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Population Structure and Reproduction of the Elongated Tortoise *Indotestudo elongata* (Blyth, 1853) at Ban Kok Village, Northeastern Thailand

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ABSTRACT.– **The population structure and reproductive biology of the elongated tortoise *Indotestudo elongata*, were investigated at a 492 ha site at Ban Kok Village, Khon Kaen Province, Thailand, from May 2007 to August 2009. A total of 1,195 individual tortoises (391 males, 369 females and 435 unsexed juveniles) were captured yielding a minimum population density of 2.43 ind. per ha. The age and size structure exhibited a normal (close to 1:1) male: female sex ratio of 1.07:1, but the proportion of early and adult developmental stages in the population was high. Thus, in a closed non-expanding population, only a small proportion of the young tortoises will replace the higher age classes in the population. Tortoises at all ages had a mortality risk from human activities, such as off-road cars, burning rubbish and landscape modifications, but no natural predators were found, although parasites were evident. Mating was observed from May to August with oviposition at the end of the rainy season (October) until March. The mean clutch size was 4.53 ± 2.26 eggs. Hatchlings emerged at the beginning of the following rainy season (April to June). One female produced more than one clutch in a season. The undisturbed hatching success was high (81%), but nest disturbances reduced the overall hatching success to 60.3%, with a relatively low hatchling survival rate over the first three months (67%). The main cause of the hatchling mortality is unknown, but minor causes were cars and large cattle. Both adult and juvenile forms consumed herbaceous leaves, fruits, mushroom, grass, earthworms, carcass, food particles and animal excrement. The elongated tortoise population at Ban Kok Village has not been threatened severely, but short- and long- term monitoring should be conducted.**

KEY WORDS: ***Indotestudo elongata*, tortoise, reproduction, population structure, conservation**

INTRODUCTION

The elongated tortoise, *Indotestudo elongata* Blyth 1853 (Reptilia: Testudines) belongs to the Family Testudinidae and ranges from Nepal, Bangladesh, India, China, Myanmar, Thailand, Laos, Cambodia and Vietnam to Malaysia (Ernst and Barbour, 1989). It is categorized as an endangered species on the IUCN Red List of Threatened Species (IUCN, 2011), and listed in Appendix II of CITES. This species has been commonly found in the Asian food markets and it is the most common tortoise shipped to the Chinese food markets from Vietnam (Hendrie, 1998). Jenkins (1995) reported that this species is one of the three Thai tortoises that have been hunted intensively, mainly for local consumption, to such an extent that populations of *I. elongata* collapsed in 1970 and have not yet recovered. Although populations of *I. elongata* were reported to still be widely distributed in the hills of western Thailand in the early 1990's (Thirakhupt and van Dijk, 1994), these populations appear to have crashed in the last 10 to 15 years and nowadays it is nowhere common.

In Thailand, there is a village named "Ban Kok" where Elongated tortoises have lived with the local people since 1767 (Sutthitham et al., 1996). In the past, most areas around this village were comprised of a deciduous forest mixed with bamboo, where the bamboo shoot formed the main diet of the tortoise. At present, this area is composed of a variety of trees, such as Neem (*Azadirachta indica*), *Ylang-yling* (*Cananga odorata*) and the dipterocarps *Shorea obtusa* and *S. siamensis*. Tortoises at Ban Kok village have been protected from exploitation by local people because of their spiritual beliefs, their way of life and the absence of any natural predators capable of killing the adults. Thus, the population size and density of tortoises here is much higher than in other areas, but the degree of habituation and adaptation to humans is unclear. However, increasing numbers of tourists visit this area continuously, which could lead to the problem of increasing tortoise mortality from cars. At the same time, many tortoises have been collected and put into gardens for the purpose of tourism (Sutthitham et al., 1996), which could increase the habituation and adaptation to humans. Moreover, the growth of the local community, in terms of economic, population level and visitors, has led to the concomitant increase in the road networks and traffic, along with urban development and habitat loss, which in conjunction with fluctuating environmental conditions at the present time, could adversely affect the structure and finally the existence of this tortoise population.

Accurate information on the biology and life history of *I. elongata* will help provide instruction in establishing plans for the conservation and sustainable management of the indigenous population. Although previous studies on the ecology and reproduction of *I. elongata* are known for some Western (Thirakhupt and van Dijk, 1994; Tharapoom, 1996; van Dijk, 1998) and Northern (Sutthitham et al., 1996) Thailand populations, these data are incomplete because the sample sizes were small. For example, the time of egg laying in the field is limited to just a few observations, the reported clutch sizes are quite variable, and the information is mostly unpublished. With respect to the diet of *I. elongata*, analysis of the fecal contents and direct observations of feeding revealed that the diet of this tortoise species included a wide range of fruits and leaves as well as some animal matters (van Dijk, 1998). Nutphand (1979) reported that *I. elongata* feed on plants, fungi and slugs, whereas flowers and fruits were reported by Das (1991). The aim of this study was to investigate and to integrate the information on the population structure and reproductive biology, including the mating time, nesting time, clutch size, incubation time, hatching success and hatchling survival rate, of the *I. elongata* population at Ban Kok Village, Khon Kaen Province, so as to be able to suggest conservation and management plans. Moreover, this can form a database from which expanded studies, in comparison with data from wild populations, will allow a better understanding of key aspects of the ecology of *I. elongata* for conservations, as well as the degree of ecological changes through habituation and adaptation to/ dependence upon humans of this population.

MATERIALS AND METHODS

Study area.– The 4.9 km^2 study area, called the "tortoise village", is located at Ban Kok Village (Fig. 1), Suan Mon Subdistrict, Mancha Khiri District, Khon Kaen Province, Thailand. The geographic position is approximately (UTM system) 48Q 238269 m E 1787990.47 m N at an average altitude of 150 meters above the mean sea level. The climate of the region is mostly hot and dry and is influenced by the southwestern monsoon. There are three seasons: summer, rainy and winter. Summer, from the end of February to May, is hot to very hot and dry, whilst May to October is the rainy season and winter is from October to January (Suan Mon Sub-district Administration Organization, 2010). The average annual rainfall (1990-2009) was 145.31 mm/year, with most rain falling from May to October. The air temperature in the hottest month (April) can reach 41.9 °C and the minimum temperature is about 6.4 °C in December (Thai Meteorology Department, 2010). The human population in the village was about 1,355 people in 295 households in 2010 (Suan Mon Sub-district Administration Organization, 2010). Figure 2 shows typical views inside the village, which is the habitat of *I. elongata* in this study area, where these tortoises are protected from hunting by the local people and there is no natural predator that kills the adults. Most people in the village are farmers and grow perennial plants, fruits and vegetables in their home gardens, and many of these are used as food by the tortoises, such as *Artocarpus heterophylus, Mangifera indica* and *Annona squamosa* (Fig. 2A). Some areas in the village are covered with relatively small dense vegetation and a very scattered plant cover (Fig. 2B). These plants grow rapidly during the rainy season and disappear during the dry season.

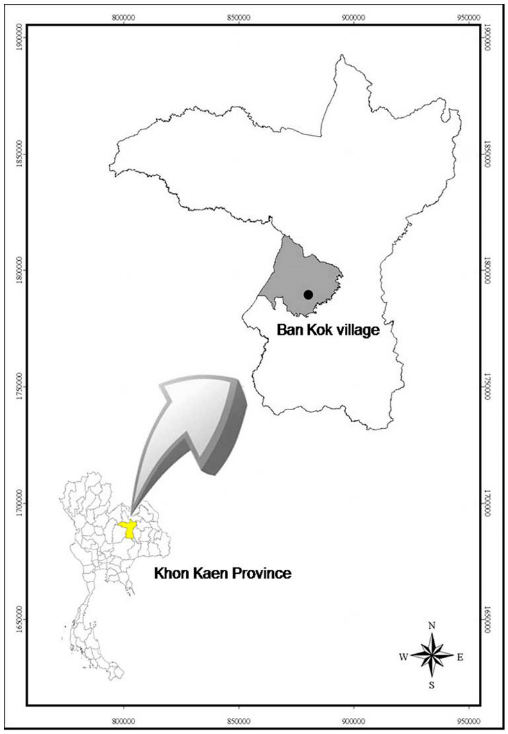

FIGURE 1. Location of Ban Kok Village, Khon Kaen Province, covering 4.92 ha.

Field methods.– Elongated tortoises (*I. elongata*) were visually searched for and the population size was estimated during May to August 2009, when there was no new individuals added to the population. All elongated tortoises in the village were collected by road cruising, intensive searches and fortuitous encounters, and were individually marked with a magic permanent marker on the marginal scutes, which remained visible for up to three months. The carapace length (CL) was measured by a digital caliper (accuracy ± 0.1 mm). Adults, subadults and juveniles were classified based on secondary sexual characteristics. Males have a concave

FIGURE 2. The habitats of *I. elongata* in Ban Kok Village. (A) The backyard of a house in the village where villagers grow perennial plants, fruits and vegetables, which form part of the diet of the tortoises. (B) An area in the village covered with relatively small dense vegetation and very scattered tree coverings, providing habitat and food for tortoises. Note the presence of the cattle, which can occasionally trample the hatchlings.

plastron and a tail length that is much longer than in females (Fig. 3) (Tharapoom, 1996; van Dijk, 1998), but were generally only reliably distinguished from 4 years of age and upwards. Any elongated tortoise without male characteristics was assumed to be a female, and tortoises that could not be separated by sex were considered juvenile. The age and size at maturity was estimated by counting the annual rings at the scute and

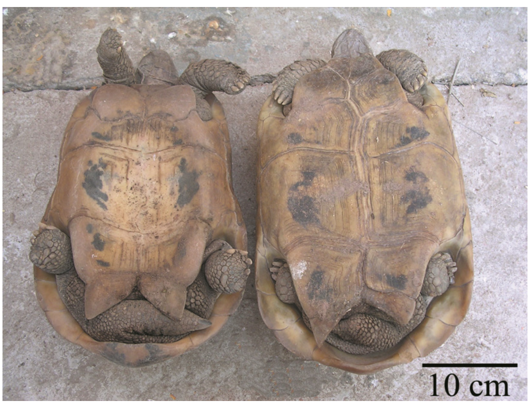

FIGURE 3. Male and female adult elongated tortoises (*I. elongata*). The (Left) male has a longer and thicker tail with a concave plastron, while the (Right) female has a shorter tail and flat plastron.

in the field was based on the observed sexual behavior in both sexes and on the reproductive status in female (i.e., egg-bearing) (Lagarde et al., 2001). The criterion of sexual maturity in males was considered if they displayed copulation with females (Lagarde et al., 2001), and in females was considered from egg laying. The smallest size at sexual maturity for males and females was 175 mm and 240 mm, respectively, and was obtained after ~5-6 and ~8 years, respectively. However, at this size males did not completely show all of the external male characteristics. In this study, the minimum size at sexual maturity was larger than the minimum size at which we could reliably determine the sex in the field. Tortoises were considered as juveniles if their sex could not be distinguished.

Tortoise age was determined by counting the number of scute annuli on the shell (Judd and Rose, 1983; Germano, 1988; Germano and Bury, 1998; Hellgren et al., 2000; van Dijk, 1998). The scute annuli on the second right pleural scute were also counted (Kaddour et al., 2006) and crosschecked with the other scutes (Znaria et al., 2005). A newly hatched animal possessed a central areola with one annulus. All counts were, therefore, started from the next annulus (Stubbs et al., 1984). All individuals born after the May-August counting period of that year were not counted. The age of old tortoises (> 20 years) with indistinct annuli were difficult to assess and so they were grouped into a single 20+ years old category.

Data on the reproductive biology of this *I. elongata* population were collected from May 2007 to May 2009. The mating behavior was observed and recorded from the beginning to the end of mating activities, and the time of egg deposition was also recorded. Eggs were removed carefully from the nest when the nest was found. Clutch sizes were determined by counting the number of eggs and the length and width of each egg was measured using a vernier caliper, whilst the egg mass was measured using an electronic balance. After that the eggs were returned to the same position, and the nest location was marked and photographed. Nests were checked regularly for emerging hatchlings. In this study, the incubation period was defined as the time between the egg deposition and hatchling emergence. One hundred hatchlings were collected randomly and marked with permanent marker on the vertebral scutes for studying their survival rate. The CL and carapace width (CW) of each hatchling was measured to the nearest 0.1 mm and weight to nearest 0.5 g. They were then released in the field. Each tortoise was observed every two weeks for up to three months. The diets of the elongated tortoise were investigated by direct observation.

Statistical analysis.– The population size was obtained by the total count method, and from that the average population density was evaluated; given the study site area was 492 ha (4.92 km^2). The age and size distributions were compared using a Chi-squared test. The clutch size and egg size were recorded from 23 *I. elongata* nests, whilst the hatching success was evaluated from 15 undisturbed (from 20 observed) nests for which exact oviposition dates were known. The differences in the average egg length, width and weight from each clutch were analyzed using the Kruskal-Wallis H test. The relationship between incubation periods and hatching success in each clutch was analyzed using a Pearson correlation test. In all cases significance was accepted at the $p < 0.05$ level.

RESULTS

Population Structure

Population size and Density.– The *I. elongata* population size in the study area (Ban Kok village) was estimated to be 1,195 individuals, yielding an average population density of 2.43 individuals / ha (= 243 individuals / km^2), and was comprised of 391 (32.7%) males, 369 (30.9%) females and 435 (36.4%) juveniles. The adult sex ratio (males: females) was 1.07: 1, but it was not possible to determine the sex, and thus the sex ratio, of juveniles in the field.

Age structure.– The age frequency distribution of the elongated tortoise population is shown in Figure 4, but note that since the gender of juveniles up to 4 years of age could not be determined they are shown as an assumed 1:1 sex ratio. Most tortoises in the village (44.2%) were more than 20 years old, although small 0-1 year tortoises were the next highest proportion at 30.8%. All other age groups were less common. The age distribution of specimens

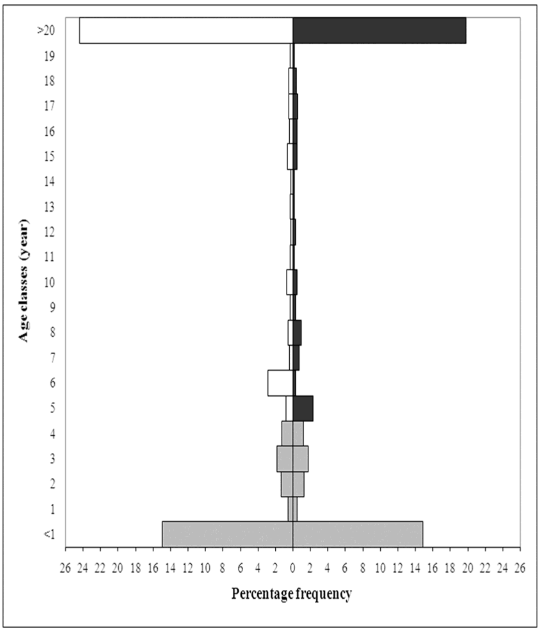

Figure 4. Age structure of the *I. elongata* population from Ban Kok Village, Khon Kaen Province, Thailand. The population pyramid shows the percentage frequency of age classes for adult and subadult males (white bars) and females (black bars), and for juveniles (grey bars). Note that juveniles at up to 4 years of age could not be sexed and so were equally divided between males and females on the graph (assumed 1:1 sex ratio).

over 4 years old (and so sexed) was significantly different between males and females ($p \leq 0.05$), with more males in the 20+ category and, in general, more young females (4, 5 and 7-10 years old).

Size structure.– The size structure of the *I. elongata* population, derived from the 1195 individuals caught, is presented in Figure 5. In the graph, as before, juveniles are arbitrarily divided equally between males and females (assumed 1:1 sex ratio) since they could not be sexed in the field. However, juveniles accounted for 36.4% of the total samples and so of the assumed population structure. With respect to the sexed adults, the body size class distribution (in terms of CL) was significantly different between males and females ($p < 0.001$) with, in general, a higher proportion of males in the larger size categories (CL of >180 mm), but note that the largest sized individuals (CL of >325 mm) were all female. Overall adult (CL of ≥ 175 mm) and subadult (CL of 158-174 mm) males represented 32.1% and 0.7%, respectively, or a total of 32.7% of the population, whereas adult (CL of ≥ 240 mm) and subadult (CL of 128-239 mm) females represented 22.4% and 8.5%, respectively, or a total of 30.9% of the population. Of the 760 non-juvenile animals, 383 (32.1%) and 268 (22.4%) were mature males and females, respectively, whilst 8 (0.7%) and 101 (8.5%) were subadult males and females, respectively. The largest living

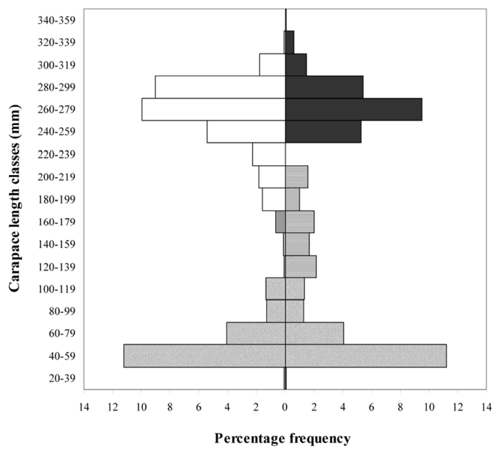

Figure 5. Size structure of the *I. elongata* population from Ban Kok Village, Khon Kaen Province, Thailand. The population pyramid shows the percentage frequency of each size class for (white bars) adult and (dotted bars) subadult males and (black bars) adult and (hatched bars) subadult females, and for (grey bars) juveniles. Note that juveniles that have a carapace length of less than 120 mm could not be sexed and are shown as an equal proportion of males and females (assumed 1:1 sex ratio).

male and female had a CL of 324 mm and 340 mm, respectively, but note that if dead animals were included the largest female observed was significantly larger with a CL of 370 mm.

Reproduction

Mating behavior.– A total of 33 adult tortoises, 15 males and 18 females (1:1.2 male: female sex ratio), were observed to display reproductive behavior during the May to August 2007 period. The conspicuous characteristic of adult males during this time was their bright pink colored nose. Courtship behavior was started by the mature male who approached the mature female. He then placed his nose around her cloaca, and used his anterior carapace to encounter the posterior end of the female. The male then climbed up the female by using his claws to hold the female's back around the costral scutes. Once mounted upon the female's back, the male fully extended and shaked his neck from side to side and tried to push his penis around the base of the female's tail, and at the same time then vocalized loudly. Copulation lasted about 5 – 20 minutes. Since most Elongated tortoises exhibited multiple mating and promiscuity was also observed a few times, then the mating system is likely to be broadly polygynandrous or promiscous.

Nesting.– Nest deposition was observed from the 29th October 2008 to the 15th March 2009. Generally, female tortoises dug out a hollow nest in the soil with their back legs, flattened the nest with their plastron and laid the eggs. Most (21/23; 91.3%) of the located nest sites were situated near a tree base and bamboo clump with a high moisture level. The other two nests (8.7%) were found on the ground away from such vegetation. The shape of the nests was flask shaped with a mean nest depth of 11 ± 1.66 cm (8.0-13.0, N = 9). The evidence of females laying more than one egg clutch annually was only observed in one tortoise, who first laid a clutch of five eggs on the 11th February, 2010, and then another clutch of two eggs was laid on the 15th March, 2010.

Clutch size and egg size.– The elongated tortoise eggs were spherical or oval in shape and of a white color. Clutch sizes were found to vary from 1 to 9 eggs with a mean clutch size of 4.5 ± 2.3 eggs per clutch (1-9, N = 23). The mean egg length, width and mass (Table 1) were 47.2 ± 2.9 mm (41.0 - 53.1, N = 74), 39.0 ± 2.5 mm (34.4- 45.4, N = 74) and 43.2 ± 7.5 g (26.2 - 60.2, N = 74), respectively. There was no significant difference in the egg length, width and mass among the different clutch sizes (Kruskal-Wallis Test, $P > 0.05$). With respect to the three dead female tortoises found at the survey site in the reproductive period, three medium sized females were found to contain mature eggs, two individuals had matured 6 eggs (CL of 25.4 and 27.7cm) and one (CL of 27.7 cm) had a single egg.

Incubation and hatching success.– Of the 23 clutches found, 20 had known deposition dates and so were suitable for analysis of hatching times. However, of these 20 clutched, 15 were not disturbed and so were analyzed for their incubation period in nature. Most hatchlings emerged over a 5-week period in the rainy season, between the 25th April and the 12th June, 2009. The mean incubation period was 157.9 ± 18 days (117-180, N = 49), and hatchlings from the same clutch emerged at a different time, ranging from 1-12 days after the previous hatching (Table 2). No clear pattern in the different successive emergence times of

TABLE 1. Mean ± 1 SD and range of the length, width and weight of *I. elongata* eggs from different clutch sizes. “n” is the total number of eggs measured.

Clutch No.	Frequency	n	Egg length (mm)		Egg width (mm)		Egg weight (g)	
			Mean ± SD	Range	Mean ± SD	Range	Means ± SD	Range
1	5	5	47.0 ± 3.6	42.7-52.6	37.8 ± 3.3	34.7-42.6	40.8 ± 7.9	33.0-52.7
2	2	3*	48.4 ± 2.4	45.8-50.7	40.0 ± 4.1	35.3-42.9	47.9 ± 11.0	35.2-54.4
3	4	12	47.6 ± 2.5	42.9-51.6	39.0 ± 2.2	36.3-43.1	44.4 ± 6.3	33.7-52.7
4	9	36	47.4 ± 3.1	41.7-53.1	39.3 ± 2.0	35.7-44.1	43.0 ± 7.4	26.2-59.3
5	1	3*	49.2 ± 1.4	48.8-50.7	40.4 ± 1.1	39.4-41.5	47.6 ± 3.2	44.9-51.1
8	1	6*	45.8 ± 2.9	41.5-49.4	39.5 ± 4.8	34.4-45.4	44.8 ± 13.1	31.2-60.2
9	1	9	45.6 ± 2.1	41.0-48.3	37.5 ± 1.5	35.5-39.5	39.7 ± 3.1	35.0-44.1

Note: * some eggs were broken and so were not measured

hatchlings within a clutch were observed between clutches of different sizes, but the sample size is too small for analysis. However, the relationship between the mean incubation period of all the eggs in a clutch and the clutch size were not significantly correlated (Pearson correlation test). Of these 15 nests observed, the average hatching rate was 81% (N = 43 eggs). The mean percentage of hatching success in clutch sizes of 1, 2, 3, 4 and 6 were 100%, 66.7%, 75.0%, 81.3% and 100%, respectively. Another five nests (25%), all with a clutch size of three eggs, could not be observed because the nest sites were disturbed by humans and / or by chickens. Nest predation was not evident and predators were not found. However, since such disturbances are part of the life history of *I. elongata* at this site their inclusion (as 0% hatching success) is warranted and as such reduces the hatching success rate for a clutch size of three to 33.3% and the overall hatching success rate to 60.3% (N = 58 eggs).

Hatchling survival rate.– The survival rates of 100 hatchlings were observed between August to October 2009 in the study area. Of the 33 dead hatchlings that were found during the study period, 29 had died from unknown causes (no evidence of wounds and the carcasses were complete), three had been killed by off-road vehicles and one by cattle trampling. Predators were not found in the study area. However, the carcasses were not examined for internal parasites or pathogens and so these causes remain possible. Overall, the monthly hatchling survival rates for the first, second and third months after hatching were 89%, 88.8% and 84.8%, respectively, giving cumulative survival rates over the first three month period of 89%, 79% and 67%.

Diets.– By direct observation, the elongated tortoises at Ban Kok Village were found to obtain their food in two ways. Firstly, they were fed by the villagers and secondly they foraged for food from within their habitat around the village. Typical examples of food they obtained from the villagers were papaya (*Carica papaya* L.), mango (*Mangifera indica* L.), star fruit (*Averrhoa carambola* L.), rose apple (*Syzygium jambos* L. Alston), cheese fruit (*Morinda citriforia* L.), guava (*Psidium guajava* L.), cucumber (*Cucumis sativus* L.), musk melon (*Cucumis*

TABLE 2. Mean incubation periods and hatching success for *I. elongata* eggs from clutches containing 1-6 eggs.

Clutch size	Clutch number	Incubation periods (days) for clutch size of:						Mean ± SD	Hatching success (%)
		1	2	3	4	5	6		
1	1	166	-	-	-	-	-		100
	2	174	-	-	-	-	-		100
	3	180	-	-	-	-	-		100
2	1	168	178	-	-	-	-	173 ± 7.1	100
	2	0	0	-	-	-	-	0	0
	3	157	163	-	-	-	-	160 ± 3	100
3	1	167	169	181	-	-	-	172.33± 7.6	100
	2	136	139	142	-	-	-	139 ± 3.0	100
	3	117	0	0	-	-	-	117	33.33
	4	0	174	178	-	-	-	176 ± 2.8	66.67
4	1	138	139	143	151	-	-	142.8 ± 5.9	100
	2	138	140	140	151	-	-	142.3 ± 5.9	100
	3	151	160	165	169	-	-	161.3 ± 7.8	100
	4	0	147	0	0	-	-	147	25
6	1	153	157	160	162	164	164	160 ± 4.3	100

melo L.), jack fruit (*Artocarpus heterophyllus* Lam.), pineapple (*Ananas comosus* L. Merr.), water melon (*Citrullus vulgaris* Eckl. Zeyh.), madras thorn (*Pithecellobium dulce* (Roxb.) Benth.), cabbage (*Brassica oleracea* L. var. *capitata* L.), and rice (*Oryza sativa*). The food that tortoises searched for themselves from their surrounding habitat included earth worms, carcass, ivy gourd (*Coccinia grandis* L. Voigt), wild amaranth (*Amaranthus lividus* L.), climbing spinach (*Basella rubra* L.), sheep potatoe (*Ruellia tuberosa* L.), gomphrena weed (*Gomphrena celosioides* Mart.), common wireweed (*Sida acuta* Burm. f.), Ya khat luang (*Sida subcordata* Span.), papyrus (*Cyperus* sp.), mushrooms and animal excrement.

DISCUSSION

Population structure

Population size and density.– In this study, the population size of the elongated tortoise at Ban Kok was estimated to be about 1,195 individuals with a population density of 2.43 individuals / ha. However, with an area of only 4.92 km^2 it is unclear if the population is still increasing in size or not and if they are going to increase in the future. The observed ratio of adult males: adult females was 1.07:1, similar to the evolutionarily stable 1:1 ratio predicted by Fisher (1930), where parental investment should be equally divided between male and female offspring (Lovich and Gibbons, 1990). However, if the sex ratio is considered from the age at maturity (male = 6 yrs old, female = 8 yrs old), the sexually mature sex ratio is then male biased at 1.43:1 (383 males to 268 females), which reflects that the older age classes contain more males than females, assuming all older males are still fertile and virile. Therefore, the effective sex ratio of adults will be affected by the age at maturity, with a bias towards the sex which reaches maturity earlier (Lovich and Gibbons, 1990; Lovich et al., 1990; Hailey and Willemsen, 2000), assuming no differential loss of fertility with age between males and females. At this study site, male Elongated tortoises with a CL of more than 175 mm are sexually mature, whereas females with a CL of more than 240 mm are mature. Therefore, with an almost equal growth rate, males take a shorter time to reach sexual maturity (6 years) than females (8 years) and so this accounts for the apparent male biased adult sex ratio, assuming they have equal longevity, or more importantly, remain sexually active until the same age as noted above.

Indeed, in many species of turtles, males and females have been reported to reach sexual maturity at different sizes and ages (Hulse, 1982; Jones and Hartfield, 1995; Diaz-Paniagua et al., 2001; Rouag et al., 2007). This shift from a primary 1:1 population sex ratio at birth to a male biased sexually mature adult sex ratio in mature tortoises is similar to that reported in the Sonoran turtle (*Kinosternon sonoriense*), where males in two different populations matured at a smaller size and at a younger age than females (Hulse, 1976, 1982). At Tule Stream, Yavapai County, the observed ratio of mature males to females was 1.9:1, although if all sexable turtles were considered the ratio was 1:1.1. This shift from a primary 1:1 sex ratio to a male biased and then back to a 1:1 asexually mature sex ratio in Sonoran turtles was explained by the fact that all males larger than 80 mm are mature and their growth rate at maturity slowed down to approximately 1.5 mm/year, whereas the females are still in a period of rapid growth at this age. When females mature, at approximately 93 mm, their growth then slows and the sex ratio reverts back to approximately 1:1. The factors influencing the sexually mature population sex ratio are the primary sex ratio, differential age at maturity for males and females, differential mortality between sexes, differential migration between sexes and sampling bias (Gibbons, 1990). The male biased sex ratio observed for adult *I. elongata* at Ban Kok is consistent with different survival rates between males and females (Ayaz et al., 2007), with a higher female mortality than males. The cause of death in our study was not determined, but mortality of females may be caused by mating attempts from many males as lesions were found around the anal region of females and the presence of eggs were found in the dead bodies of three females in the field. Therefore, injury and infection may lead to the death of females. In agreement, in Hermann's tortoise (*Testudo hermanni*), it was found that increasing female mortality due to male-biased sex ratios occurred from wounds obtained during courtship (Hailey, 1990). Moreover, a high female mortality may result from an increased susceptibility to pathogens, impaired movement, or directly from calcium deficiency (Hellgren et al., 2000).

Age and size structure.– The age and size structure (Figs. 4 & 5) of the *I. elongata* population at Ban Kok village exhibited a similar pattern, which is different from that reported for other Chelonian populations (Bourn and Coe, 1978; Znari et al., 2005; Kaddour et al., 2006; Ayaz et al., 2007). However, age estimation is one of the problems for these tortoises, where no correlation between the age and the scute growth ring was found for specimens of more than 7 years old. This agrees with the studies of Bertolero et al. (2005), who assessed the reliability of ring counts for age determination in *T. hermanni* by direct observations in the field and photographs and concluded that both methods were comparable and reliable for individuals between 0 and 7 years old but tended to underestimate the age for those between 8 and 11 years old. Therefore, ring counts are only reliable for juveniles and subadults. In addition, van Dijk (1998) reported the same problem for estimating the age of *I. elongata* in a hill forest mosaic in Western Thailand, with a less than perfect correlation between the scute growth ring counts and the known age. Tracy and Tracy (1995) reported that in the Desert tortoise (*Gopherus agassizii*) the number of scute growth rings is related more closely to their growth than to their known age.

The shape of the population age and size distribution tends to predict that the pre-reproductive size classes form a relatively small proportion of the population. However, the tortoise is a long lived animal and so this may not be the case, whilst 44.2% of the adults may not all be old tortoises. Only a low proportion of the young tortoise cohort in each age class may develop to replace the higher age classes in the population. In contrast, at this study site, which is free of natural adult predators, the adult tortoises have a mortality risk from various human mediated activities, such as car traffic, burning of rubbish and land development. Thus, this species should be monitored continuously in order to maintain its survivorship. The result also indicated that the survival rate of juveniles was low with a likely concave or type III survivorship curve (Campbell et al., 1997) of a very high mortality among the young age classes whilst adult survivorship is relatively high and more nearly constant (Rockwood, 2006).

The majority of tortoises found in the village were adults, which is unlikely to be due to oversight of younger tortoises. Indeed, small tortoises (< 1 year old) were also easily encountered, because the survey was performed during the hatching period in the early and middle rainy season. That the population age distribution is highly biased towards old individuals likely reflects a high mortality in the early stages of their life history (Chen Tien-His and Lue Kuang-Yang, 1999), especially after hatching (0-1 year). Car accident, trampling by large ungulates (such as cows and buffalos), food availability and environmental conditions in the village, which are unsuitable for small tortoises, were the recorded causes of mortality of juveniles and small tortoises in the study area. However, they account for only a low proportion of the total mortality, so that other unknown cause(s) which were higher in the juveniles are the most important cause(s) of death. The mortality in neonate Bolson tortoises (*Gopherus flavomarginatus*) was apparently very high in the nest and hatchling stages due to sun light, cold decalcification, desiccation and drowning, as well as undetermined (Adest et al., 1989a,b). Constantly high or fluctuating mortality, including from unknown causes, appears characteristic of immature chelonians in general, where the mortality of tortoises varies among years, probably as a function of the climatic fluctuations (Keller et al., 1998). Subject to the caveat of the effect of adaptation and habituation to/ dependence upon humans, the long-term monitoring of this population to gain a clearer picture of the mortality rates and causes across the different age classes may be useful for future conservation management.

Reproduction

Mating behavior.– The observed mating behavior and activity patterns in the study area indicated that the mating season of *I.*

elongata occurred in the rainy season. This agrees with the report of van Dijk (1998) who reported that the mating behavior and pink nose of male Elongated tortoises in a hill forest mosaic in Western Thailand were found in the early part of the rainy season.

The courtship behaviors of tortoises are somewhat varied between species and possibly between populations of the same species, but generally use multiple signaling systems based upon optical, chemical and auditory signals (Sacchi et al., 2003). Auffenberg (1977) found that tactile and chemical signals were more important in land tortoises than visual and auditory signals, with shell ramming being the main tactile signal that was used in either combat or courtship. However, in *T. marginata* male mounting success did not relate to the call duration but to the male/female size-ratio (Sacchi et al., 2003).

In this study, male elongated tortoises were found to exhibit multiple mating. This pattern might be an advantage to the male in sexual selection by increasing the male's inclusive fitness with mate number (Sacchi et al., 2003).

Reproductive traits.– The nesting season of elongated tortoises found in this study (October to March) was similar to that reported for hill forest populations of this species in Western Thailand (Bourret, 1941; Spencer, 1987), where the nesting season occurred during October to January, although eggs could also be laid at other times of the year (van Dijk, 1998). Although, Dunn (1976) reported that nesting season of the elongated tortoises in captive breeding at Melbourne (Australia) started from May to July, this still represents the cooler winter period in that region (Australia). The observation of one female elongated tortoise ovipositing two clutches in a year in this study concurs with the report of captive elongated tortoises (Zweitz, 1988). The rational of multiple clutches may be to decrease the risk of nest predation (Auffenberg and Iverson, 1979), to increase the hatching success (Reid and Rakotobearison, 1989), and to increase their fecundity (Hailey and Loumbourdis, 1988; Pedrono et al., 2001).

The clutch size of elongated tortoises has been reported to vary at different locations (van Dijk, 1998) and is likely to be influenced by environmental conditions throughout their range (Butler and Hull, 1996). In this study, the clutch size consisted of 1-9 eggs per clutch, which is broader than the 2-5 eggs reported by van Dijk (1998) for this species in a hill forest mosaic of Western Thailand. Regardless, the egg length, width and mass of the elongated tortoise observed at Ban Kok village in this study were not related to the clutch size. Indeed, several studies have reported that the clutch size depends on the body size of the female, where small female tortoises usually produced a smaller clutch size than larger ones (Landers et al., 1980; Turner et al., 1986; Butler and Hull, 1996). With respect to the mature egg load in the three dead medium sized (CL of 25.4 – 27.7 cm) females found, although one had only one mature egg, in contrast to the six eggs in the other two similarly sized cadavers, she may have already laid all the other eggs before dying. Regardless, in this study, the mean size of eggs of the Elongated tortoise at Ban Kok Village were smaller than the mean size reported by van Dijk (1998) from other locations. This may be due to differences in the food availability in the study area, or population specific differences in their genetics controlling resource allocation per egg versus the number of eggs per clutch.

The emergence of hatchlings in the present study was similar to that reported by van Dijk (1998), in that hatchlings emerged during the early and middle part of the rainy season. However, the incubation period of this species was about 117-180 days, which partially contrasts to the 96 – 146 days at more than 20 °C at Minnesota zoo (van Dijk, 1998) and 98-150 days at 28 - 31.5 °C at Bank (Das, 1991), and strongly contrasts with the 69 days and 42-56 days reported by Dunn (1976) and Zweitz (1988), respectively. Incubation periods are likely to be affected by the soil rather than air temperature (Swingland and Coe, 1978), with increasing soil temperatures decreasing the incubation period. The emergence pattern within a clutch seen in this study for the elongated tortoise population at Ban Kok, with successive hatchlings from within the same clutch emerging 1-12 days apart from each other, is markedly different to the incubation period of the Ploughshare tortoise (*Geochelone yniphora*), where hatchlings within a nest emerged on the same day or, rarely, over a second day (Pedrono et al., 2001).

The hatching success (51.7%) observed for the elongated tortoise in this study resembled the 54.6% reported for the Ploughshare tortoise in northwestern Madagascar (Pedrono et al., 2001). The absence of adult predators in this study area at Ban Kok indicated that successful reproduction could occur and might increase the population size.

Three months after hatching, the survival rate of elongated tortoise hatchlings at Ban Kok Village was 67%, but the cause of death in most cases (29 of 33) was unknown. Car accident and trampling by cattle were the only two observed causes of hatchling death. The far more significant mortality from unknown cause(s) might occur from maternal and environmental factors (Brooks et al., 1991), such as energy allocation to eggs and nest site selection by females that could affect the offspring fitness (Brooks et al., 1991; Valenzuela, 2001; Warner et al., 2010). A low incubation temperature in the nest might produce weak hatchlings (Roosenburg, 1996; Keller et al., 1998), whilst dehydration might also be a cause of death, as reported in the Bolson tortoise (*G. flavomarginatus*) (Adest et al., 1989a, cited in Butler and Sowell, 1996). Besides, Landers et al. (1980, cited in Butler and Sowell, 1996) and Smith (1996, cited in Butler and Sowell, 1996) reported that fire ants (*Solenopsis* spp.) were predators of Gopher tortoise hatchlings. During this study at Ban Kok village, many ants (*Solenopsis geminata* and *Oecophylla smaragdina*) were observed in the field and they were found to bite the weak tortoises and the dead ones. However, no proof of predation by ants in Elongated tortoise hatchlings was found. No large predators, such as monitor lizards, were found in the study area. During the study period, three fresh excrements of adult elongated tortoises were encountered and large numbers of endoparasites (round worms and thread worms) were found in all excrements. Hence heavy infection by parasites could not be discounted as a cause of death. Clearly, the cause of mortality in the elongated tortoise hatchlings should be further investigated in order to increase their survival rate.

Diet.– Nutphand (1979) and van Dijk (1998) reported that elongated tortoise feed on a wide diversity of plants, fruits, fungi, slugs, carcasses and carnivore scats whereas earthworms, food particles (such as rice and bones), and excrement were directly observed in this study to be eaten by the tortoises. It can be concluded that at Ban Kok this species is both partially omnivorous and a scavenger, which may reflect its habituation and adaptation to human provisions.

Conservation.– The results of this study indicated that the elongated tortoise (*I. elongata*) population at Ban Kok Village has not been threatened severely in terms of the population number. The adult sex ratio is 1.07:1, which is close to the 1:1 ratio proposed by Fisher (1930). The age and size structures exhibited a high number of very young and adult tortoises with a low number of juveniles. However, the tortoise is a long lived animal, explaining the large proportion of the adult stage in the population and so only a small number of young tortoises in each age class may develop to replace the higher age classes of the population. In contrast, adult tortoises have a risk from various human activities, such as cars, fire from burning rubbish and landscape modification by the local people. Therefore, future management plans and continuous short and long term monitoring are required in order to maintain its population.

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