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# Reproduction and Morphology of the Travancore Tortoise (*Indotestudo travancorica*) Boulenger, 1907

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## 1. Introduction

The most threatened chelonians occur in Asia, where virtually all species are heavily harvested for food and traditional medicinal trades (van Dijk *et al.* 2000). This includes the two endemic chelonians, *Indotestudo travancorica*, and the sympatric *Vijayachelys silvatica* in the Region of the Western Ghats, South India. *Indotestudo travancorica* is listed as Vulnerable under the IUCN Red List, and comes under Schedule IV of the Indian Wildlife (Protection) Act.

Phylogenetic relationships between the three species of *Indotestudo*, these being *forstenii*, *elongata*, and *travancorica*, have been in flux. Iverson *et al* (2001) examined these clades, and found that *I. travancorica*, the species in question here, was found to be more closely related to *I. elongata*. They also place *Indotestudo forstenii* from Sulawesi and Halmahera, as a distinct species unrelated to *I. travancorica* and *I. elongata*, refuting information that *I. forstenii* were introduced from India to Indonesia.

In 1982, 14 sub-adult *Indotestudo travancorica* were collected from Kerala (10° 5, 76°4), by the then MCBT (Madras Crocodile Bank Trust) researcher J. Vijaya, who also worked on *Vijayachelys silvatica* (Whitaker & Jaganathan, 2009). Between 1988 – 1995, the captive group of Travancore tortoises (*Indotestudo travancorica*) at the MCBT have produced 21 clutches of eggs (Whitaker and Andrews, 1997). However, not much information resulted from these clutches, as most of them were infertile (but see below). Apart from this publication, there are only a small number of other publications on the biology of this species, by Appukuttan (1991), Ramesh (2002, 2003, 2007, 2008), Bhupathy and Choudhury (1995), Vasudevan *et al* (2010), and Vijaya (1983). Here I examine factors related to the reproductive biology, morphology, and temperature selection in the species, in between the years 1999 – 2001, and 2008 – 2011.

## 2. Methods

The adult *Indotestudo travancorica* breeding pen at the MCBT houses two males, fifteen females, and two sub-adults. It consists of two interconnected enclosures, measuring 105 sq meters. One of the two enclosures was meshed off for a *Geochelone elegans* enclosure, on 18<sup>th</sup>

December 2010, which left a single enclosure for *Indotestudo travancorica*, reducing area to 87 sq meters. The enclosures contain *Pongamia* and *Bambusa*, shade trees. Leaf litter is removed and replaced every six months. A circular pond 100 centimeters in diameter varies from 5 – 10 cm in depth, and this provides drinking water and heat sinks. Hatchlings are housed in a separate outdoor terrarium measuring 2.54 x 0.55 x 0.28 m. The substratum is beach sand covered with dry bamboo leaf litter, and both substrata are changed on a regular basis. A bowl of water is provided filled with pebbles leaving 2 – 4 cm exposed, to prevent accidental drowning. V-shaped roof tiles are used as shelters.

Juvenile and adult tortoises are fed on tomato, carrots, beans, and various types of spinach, pumpkin, grasses, and beef. Food is placed at three feeding stations, on granite slabs measuring 1.2 x 1.2 meters, and 5 centimeters off of the enclosure floor. This occurs between 1000 – 1030 hrs, and 1530 – 1600 hrs, and any remnant feed is removed the following morning/evening. Precise quantities of feed offered are not recorded. Feed is provided every day.

Chelonian embryos are at the gastrula stage (at a presomite stage of development) at oviposition (Ewert, 1979), as compared to crocodilians, with 16 – 18 somites at oviposition (Ferguson, 1985). The most advanced eggs of the Reptilia at egg laying are the lepidosaurs with 20-30 pairs of somites at oviposition (Muthukkaruppan *et. al.* 1970). Eggs are candled utilizing the technique used to candle crocodilian eggs as described by Hutton & Webb (1990), under a focused light, to determine the presence or absence of sub-embryonic fluid. This is found to be inaccurate in *I. travancorica*, and eggs deemed non viable hatch and vice versa (see section 3.3). Part of the chalking process in turtles, the development of an opaque band, involves adhesion of the vitelline membrane to the shell membrane, and this determines to some degree subsequent embryonic orientation (Ewert 1985). In addition, Andrews and Mathies (2000), note that adhesion of the embryo to the egg shell following oviposition may have a respiratory purpose “since chalking (drying) of the shell that is associated with adhesion increases the conductance to gases”. However, in the travancore tortoise, viability of eggs is best confirmed by the presence of vascularisation under a candling lamp around a month into incubation, and by embryonic movement later in incubation.

Eggs were collected from 22 nests laid between December 1999 and September 2011 (Table 1). Eggs and hatchling tortoises were measured with vernier calipers ( $\pm 0.1$  mm) and weighed with an ACCULAB <sup>TM</sup> electronic weighing scale ( $\pm 1$  gram resolution). Eggs were then candled for presence or absence of sub-embryonic fluid. Clutches were segregated into different boxes, half immersed in vermiculite media, and allowed to develop at ambient room temperature. When egg laying was observed, female morphometrics, namely carapace length (mm), carapace width (mm), plastron length (mm), and weight (grams) were measured after females had compacted the nest. Where sexual size dimorphism in adults was done, four male and eighteen females were used from both the current MCBT population and animals measured in-situ by the late MCBT researcher J. Vijaya. Two females were included from a study by Bhupathy & Choudhury (1995), and nineteen females were from a dataset collected by Arun Kalagaven, from Eastern Kerala. The online database of the Global Diversity Information Facility revealed 26 specimens of unknown sex/size residing at the Florida Museum of Natural History (GBIF, 2011). Locations and GPS coordinates are not given on purpose, to protect in-situ populations.

Incubation temperature was monitored utilizing a HOBO XT™ automatic temperature logger (Onset Instruments, P.O. Box 3450, Pocasset, MA 02559, USA) set to record temperature 4 times a day throughout the incubation period, at 800, 1200, 1600, and 2000 hrs for a group of 11 clutches laid in 1999. To get mean temperatures of all of the incubation boxes, the thermocouple from the logger was positioned in the middle of all boxes. Eggs were placed in 10 centimeter by 8 centimeter Tupperware boxes, within a plywood cupboard, to avoid predation of eggs by *Rattus bengalensis*. Incubation substrate was fine grain vermiculite. In addition, a bottle of beer with ca. ¼ of the contents left, and a piece of small beef within, was used in 2009 – 2011 to provide additional protection of eggs from fruit flies, as described by Wolff (2007) When oviposition was observed, eggs were removed from nests following compaction of the nest by the female.

Eggs that have rotted or cracked were discarded to avoid attracting flies and ants to other eggs in the same box. This was clearly evident from loss in egg weight and/or a sulphur-like smell. Morphometric measurements were recorded once hatching occurred, these being carapace length (millimeters), carapace width (millimeters), plastron length (millimeters), plastron width (millimeters), and weight (grams). A “successful hatching” was defined as an event where a hatchling managed to “pip”, emerge from the egg, and survive >7 – 10 days post hatch This was the number of days typically required to absorb external yolk from pre-mature hatchlings. Hatchlings were measured and weighed within 12 hours of hatching, residual yolk outside the abdominal cavity varied from small, normal quantities, to abnormally large yolk sacs, with these hatchlings not surviving.

To record tortoise temperature, an I-button TM was lodged on top of the carapace, and affixed with Gorilla glue™. At between 30 – 90 days, animals were captured, and temperatures for the preceding days were recorded via the USB interface provided with the I-button software/I-buttons onto a Lenovo™ laptop. Resolution of the I-buttons was at ± 0.5 °C. One male and four female tortoises were measured for a period of 400+ days, and a sample is given here for 157 days, resulting in 943 observations (temperature loggers were programmed to record temperature every six hours), between 30<sup>th</sup> May – 3<sup>rd</sup> December 2011. The number of observations per individual varies, as loggers fell off of animals. Searches in the leave litter had to be done to retrieve lost loggers. Temperatures for these periods were eliminated.

Statistical analysis follows that of McGuinness (1999) and Fowler et al. (1998). In addition, SPSS 10.0 was used to confirm manual calculation of statistics. The level of significance for all analyses was  $P < 0.05$ .

### 3. Results & discussion

#### 3.1 Clutch and egg sizes of *Indotestudo travancorica*

Clutch size of *Indotestudo travancorica* clutches collected ranged from one to six eggs. Clutch sizes and morphology of eggs is presented in Table 1. One particularly large egg from a clutch laid on the 9<sup>th</sup> September 2011 measured 152.39 mm (egg length), 123.41 mm (egg width), and weighed 85 grams. Sane & Sane (1988) hatched a single *Indotestudo travancorica*, incubation period for this one egg was 139 days. Das (1995) puts the average incubation period of this species at 146-149 days. Incubation period for the seven hatched *Indotestudo travancorica* in 1999 ranged from 128 – 159 days ( $X = 141.5$  days), with temperatures ranging between 22.4 °C - 28.7 °C. All clutches with more than one egg had hatchlings emerging on different days.

Clutch # /Date	X egg length (mm)	X egg width (mm)	X egg weight (gms)	Clutch size	Total clutch weight (gms)
01 : 7 <sup>th</sup> December 1999	44.73	37.08	36.03	3	108.1
02 : 7 <sup>th</sup> December 1999	47.4	36.7	38.1	2	76.2
03 : 7 <sup>th</sup> December 1999	46.47	37.5	38.07	3	114.21
04 : 7 <sup>th</sup> December 1999	48.47	38.77	43.43	3	130.29
05 : 2 <sup>nd</sup> December 1999	45.77	35.98	34.93	3	104.79
06 : 4 <sup>th</sup> December 1999	51.56	39.07	44.78	4	179.12
07 : 8 <sup>th</sup> December 1999	42.23	36.18	33.05	2	66.1
08 : 8 <sup>th</sup> December 1999	53.1	42.38	57.1	2	114.20
09 : 8 <sup>th</sup> December 1999	45.3	36.53	36.13	3	108.39
10 : 14 <sup>th</sup> December 1999	44.39	37.5	36.25	4	145.0
11 : 26 <sup>th</sup> December 1999	50.48	39.62	47.33	3	141.99
12: 8 <sup>th</sup> November 2010	51.5	40.7	51.7	3	155
13: 8 <sup>th</sup> November 2010	48.4	37.2	37.0	2	74.0
14: 8 <sup>th</sup> November 2010	49.9	38.6	44.0	1	44
15: 8 <sup>th</sup> November 2010	52.4	39.2	46.8	5	234
16: 4 <sup>th</sup> January 2011	48.7	37.1	42.7	6	256
17: 21 <sup>st</sup> January 2011	50.3	38.5	44.9	2	90
18: 1 <sup>st</sup> March 2011	48.2	33.2	44.1	2	88.10
19: 2 <sup>nd</sup> March 2011	51.7	38.3	46.7	2	93.40
20: 22 <sup>nd</sup> March 2011	50.8	37.4	44.7	3	134
21: 9 <sup>th</sup> September 2011	84.0	67.3	59.7	3	179
22: 22 <sup>nd</sup> September 2011	49.6	39.7	48	2	96
23: 1 <sup>st</sup> October 2011	50.48	39.78	48	2	96
Average S.D. (Range)	50.26 ±7.89 (42.23- 84)	39.32 ±6.38 (33.2-67.3)	43.63 ±6.89 (33.05-59.7)	2.83 ±1.11 (1-6)	122.96 ±51.3 (44 – 256)

Table 1. Clutch sizes, morphometrics of eggs, of *Indotestudo travancorica* nests at the Madras Crocodile Bank.

Hatching success was 63.6 % from eggs laid in 1999, and it was not possible to incorporate eggs laid post this period as they are currently undergoing incubation. Interesting to note is that Viarda (2003), who maintains a captive colony of the sister species, *Indotestudo forstenii*, had clutch sizes ranging between one and two eggs. The same author noted that incubation period was between 101 – 130 days for this species, which overlaps with incubation periods of *Indotestudo travancorica*.

3.2 Female size, clutch correlates and notes on related behavior

I found six nests associated with females, as hole digging (Ramesh 2002) or oviposition was in progress. All nests were observed being dug post 1600 hours in all cases, save for one laid on 13<sup>th</sup> March 2006, laid at 1030 hrs. Results are presented in Table 2. It is noted in that in this study clutch size ranged from 1 – 6 eggs, the clutch with 6 eggs appears to be the largest clutch observed. Vasudevan *et. al.* (2010) summarized clutch size, and reported a range of 1 – 5 eggs.

In all cases, female weight post oviposition was not related to clutch size (Pearson Correlation= -2.86, Significance = 0.582, N=6), Figure 1. Overall, clutch masses represented 4 % of total female weight. No information was available on inter-nesting intervals, or which females were the most fecund. Clutch size was not related to female carapace length (ANOVA, F=1.95, d.f=4, P=0.257). Seasonality of oviposition varies highly in *I. travancorica*, with eggs being laid in January, March, September, October, and December. It appears that this species, with its tropical climate, may lay twice a year, once in the wet season, (October - February), and once in the dry (March - September).

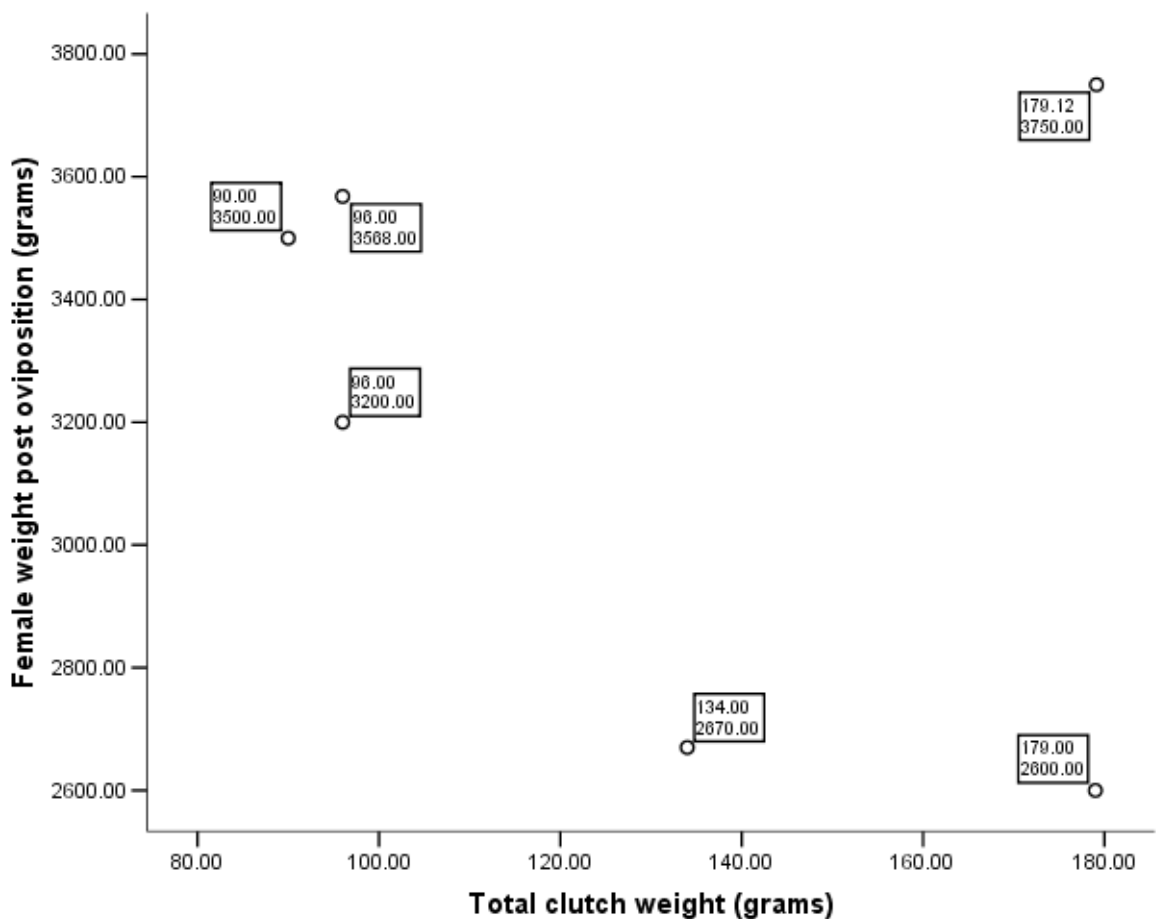


Fig. 1. Clutch weight (above text box, in grams) related to female weight post oviposition (grams).

Females were in a trance like state whilst digging/laying eggs (Plate 1), up until the time when they were packing the nest. Human observers and other tortoises were ignored during this period. In one instance, a female that laid on 20<sup>th</sup> September 2011, was noticed gathering/covering with *Bambusa* leaf litter at 1630, after which oviposition occurred, and the female was observed covering her nest post 1700. The nest was located at the periphery of a *Bambusa* clump. Following packing of the nest, she was observed to move directly towards the enclosure pond, and spent ca. one minute soaking herself and drinking water. She then went to one of the feeding stations and began to gorge on carrots, grass, and pumpkin with two other females.



Date laid	Female CL (mm)	Female CW (mm)	Female PL (mm)	Female Wt (gms)	Clutch size	X egg Length(mm)	X egg width (mm)	X egg weight (gms)	Total clutch wt (gms)
4 <sup>th</sup> December 1999	290	250	200	3750	4	51.6	39.1	44.8	179.12
21 <sup>st</sup> January 2011	261	161	208	3500	2	50.3	38.5	44.9	90
22 <sup>nd</sup> March 2011	-	-	-	2670	3	50.8	37.4	44.7	134
9 <sup>th</sup> September 2011	250	157	191	2600	3	84	67.3	59.7	179
22 <sup>nd</sup> September 2011	257	163	207	3200	2	49.6	39.7	48	96
1 <sup>st</sup> October 2011	268	171	222	3568	2	50.48	39.78	48	96

Table 2. Relationship between clutch and female morphometrics in *Indotestudo travancorica*.



Plate 1. Oviposition in *Indotestudo travancorica*. Photograph by Shakti Sritharan, © Madras Crocodile Bank Trust.



Plate 2. *Indotestudo travancorica* female packing the nest; alternate hind limbs were used to do this. Photo by Nikhil Whitaker © Madras Crocodile Bank Trust.



Plate 3. Female *I. travancorica* were marked with a permanent marker once they start packing the nest; tortoises were easily identified and measured and weighed the following day. Photo by Nikhil Whitaker © Madras Crocodile Bank Trust.



3.3 Monitoring embryonic development

Of the four types of developmental arrest occurring in turtles described by Ewert (1985), embryonic diapause may be the situation in *Indotestudo travancorica* eggs. Once shifted from “natural” nests to the laboratory it was possible that humidity and temperature regimes might have changed to more favorable regimes for the species. Ewert (1985) defines embryonic diapause as “early developmental arrest at normal temperatures, irregular duration of this arrest, and the occasional detrimental effects of continuous normal development temperatures”. Successful “natural” incubation within the *Indotestudo travancorica* enclosure is known. However, the time taken for eggs with unknown oviposition dates to hatch are similar to incubation periods described for the species. An alternative to the diapause theory was that eggs are laid shortly before collection. Another testudine, *Geochelone pardalwas*, is known to have diapause-like development (Carincross & Greig, 1977).

Chalked eggs in this study of *Indotestudo travancorica* appeared to indicate dehydration of the egg to the point where the embryos succumbed. Chalking was neither evident in eggs observed within the incubation boxes, or when viewed in front of a focused beam of light during the candling sessions. Given the importance of chalking, with regards to embryonic orientation and its association with gas exchange within the egg (Ewert, 1985; Andrews & Maties, 2000), this deserves further research. What was evident during the candling sessions was the extent of the extra-embryonic membranes in normally developing eggs. However, out of a total of 34 eggs candled in the 1999 incubation sessions, 18 had sub embryonic fluid visible, whilst 16 did not.

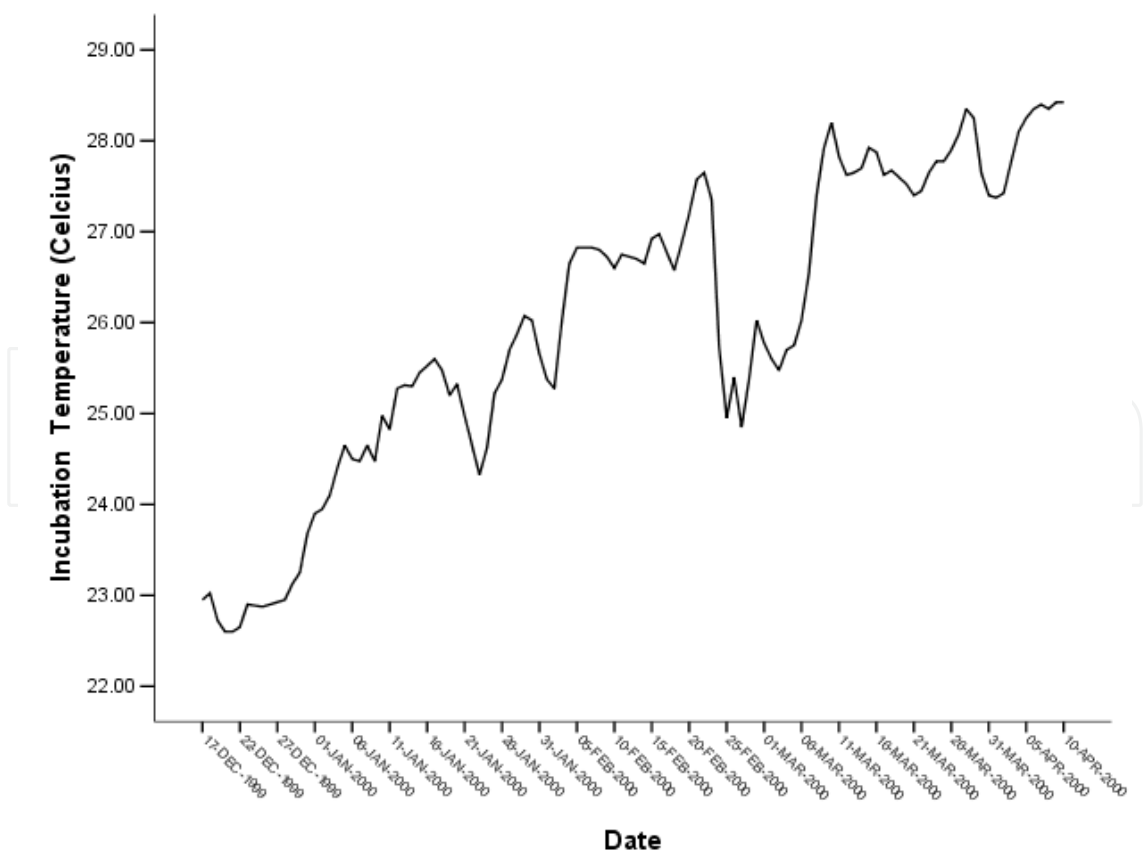


Fig. 2. Incubation temperatures for *Indotestudo travancorica* eggs incubated in 1999.

Air spaces were a common factor in *Indotestudo travancorica* eggs nearing termination of the incubation period, being confirmed by the afore mentioned candling technique, and they reflect a state of hydration (Ewert 1985). Ewert (1985) notes that air spaces were common in viable, brittle-shelled eggs, and recorded air spaces in *Rhinoclemmys annulata*, *R. wereolata*, and *R. punctularia*, evident from a few days before hatching. Metabolic heat produced by late stage embryos may promote water loss (Tracy, 1982). Figure 2 had six drops in average incubation temperature, and fourteen peaks; indeed in the last week of incubation, temperature became elevated to 28.4 °C, from an average of 25.5 °C.

3.4 Diel variation in incubation temperature and incubation period

Temperatures at different times of the day, recorded for clutches between 1999 – 2000, are presented in Figure 3. At 800, temperature averaged 25.59, at 1200 25.92, at 1600 26.22, and at 2000 26.13 °C; there is no significant variation in temperature between the 4 different times (ANOVA;  $F=3.19$ ;  $p=0.032$ ;  $d.f=467$ ). Temperatures occasionally dropped drastically due to wetting of incubation media. Incubation temperature from the same group of eggs ranged from 22.4 °C to 28.7 °C ( $X=25.5^{\circ}\text{C}$ ;  $\pm 1.68$  Figure 2). In a review of incubation times in reptiles, Birchard & Masseleni (1996) noted that mean incubation period for a group of 28 testudines averaged 30.0 °C  $\pm 0.7$ , which was higher than the (25.5 °C) mean I observed in this dataset.

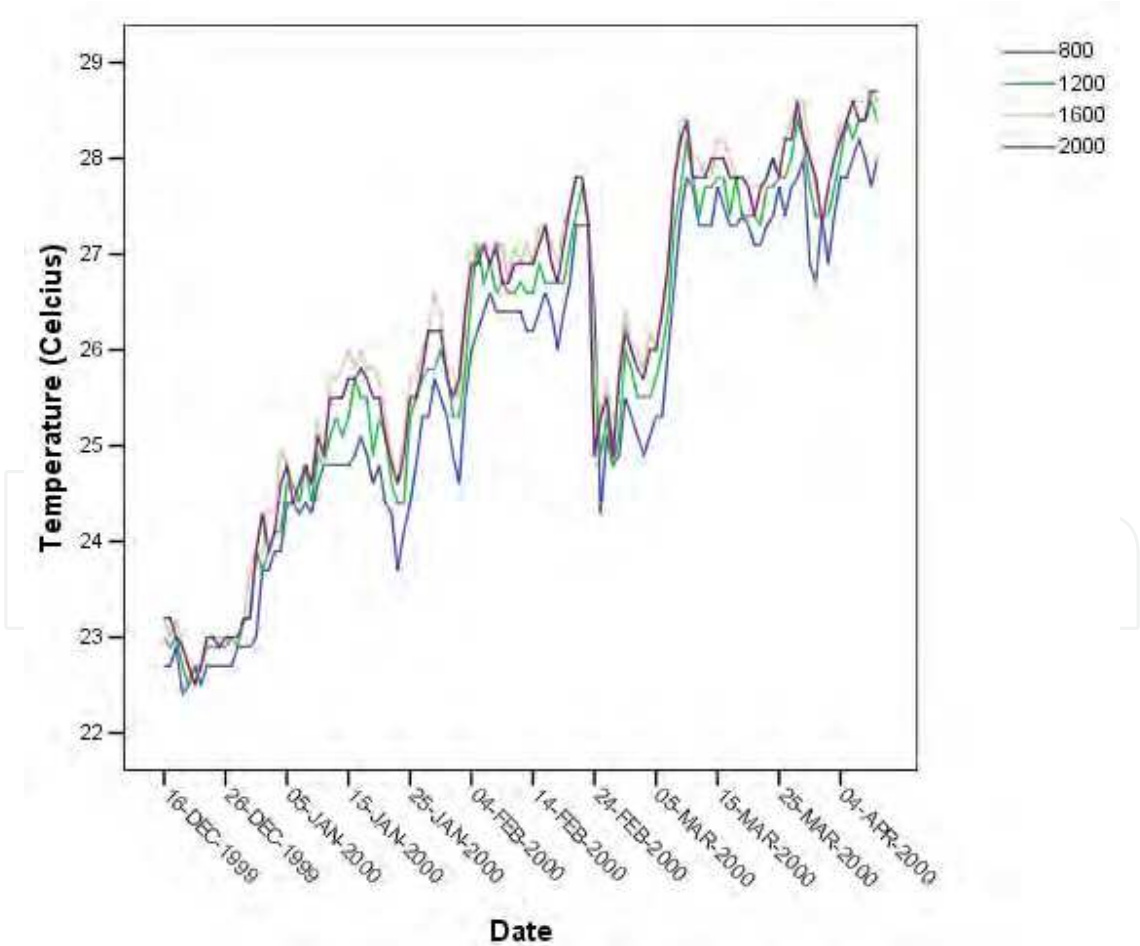


Fig. 3. Diel variation in incubation temperature of *Indotestudo travancorica* eggs incubated in 1999.

3.5 Hatchling morphometrics

One hatchling from eggs incubated in 1999 had a particularly large yolk sac and hatched 3 days premature to its single clutch mate, which hatched on day 128 of incubation and had an almost fully internalized yolk sac. The premature hatchling had the exposed yolk sac and umbilicus swabbed with Providine Betadine™, and was placed in a sterile container and then put into an incubator set at a constant 32.5° C in an attempt to speed up yolk internalization. However, the hatchling was found dead the next day.

Another hatchling with the same condition hatched 6<sup>th</sup> July 2011 (Plates 2 and 3) and had a much larger unabsorbed yolk sack. This animal died following 12 hours post hatch. Most individuals hatched with an external yolk sac, but these were rapidly absorbed within six to twelve hours (Plate4).

No.	CL (millimeters)	CW (millimeters)	PL (millimeters)	Hatchling weight (grams)	Initial egg weight (grams)
1	43.60	44.90	36.40	27.30	36.90
2	47.40	41.30	43.10	28.80	39.50
3	48.70	49.30	39.20	27.20	36.60
4	48.60	46.50	41.30	26.20	37.00
5	49.50	46.30	40.00	28.20	38.10
6	46.80	45.60	40.00	26.50	36.90
7	41.50	45.20	36.50	20.60	30.90
8	44.24	43.87	34.20	32.00	.
9	52.80	47.52	45.39	33.67	.
10	50.85	50.07	44.21	30.49	.
11	50.71	45.87	43.42	32.81	.
12	58.70	50.03	43.30	27.10	.

Table 3. Hatchling morphometrics derived from clutches incubated in 1999 (with initial egg weight), and in 2011 (without initial egg weight).

Hatchling morphometrics, and relations to initial egg weight are presented in Table 3. Permeability of eggshells of *Chrysemys picta*, *Pseudemys concinna*, and *Trionyx muticus* almost doubles at mid to late incubation stages (Tracy 1982, in Ewert 1985). Average initial egg weight for seven hatchlings from 1999 was 10.2 gm heavier than hatchling weight. Average loss in percentage of initial egg weight as compared to hatchling weight was 72 %. This lies within Ewert’s (1979) observations on juvenile turtles that were hatched from brittle shelled eggs, weighing 60 – 75 % of initial egg weight.



Plate 4. Premature *I. travancorica*, with a large external yolk. Photo by Nikhil Whitaker © Madras Crocodile Bank Trust.



Plate 5. Premature hatchling *I. travancorica*. Photo by Nikhil Whitaker © Madras Crocodile Bank Trust.





Plate 6. Plate 6. A normal, healthy *Indotestudo travancorica* with the yolk sac absorbed 24 hrs post hatching. Photo by Nikhil Whitaker © Madras Crocodile Bank Trust.

### 3.6 Sexual size dimorphism in *Indotestudo travancorica*

Sexes of *I. travancorica* did not differ significantly in any morphological attribute (Table 5). Specimens examined were from the Madras Crocodile Bank Trust's captive collection, and data collected within the archives of the MCBT by past researcher J.Vijaya at Nadukani, Kerala. Other data from the literature was gleaned from Bhupathy & Choudhury's (1995) work, and Arun Kanagavel, obtained from the Vazachal, Athirapally, and Chalakudy Forest ranges in Kerala during his surveys of *I. travancorica* in these areas. This agrees with Ramesh's (2008) work, wherein she examined 24 males and 25 females, and did not come to a consensus that sexes differed in carapace length. Interesting to note here, this is perhaps the first time individuals of *I. travancorica* from several locales have been combined for analyses of size.

Wilbur and Morin (1988), noted that if males were able to control copulation, such as in the MCBT's captive tortoise breeding enclosure, where copulation occurred regardless of interference by other males, then males will exceed females in body size and this allows them to forcibly inseminate females (plate 7). The variables introduced by maintaining *I. travancorica* in a captive environment as opposed to a natural population where they are free to choose diet, microhabitats, distance between animals, does not occur. Neither is there data available from the natural populations mentioned.



Plate 7. Mating in *Indotestudo travancorica*. Photo by Nikhil Whitaker © Madras Crocodile Bank Trust.

Sex	N	Parameter	X	SD	SEM	Range	Dimor- phism	F Crit	P
M	10	SCL	248.3	48.38	15.23	187-331	M=F	0.522	0.476
F	20	SCL	238.9	23.58	5.27	192-273	-		
M	10	CW	157.1	26.59	8.41	120-195	M=F	0.061	0.806
F	20	CW	159.26	19.91	4.57	135-225	-		
M	9	PL	182.89	34.91	11.64	139-224	M=F	0.359	0.554
F	20	PL	189.03	17.8	4.32	165-221	-		
M	9	MASS	2420.3	1470.37	490.12	876-4800	M=F	0.018	0.896
F	20	MASS	2036.8	729.55	167.37	1100-3600	-		

Table 4. Morphometric analysis was via ANOVA of adult *Indotestudo travancorica* from the Madras Crocodile Bank Trust’s captive collection, data collected within the archives of the MCBT by past researcher J.Vijaya at Nadukani, Kerala , Choudhury & Bhupathy (1995), and Arun Kanagavel, collected from the Vazachal, Athirapally, and Chalakudy Forest ranges in Kerala.

2 male and 3 female *I.travancorica* were necropsied by J. Vijaya from the natural habitat of the species. CL for the 2 males averaged 154.5 millimeters (S.D. 6.36, 150 – 159), carapace width averaged 106.25 millimeters (S.D. 3.18, 104 – 108.5). The right testes length averaged 10.5 millimeters (S.D.3.54, 8-13), whilst the right testes width averaged 3.15 millimeters (S.D. 2.12, 2-5). The left testes length was 11.0 millimeters for both specimens.

With regards to the three females, CL averaged 190 millimeters (S.D. 22.07, 167 – 211), carapace width averaged 131 mm (S.D. 6.08, 124 – 135), plastron length for two females averaged 157.3 millimeters (S.D. 18.73, 144 – 170.5). In one of the necropsied females, (Carapace length, 192 millimeters, carapace width 135 millimeters, plastron length 170.5 millimeters, and weight 1100 grams) the right oviduct weighed 2.5 grams, whilst the left weighed 3 grams. Newly developed corpea lutea in the right oviduct weighed one gram. Older corpea lutea in the left oviduct weighed two grams, whilst in the right oviduct this was one gram. Oviducal eggs were 1 each in the left and right oviduct. This indicates that female *I. travancorica* reach maturity at between 192 – 290 millimeters, and around one kilogram in weight. (Table 4, J.Vijaya’s information metioned above). A caveat here is that body size and age are not necessarily correlated (Justin & Gibbons, 1990).

The 1 male and 4 females from this study were measured on June 30<sup>th</sup> 2010, and the male measured 33 centimeters carapace length and weighed 5 kilograms. The four females averaged 24.34 centimeters carapace length, and 2900 grams. At the next measurement on 3<sup>rd</sup> August 2011, the male’s carapace length was 32.4 centimeters, and weight was 4800 grams. The females averaged 26.73 centimeters carapace length , and 2350 grams in weight. The reduction in weight is real, whilst the reduction in carapace length by 0.6 centimeters was probably an observer error. Ernst & Barbour (1972), note, as observed in this study, that growth in turtles decreases following maturity, evident from the 1 year between measurements of captive animals here. Snider & Bowler (1992), record longevity of *Indotestudo travancorica* (then *I. forstenii*), as 26 years, however males and females in the MCBT captive group are approximately 30 years old.

The largest male from this study had a carapace length of 331 millimeters, and weighed 4800 grams, whilst the largest female had a carapace length of 271 millimeters and weighed 3600 grams. Both these tortoises were from the Madras Crocodile Bank’s captive collection.

3.7 Temperature selection

The basic morphological versus temperature related parameters are presented in Table 5. The highest average temperatures were for the male, the heaviest animal considered here, 35.5 ° C. The smallest female’s maximum average, female 3 was identical. No inferences can be made at this stage on this pattern. Both these animals also had the highest variance, inferring that they were perhaps the most active animals in this group. With regards to the male, he spent a large amount of the early morning and evening walking around the enclosure, in contrast to the females which had their movements largely restricted to the feeding stations.

Tortoise number and weight (grams)	Minimum	Maximum	Mean	Std. Deviation	Variance
Male 1 (4800)	19.5	35.5	28.01	2.31	5.33
Female 2 (2200)	20	33.5	27.36	2. 98	4.4
Female 3 (1900)	19	35.5	27.56	2.20	4.85
Female 4 (3300)	19.5	34	27.05	2.04	4.17
Female 5 (2000)	21.5	33.5	27.56	1.82	3.32

Table 5. Statistics relating to tortoise temperature (1 male and 4 females), between 30<sup>th</sup> May 2010 to 3<sup>rd</sup> December 2010.



Despite large size differences between the male and the females, temperature variation between the sexes was lower than expected (Figure 4). The male had the highest mean temperature  $28.01^{\circ}\text{C}$ , ranging between  $21.5 - 35.5$ , and the highest variance ( $5.33^{\circ}\text{C}$ ). Consolidated female temperatures averaged  $27.56^{\circ}\text{C}$ , with a minimum and maximum of  $20.0^{\circ}\text{C}$  and  $34.1^{\circ}\text{C}$  respectively, and the highest maximum temperature at  $34^{\circ}\text{C}$ .

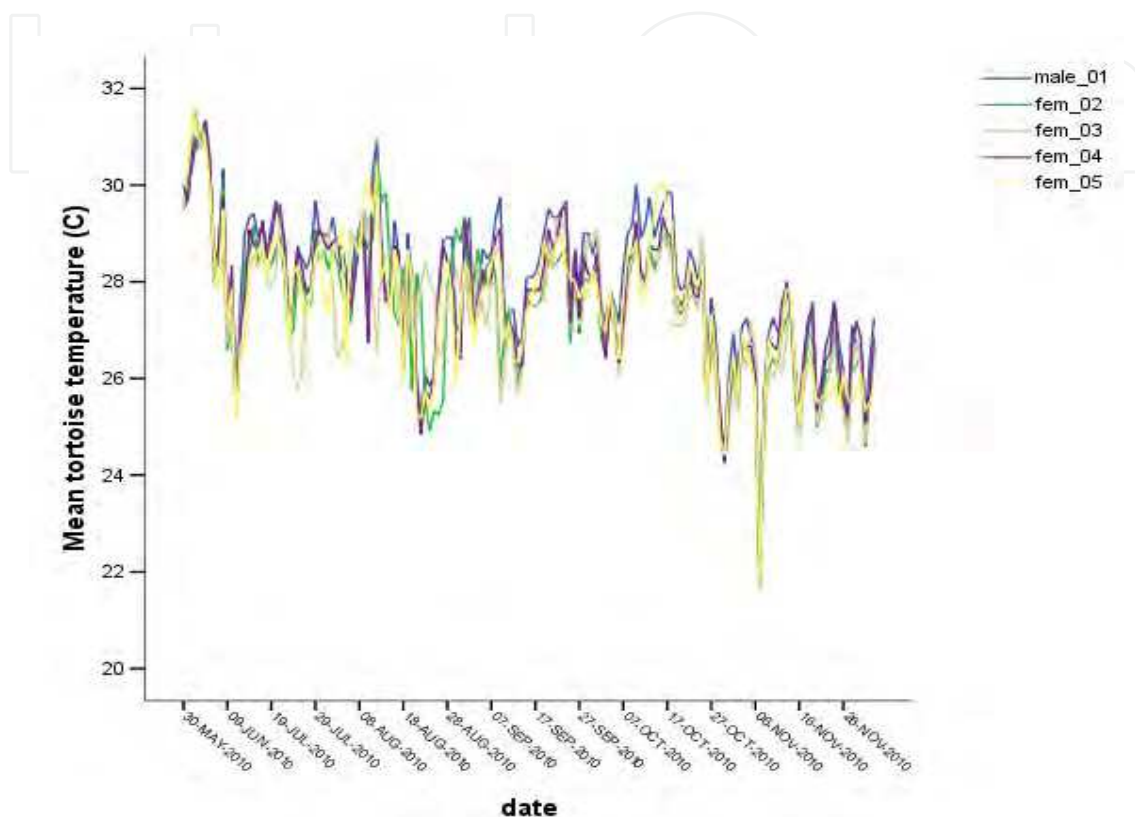


Fig. 4. Tortoise temperatures (1 male and 4 females) between 30th May and 3rd December 2010.

Females 2 and 5 had sudden drops in temperature, due to 5 millimeters of rainfall on November 5<sup>th</sup> 2010. Hailey & Coulson's (1995) observations on *Kinixys spekii* were similar to those observed in *Indotestudo travancorica*, in that during particularly hot days (i.e.  $> 35^{\circ}\text{C}$ ), movement was at a minimum, and on days that rainfall occurred, maximum activity was observed, this including courtship/mating, male combat, and nesting.

#### 4. Conclusions

In this chapter I discussed the reproductive biology, morphometrics, and temperature selection in a small group of *Indotestudo travancorica*. Incubation period varied between 128 – 159 days ( $X = 141.5$  days), in a group of 34 eggs from 11 clutches; out of these eggs candled in the 1999 incubation sessions, 18 had sub embryonic fluid visible, whilst 16 did not. From this series, diel variation did not differ between four measurements of temperature in a day. Initial determination of viability was not accurate, and definitive determination of viability did not occur until one month into incubation when vascularisation was visible.



Incubation periods were found to be similar in the sister species *Indotestudo forstenii*, but maximum clutch size was two, compared to six in *I. travancorica*. Clutch size was not related to female carapace length. Following egg laying, total clutch weight represented 4 % of the female's weight. Initial egg weight as compared to hatchling weight was 72 %. With regards to sexual size dimorphism, no differences were noted between males and females. *I. travancorica* females reach maturity at between 192 – 290 millimeters, and a kilogram in weight. Future studies may find females reaching maturity at smaller sizes. Temperature selection presented here in captivity as opposed to natural populations was a preliminary attempt at best; higher resolution loggers than the ones used here ( $\pm 0.5^\circ \text{C}$ ) in combination with behavioral observations would result in a better data set.

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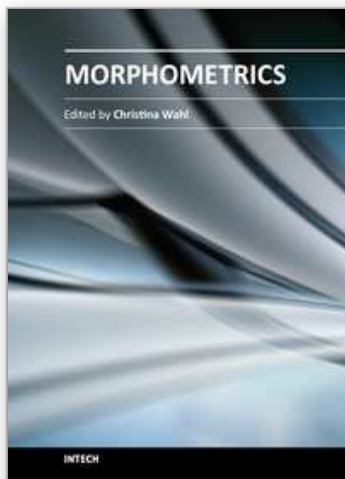
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It is human nature to measure things, and this holds true for science as well as everyday life. The five papers in this book demonstrate the usefulness of a morphometric approach to a variety of subjects in natural history, including systematics, phenotypic plasticity in response to environmental variation, and ontogenetic adaptation. As our understanding of genetic control mechanisms and epigenetics has matured over the last several decades, it has become clear that morphometric assessment continues to be important to our overall understanding of natural variability in growth and form. The tremendous growth of our knowledge base during the last century has necessitated that we find new ways to measure and track greater detail as well as greater numbers of parameters among populations and individuals.

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