suggested that canopy cover is important in body temperature control of poikilothermic animals living in tropical regions. Places with no canopy tend to be very hot (>30°C) and dry during the day time and will typically lead to heat stress if the animal is exposed for longer period. Thus, tortoises living in the tropics often face the problem of keeping themselves cool enough as opposed to their relatives living in temperate regions where the problem is keeping sufficiently warm. Observations on the tortoises in open canopy showed that they were associated with basking, the preference for an open canopy is likely to be linked to the thermoregulation requirements of tortoises.

Results from Table 22 suggested that adult tortoises spent most of their time far from the stream in wet season. This result was similar to Mortensen (2004). He reported that *M.e.emys* was found to be more than 50 meters away from the nearest


**Figure 25** Red circle shows *M.e.phayrei* was hiding under fallen branches during inactive period in cold-dry season.

**Figure 26** Mud swamp. The habitat type was abundantly vegetated with *Phrynium pubinerve*.


**Figure 27** Juvenile *M.e.phayrei* submerged in mud swamp.


**Figure 28** Hiding place of JMEP3 during inactive period.

water body in 73% of all encounters. Juvenile tortoises, including adult tortoises in hot dry season, spent most of their time near to the stream or water resources. This result was concordant with Nuthapund (1979) who reported that *M.emys* tend to have a strong commitment to water.

The patterns of seasonal variations in habitat use have been recorded in many turtles such as the desert tortoise, *Xerobates agassizi*. They occupied larger dens in summer than in other seasons and moved to steeper rocky slopes in winter (Barrett, 1990). In the spotted turtle, *Clemmys guttata*, in spring (May-June), they aggregated in ponds to court and mate. In late June, females nested on open rock outcrops. During July and August, turtles spent about half of their time buried in terrestrial forms on rock outcrops and in forests. From September to April, they hibernated in sphagnum swamps (Litzgus and Brooks, 2000).

**Table 18** Percentages of habitat use of *M.e.phayrei* adults in the wet season.

| Individual | Habitat use : Wet season (%) | | | | | No. of fixes |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | |
| MEP2 (M) | 50 | 0 | 50 | 0 | 0 | 4 |
| MEP3 (M) | 100 | 0 | 0 | 0 | 0 | 6 |
| MEP4 (M) | 100 | 0 | 0 | 0 | 0 | 7 |
| MEP5 (M) | 37.5 | 25 | 0 | 0 | 37.5 | 8 |
| MEP6 (F) | 92.31 | 7.69 | 0 | 0 | 0 | 13 |
| MEP7 (M) | 63.16 | 26.32 | 5.26 | 0 | 5.26 | 19 |
| MEP8 (F) | 63.64 | 9.09 | 18.18 | 0 | 9.09 | 11 |
| MEP9 (F) | 100 | 0 | 0 | 0 | 0 | 6 |
| MEP10 (M) | 60 | 20 | 20 | 0 | 0 | 5 |
| MEP11 (F) | 37.5 | 12.5 | 12.5 | 25 | 12.5 | 8 |
| MEP12 (M) | 83.33 | 16.67 | 0 | 0 | 0 | 6 |

**Note:** (M) = Male, (F) = Female, A = Bamboo forest, B = Dry evergreen forest, C = Dry evergreen forest mixed with bamboo, D = Damp area and E = Stream

**Table 19** Percentages of habitat use of *M.e.phayrei* adults in the cold dry season.

| Individual | Habitat use : Cold dry season (%) | | | | | No. of fixes |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | |
| MEP2 (M) | 0 | 50 | 50 | 0 | 0 | 2 |
| MEP3 (M) | 0 | 75 | 0 | 0 | 25 | 4 |
| MEP4 (M) | - | - | - | - | - | - |
| MEP5 (M) | 50 | 0 | 0 | 50 | 0 | 2 |
| MEP6 (F) | 60 | 0 | 40 | 0 | 0 | 5 |
| MEP7 (M) | 0 | 71.43 | 0 | 0 | 28.57 | 7 |
| MEP8 (F) | 16.67 | 66.66 | 0 | 0 | 16.67 | 6 |
| MEP9 (F) | 57.14 | 28.57 | 14.29 | 0 | 0 | 7 |
| MEP10 (M) | 100 | | 0 | 0 | 0 | 4 |
| MEP11 (F) | 0 | 2 | 0 | 0 | 4 | 6 |
| MEP12 (M) | 100 | 0 | 0 | 0 | 0 | 6 |

**Note:** (M) = Male, (F) = Female, A = Bamboo forest, B = Dry evergreen forest, C = Dry evergreen forest mixed with bamboo, D = Damp area and E = Stream

**Table 20** Percentages of habitat use of *M.e.phayrei* adults in the hot dry season.

| Individual | Habitat use : Cold dry season (%) | | | | | No. of fixes |
|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | |
| MEP2 (M) | 25 | 50 | 0 | 0 | 25 | 4 |
| MEP3 (M) | 50 | 0 | 0 | 0 | 50 | 4 |
| MEP4 (M) | 33.33 | 0 | 33.33 | 0 | 33.33 | 3 |
| MEP5 (M) | 0 | 25 | 25 | 0 | 50 | 4 |
| MEP6 (F) | 0 | 50 | 0 | 0 | 50 | 2 |
| MEP7 (M) | 0 | 50 | 0 | 0 | 50 | 2 |
| MEP8 (F) | 0 | 0 | 50 | 0 | 50 | 2 |
| MEP9 (F) | 0 | 0 | 25 | 0 | 75 | 4 |
| MEP10 (M) | 0 | 0 | 0 | 0 | 100 | 2 |
| MEP11 (F) | 0 | 0 | 0 | 50 | 50 | 2 |
| MEP12 (M) | 0 | 50 | 0 | 0 | 50 | 2 |

**Note:** (M) = Male, (F) = Female, A = Bamboo forest, B = Dry evergreen forest, C = Dry evergreen forest mixed with bamboo, D = Damp area and E = Stream

**Table 21** Percentages of habitat use of *M.e.phayrei* juveniles in wet season.

| **Individual** | **Habitat used : Wet season (%)** | | | | | **No. of fixes** |
|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | |
| JMEP1 | 0 | 16.67 | 16.67 | 61.11 | 5.55 | 18 |
| JMEP2 | 7.14 | 14.29 | 0 | 78.57 | 0 | 14 |
| JMEP3 | 0 | 33.33 | 0 | 33.33 | 33.33 | 3 |

**Note:** A = Bamboo forest, B = Dry evergreen forest, C = Dry evergreen forest mixed with bamboo, D = Damp area and E = Stream

**Table 22** Percentages of habitat use of *M.e.phayrei* juveniles in cold dry season.

| **Individual** | **Habitat used : Cold dry season (%)** | | | | | **No. of fixes** |
|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | |
| JMEP1 | 0 | 75 | 0 | 12.5 | 12.5 | 16 |
| JMEP2 | 0 | 0 | 0 | 100 | 0 | 6 |
| JMEP3 | 25 | 25 | 0 | 0 | 50 | 4 |

**Note:** A = Bamboo forest, B = Dry evergreen forest, C = Dry evergreen forest mixed with bamboo, D = Damp area and E = Stream

**Table 23** Percentage of habitat use in the hot season of *M.e.phayrei* juveniles.

| **Individual** | **Habitat use : Hot dry season (%)** | | | | | **No. of fixes** |
|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | |
| JMEP1 | 0 | 66.67 | 0 | 0 | 33.33 | 6 |
| JMEP2 | 0 | 0 | 0 | 100 | 0 | 2 |
| JMEP3 | 0 | 0 | 0 | 50 | 50 | 2 |

## 4.5 Diet

During the study period a total of 58 diet items was collected from the study site, representing 11 different plant species. All plant were identified to genus and if possible to species, except for two species of fungi.

Adult tortoises fed on varieties of herbaceous groundcover plants (Figure 26). For 8 plant species from a total of 46 diet items, three were identified to species, *Amorphophallus paeoniifolius*, *Phrynium pubinerve* and *Amischotolype monosperma* and five were identified to genus, *Bambusa* sp., *Zingiber* sp., *Alocasia* sp., *Musa* sp. and *Elastostema* sp.. Bamboo shoot (*Bambusa* sp.), 72.73% was the main diet in wet season followed by *Elastostema* sp. (18.18%). In dry season, adult tortoises fed on a variety of plant species. *Elastostema* sp. (30.78%) was eaten most frequently followed by *Alocasia* sp. (23.08%), *Bambusa* sp. (15%) and *Zingiber* sp. (15%).

The diets of juveniles were similar to adults (Table 27). Three species were identified, *Lasia spinosa*, *Phrynium pubinerve* and *Amischotolype monosperma* and three were identified to genus; *Bambusa* sp., *Zingiber* sp. and *Musa* sp. Two unidentified mushrooms growing on rotten logs were also eaten by juveniles (Figure 27). However, the main diet was slightly different. *Lasia spinosa* (44.45 %) was the main diet in wet season followed by Bamboo shoot (*Bambusa* sp.) (22.22%), unidentified mushroom (22.22%) and *Amischotolype monosperma* (11.11 %) whereas in dry season, juveniles ate slightly different diets, *Phrynium pubinerve* (33.33%), *Zingiber* sp. (33.33%) and *Musa* sp. (33.33%).

The result showed that *M.e.phayrei* at Kaeng Krachan National Park fed on variety of plants species and showed distinct selection for some of them. Bamboo shoot was the main diet in wet season, which is most likely a reflection of seasonality and plant abundance because bamboo shoot normally occurs during the wet season (May-October) and will decline in the dry season (November-April) whereas *Zingiber* sp. and *Elastostema* sp. are common in both seasons but was most frequently observed eaten by *M. emys phayrei* in dry season. The result suggested that tortoises show no interest in other herbs surrounding the Bamboo shoot. This indicates that *M.e.phayrei* selectively forage for this plant. Bamboo shoot has a high level of calcium. It is possible that tortoises eat bamboo shoot to make up the balance of calcium because herbivorous tortoises are known to face limitation from calcium balance (Hailey *et al.*, 1998). This pattern of diet selection was also reported in *M.e.emys* by Montensen (2004) who reported that in places with a wide variety of different herb species, the *Alocasia* species were always selected if present.

The difference in main diet between adults and juveniles may be from foraging efficiency and food quality. Selecting high quality diets may be important in accelerating the growth rate of chelonians (Okamoto, 2002). Juveniles tend to travel short distances and forage for short period of time; therefore, they would seem to be able to feed only on relative good quality of food. *Phrynium* sp. and *Lasia spinosa* were frequently encountered along the main habitat type (mud-swamp) of juveniles, making them easy for feeding. However, *Lasia spinosa* was eaten most frequently. It is possible that *Lasia spinosa* contain relatively high amounts of some important nutrients for juveniles.

The difference between juvenile and adult tortoises has been reported in gopher tortoises, *Gopherus polyphemus*. Macdonald and Mushinsky (1988) who reported that foraging habits of G. *polyphemus* juveniles suggested that they tend to ingest fewer grasses and plants with external defense mechanisms and consume more plants with high nitrogen content, such as legumes, than adults.

**Table 24** Plant species eaten by *M.e.phayrei* adults

| **Species** | **Family** | **Part(s) eaten** | **Number of observations** (%) | |
|---|---|---|---|---|
| | | | **Dry season*** | **Wet season*** |
| *Bambusa* sp. | Gramineae | shoot | 2 (15.38) | 24 (72.73) |
| *Zingiber* sp. | Zingiberaceae | stem and leaf | 2 (15.38) | 0 (0) |
| *Amorphophallus paeoniifolius* | Araceae | stem and leaf | 0 | 1 (3.03) |
| *Alocasia* sp. | Araceae | whole plant | 3 (23.08) | 1 (3.03) |
| *Musa* sp. | Musaceae | stem and leaf | 0 | 1 (3.03) |
| *Phrynium pubinerve* | Marantaceae | stem | 1 (7.69) | 0 |
| *Elastostema* sp. | Urticaceae | leaf | 4 (30.78) | 6 (18.18) |
| *Amischotolype monosperma* | Commelinaceae | flower, stem and leaf | 1 (7.69) | 0 |

* Dry season = January – April
Wet season = May-September



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**Table 25** Plant species eaten by *M.e.phayrei* juveniles

| Species | Family | Part(s) eaten | **Number of observations** (%) | |
|---|---|---|---|---|
| | | | **Dry season*** | **Wet season*** |
| *Bambusa* sp. | Gramineae | shoot | 0 | 2 (22.22) |
| *Zingiber* sp. | Zingiberaceae | stem and leaf | 1 (33.33) | 0 |
| *Lasia spinosa* | Araceae | stem | 0 | 4 (44.45) |
| *Musa* sp. | Musaceae | stem and leaf | 1 (33.33) | 0 |
| *Phrynium pubinerve* | Marantaceae | stem | 1 (33.33) | 0 |
| 2 Unidentified mushroom | - | whole mushroom | 0 | 2 (22.22) |
| *Amischotolype monosperma* | Commelinaceae | flower, stem and leaf | 0 | 1 (11.11) |

* Dry season = January – April
Wet season = May-September



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A

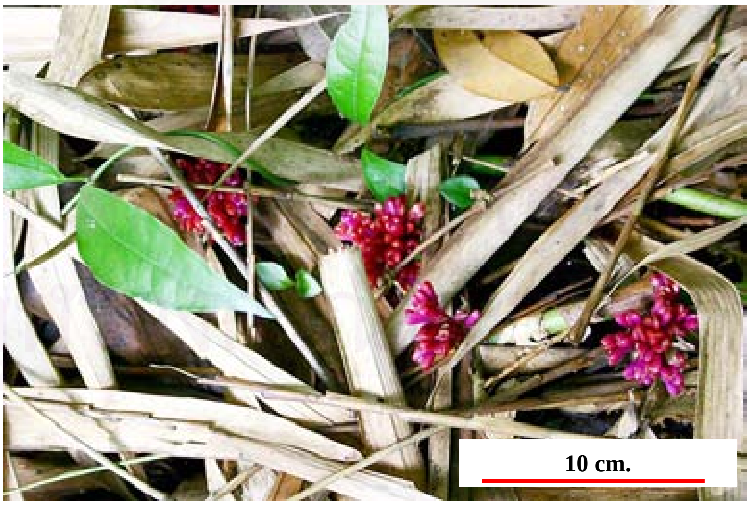

B


C

**Figure 29** Diets of *M.e.phayrei* ; A = *Lasia spinosa*, B = *Alocasia* sp, C = *Amorphophallus paeoniifolius*


D


E




F

**Figure 29** (cont.) Diets of *M.e.phayrei* ; D = *Elastostema* sp., E = *Phrynium pubinerve*, F = *Amischotolype monosperma*.


G


H


I

**Figure 29** (cont.) Diets of *M.e.phayrei* ; G = Unidentified mushroom, H = *Bambusa* sp., I = *Musa* sp.


J

**Figure 29** (cont.) Diet of *M.e.phayrei,* J = *Zingiber* sp.


**Figure 30** A Juvenile *M.e.phayrei* was eating mushroom on rotten log.

# CHAPTER V

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusion

### 5.1.1 Home range size

Home ranges of *M.e.phayrei* in wet season, dry season and year-round varied greatly among individuals. The median home range sizes within season and year-round between adult male and female tortoises were not significantly different but were significantly larger than the home range sizes of subadults. The median home range sizes of adult males and females in wet season were significantly larger than in dry season. However, for subadults, the median home range sizes were not significantly different between wet and dry season.

### 5.1.2 Activity

Adult activities were classified as basking, eating, hiding, resting, soaking and walking. During wet season (May-October), adult tortoises were mostly found eating. For juvenile tortoises, they were mostly found soaking followed by eating. During the cold dry season (November-February), a few tortoises were active and spent the majority of their time hiding. During hot dry season (March-April), both adults and juveniles spent the majority their time soaking.

### 5.1.3 Habitat temperature and relative humidity

Both adult and juvenile tortoises had hinding activity when the relative humidity was low and when air temperature was high, adult tortoises used damp area for soaking.

The averages of year-round air temperature, ground surface temperature and relative humidity at the areas where between male and female tortoises were found were not significant different.

There was no significant difference in the habitat air temperature and relative humidity between adult and juvenile tortoises. However, the ground surface and carapace temperature of juvenile tortoises were significantly lower than adult male and female tortoises.

### 5.1.4 Habitat use

Throughout the year, *M. e. phayrei* were found in five habitat types; bamboo forest, dry evergreen forest, dry evergreen forest mixed with bamboo, stream and mud-swamp. In wet season (May-October), most adult tortoises were found in bamboo forest whereas juvenile tortoises mostly spent their time in mud-swamp. During the cold-dry season (November-February), tortoises were commonly found under the fallen branches or leaf litter. In hot dry season (March-April), they were frequency found near to the stream and damp area

### 5.1.5 Diet

The result showed that they are generalist herbivores, consuming at least 10 species of plants such as *Amorphophallus paeoniifolius*, *Phrynium pubinerve*, *Amischotolype monosperma*, *Bambusa* sp., *Zingiber* sp., *Alocasia* sp., *Musa* sp. and *Elastostema* sp.. Bamboo shoot (*Bambusa* sp.) and *Lasia spinosa* were the main diet in wet season for adults and juveniles, respectively. In dry season, adults and juveniles ate slightly different diets.

## 5.2 Recommendation

To improve the accuracy of estimating home range size, number of fixes should be collected as many as possible in order to reduce empty area in Minimum Convex Polygon method.

For future researches, the trial string method and electronic equipment such as the data logger should be applied since it would show the patterns of the movement, distance moved and daily activity pattern of tortoise as well as their detailed environmental conditions.

Population size and minimum area for conservation of this species should be estimated in the future.

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# Biography

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