Population characteristics of a terrestrial geoemydid, *Melanochelys tricarinata*, from the Doon Valley, northern India

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Melanochelys tricarinata is a poorly known terrestrial South Asian geoemydid turtle with a small distributional range. From 2002 to 2008, we monitored a population of the species in the Doon valley of northern India, and obtained information on its population characteristics, general activity pattern and diet. In total, 120 individual turtles were captured (47 males, 37 females and 36 unsexed juveniles and hatchlings). Turtles were captured mainly during the rainy months (94.4%), and captures were significantly correlated with periods of high rainfall. The overall adult sex ratio was unbiased. The larger body size was, however, biased towards males. With an average carapace length of 154 mm (range 127–175 mm) and a weight of 461.5 g (range 280.0–621.1 g), males were larger than females, who had an average carapace length of 138 mm (range 117–151 mm) and an average weight of 382.5 g (range 240.0–511.1 g). No increase in carapace length in either male or female turtles was observed after they attained ten years of age. Observations of diet suggest the species is omnivorous, feeding on both fruits and animal matter.

Key words: age estimation, capture–recapture, diet, growth, sexual size dimorphism, tricarinate hill turtle

INTRODUCTION

The tricarinate hill turtle *Melanochelys tricarinata* is a small terrestrial turtle restricted to the northern parts of the Indian subcontinent (Das, 2009). There, it is reported to occur along the Himalayan foothills and riverine grasslands along the rivers Ganga and Bramhaputra (Boulenger, 1890; Smith, 1931; Pritchard, 1979; Ernst & Barbour, 1989; Choudhury & Bhupathy, 1993a; Busack, 1994; Das, 1991, 2009; Mitchell & Rhodin, 1996; Schleich & Kastle, 2002). However, the record by Khan (1987) from the Whykong Reserve Forest, Cox's Bazar District of Bangladesh suggests the occurrence of the species also at a considerable distance from the Himalayan ranges. In addition, the species is known to occur in the sal (*Shorea robusta*) dominated forests of Chaibassa District, Jharkhand (Das, 1991) and further south in the Similipal Biosphere Reserve in northern Orissa (Dutta et al., 2009). While it is believed that the destruction of primary forests along the plains of the Ganga and Brahmaputra rivers may be the cause for the disjunct distribution (Das, 2009), the exploitation of the species for food and commercial trade are a concern for the survival of the species (Tikader & Sharma, 1985; Choudhury & Bhupathy, 1993a,b; Das, 1995; Javed & Hanfee, 1995; Mitchell & Rhodin, 1996; Shrestha, 1997; Zhou et al., 2008; Gong et al., 2009). Although the species is included in Schedule I of the Indian Wildlife (Protection) Act of 1972 and Schedule III of the Bangladesh Wildlife (Preservation) Act of 1974, listed in Appendix 1 of CITES and classified as Vulnerable on the IUCN Red List (Asian Turtle Trade Working Group, 2000), there is virtually no information on its population status, habitat requirements, habit, diet or breeding biology from the wild. Knowledge of the life history of the species is almost entirely a result of observations from captive individuals (Tikader & Sharma, 1985; Das, 1988; Mitchell & Rhodin, 1996; Valentin & Gemel, 1999). It is therefore important to investigate the life history of the turtle in the wild to be able to develop scientifically sound management practices. In this study we present population characteristics of the species from the campus of the Wildlife Institute of India, Dehradun, in the Doon valley, and highlight some aspects of the species' ecology and behaviour.

MATERIALS AND METHODS

Study site

This study was conducted from 2002 to 2008 on the campus (32 ha) of the Wildlife Institute of India (WII), Dehradun (77°58′26.8″E, 30°16′59.9″N), Uttarakhand State. The Doon valley is surrounded by the Himalayas in the north, Shivalik hills in the south, the river Ganga in the east and the river Yamuna in the west. The climate of the region is sub-tropical, with very hot summers (34 °C) in April and May and very cold winters (4 °C) from December to February, at a mean annual temperature of 20 °C. On average the region receives an annual rainfall of 2000 mm, much of which falls during the monsoons (June to September). The WII campus, located near to the Shivalik hills along the southern end of the Doon valley (Fig. 1), is well protected from human disturbances and

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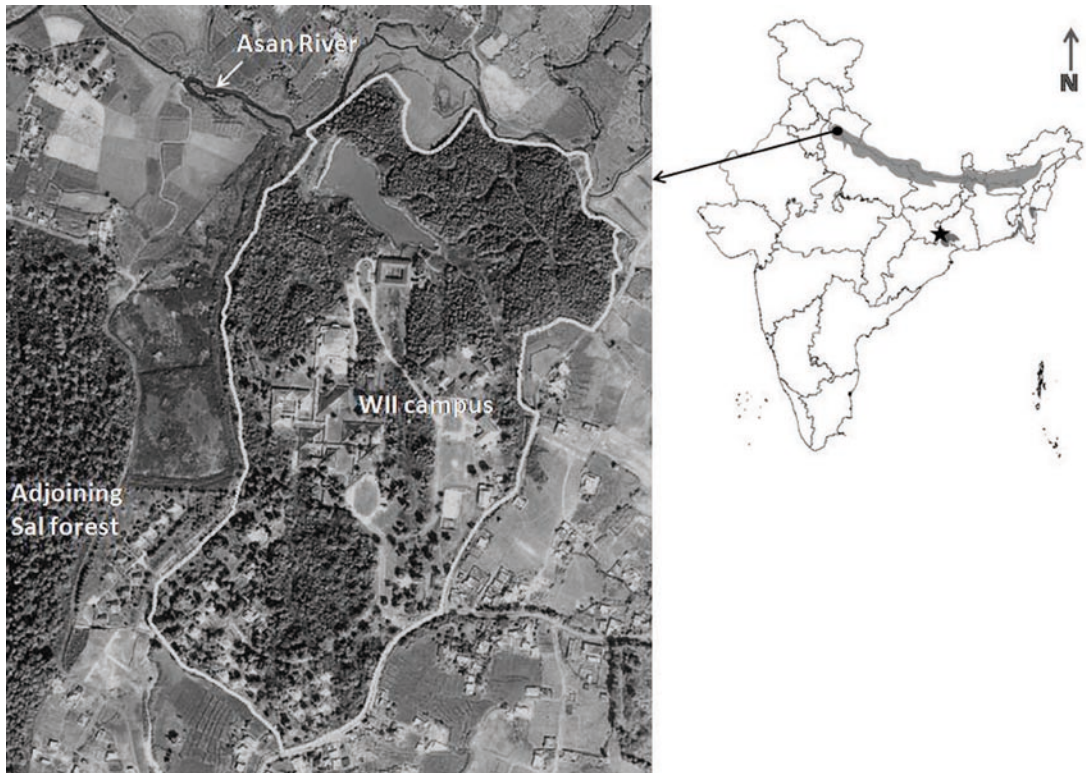

Fig. 1. Map showing the distribution range of *Melanochelys tricarinata* (based on Das, 2009) and location of the study site in the Doon valley, northern India. The location marked with a star is the type locality of the species in the Chaibasa District of Jharkhand State in eastern India.

serves as a refuge for native species. The terrain within the campus is undulating and its vegetation consists of a luxuriant growth of *S. robusta* forest with a dense understorey dominated by bushes of *Lantana camara*, *Maclura cochinchinensis*, *Carrisa opaca* and *Jasminum multiflorum*, interspersed with perennial water sources and an artificial lake. The surrounding areas of the campus are largely agricultural fields and human settlements.

Field methods

Turtles were captured by regularly walking the series of trails, paths and roads within the campus at different times of the day. Active searches in the undergrowth were made by teams of volunteers. In addition, an advertisement asking people to bring in turtles when sighted on campus was also used. Upon capture, date, time, GPS location and sex of the turtle were recorded. We classified the turtles as hatchlings, juveniles and adults based on their size. Adult turtles were sexed as male if the plastron was concave. In addition, females were found to have a prominent pink superciliary stripe that is absent in adult males (Figs 2 & 3). Juveniles and hatchlings could not be sexed. All captured turtles were weighed with a digital weighing scale (in g) and morphometric measurements (mm) such as carapace length (SCL), carapace width (SCW), carapace height (CH), plastron length (PL), plastron width (PW) and concavity (PC) were recorded with digital calipers to an accuracy of ±1 mm. The approximate age of each turtle was determined by counting the annuli rings on the pleural scutes (technique reviewed in Wilson et al., 2003). Prior to release, each turtle was marked by filing notches into the marginal scutes of the carapace following Cagle (1939). Hatchlings and yearlings were not marked, as their carapace was very soft. Natural markings and injuries, if present, were also recorded for individual identification and turtles were released at the location of capture either immediately or within a few hours.

Fig. 2. An adult male *Melanochelys tricarinata* in its natural habitat showing the distinct yellow keels on the carapace. Photo credit: Bivash Pandav.

The diet of *M. tricarinata* was assessed based on droppings and observations made during capture or release. The turtles often defaecated upon capture and the droppings were collected for analysis of food habits. They were washed, passed through a sieve and dried. The remains were then classified as being of plant or animal

Table 1. Summary of captures and recaptures of *Melanochelys tricarinata* in the WII campus across the sampling years. Numbers given in parentheses refer to individuals that were captured from outside and released in the campus, and these were not used in the calculation of the population sex ratio. * refers to captures that were opportunistic during these years and were not included in analysis of seasonality and time of capture.

	Capture					Recapture		
Years	♂	♀	Juvenile	Hatchling	Total	♂	♀	Total
1999–2001*	4 (+1)	1	–	–	5 (+1)	–	–	–
2002	10 (+1)	13	2	6	31 (+1)	5	3	8
2003	9 (+1)	11	5	11	36 (+1)	28	13	41
2004*	0 (+1)	2	3	0	5 (+1)	4	0	4
2005	5 (+2)	7	2	4	18 (+2)	17	10	27
2006*	2	0	0	0	2	5	4	9
2007	2 (+1)	0	2	0	4 (+1)	11	16	27
2008	6 (+2)	2 (+1)	1	0	9 (+3)	20	18	38
Total	38 (+9)	36 (+1)	15	21	110 (+10)	90	64	154

origin and identification was attempted up to the species level whenever possible.

Analytical methods

Significance testing of our observational data on sex biased capture frequencies and sex ratio were carried out using G-tests. Non-parametric (Mann–Whitney *U*-test) comparison of means was carried out to assess sex-dependent variation in the morphometric measurements and weight. The weight–length relationships for males and females were assessed using a regression of log (body weight) on log (carapace length), and an analysis of covariance (ANCOVA) was used to compare the sexes. Growth with respect to age (number of annuli) was examined using a regression between the estimated age of individuals or number of annuli and SCL and PL. All statistical analysis was carried out using SPSS 15.0 (SPSS Inc.).

RESULTS

Capture–recapture

A total of 114 individuals across all age-sex classes was captured on 268 occasions (Table 1). In addition, six individuals (five adult males and an adult female) were captured and marked on campus prior to this study (during 1998–2001), and of the overall total of turtles captured nine adult males and an adult female were caught off the campus. Eight of the ten turtles captured from outside (all adult males) were released into the campus as their exact capture location was not known. We also captured three non-target testudines within the campus: three Indian flapshell turtles (*Lissemys punctata*), two Indian black turtles (*M. trijuga*) and one yellow-headed tortoise (*Indotestudo elongata*).

Fig. 3. Males of many turtle species are known to get melanistic with age. Similarly, adult male (left) *Melanochelys tricarinata* lose the pink superciliary stripe that is seen in adult females as they mature. Photo credit: Bivash Pandav.

Captures were mainly (94.4%) during the monsoon months (June to August), while no individuals were captured from November to February (winter months) (Fig. 4). In general, capture frequency was significantly correlated with periods of high rainfall (r=0.92, P>0.001). The species appears to be crepuscular in activity as most captures (73.8%) were during the morning (0700 to 1100) and evening (1500 to 1800) hours and none were encountered during the several late night-trail-walks. Of the 268 captures, GPS locations were recorded for 230 capture events; of these, 60% captures were recorded within an area of around one hectare located at the northern end of the campus adjoining the artificial lake (Fig. 5). This area is relatively little disturbed, and characterized by dense stands of vegetation.

Thirty-four of the marked turtles (18 males and 16 females) were never recaptured, while 50 turtles (29 males and 21 females) were recaptured at least once during the study. Thirty-one of these were recaptured more than once within a season, with one male turtle captured a maximum of five times. Many of the turtles were recaptured repeatedly at specific locations either during the season or across the years. One female turtle was recaptured at the same location 88 days after its first capture, suggesting some degree of site fidelity.

Population characteristics

Sex ratio and body size structure. Of the 110 individuals captured, 38 were males, 36 were females and 36 were

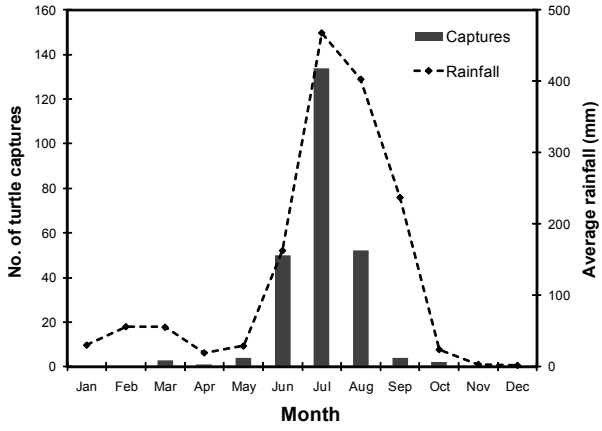

Fig. 4. Turtle captures from 2002 to 2008 across the months in relation to the average rainfall during the period recorded in the WII campus, Doon valley.

Fig. 5. Map of the WII campus showing the turtle capture locations with the Kernel Home Range contour lines (prepared in ArcView GIS 3.0). The outer hatched contour line and the inner thick line are the 95% and 50% probability Kernel contours respectively. 60% of the turtle capture locations were within the 50% probability contour.

unsexed juveniles and hatchlings. Across the sampling years we encountered males more often than females (G-test, G=5.85, $P<0.05$; approximately 24 males per year to approximately 19 females per year). However, the sex ratio was unbiased (G=0.027, $P>0.1$; 1 male: 0.94 females). The body size distribution of the captured turtles was found to be biased towards larger turtles (Fig. 6). Maximum turtle captures (66.7%) were in the size class 130–170 mm, dominated by males in the size classes between 150 and 170 mm (74.5%), and by females in the size classes between 130 and 150 mm (91.9%). The average SCL recorded for adult male and female turtles was

Table 2. Morphometric measurements – mean ± SD (range) – of *Melanochelys tricarinata* captured during the study. Adult males were significantly larger in body size than adult females, while carapace height (CH) and plastron width (PW) were not significantly different between the sexes.

Characteristics	Male (47)	Female (37)	Mann–Whitney *U*-test	Juvenile (15)	Hatchling (21)
Carapace length (SCL)	153.8±10.5 (127.0–175.0)	137.8±7.0 (117.1–151.2)	–5.997, $P<0.001$	78.1±20.0 (20.0–54.8)	40.1±3.3 (32.7–47.7)
Carapace width (SCW)	95.2±5.8 (82.1–110.7)	88.0±4.2 (75.4–94.9)	–5.677, $P<0.001$	56.8±10.5 (42.9–71.5)	34.2±3.0 (25.1–39.0)
Carapace height (CH)	63.2±5.2 (51.0–72.1)	60.1±3.7 (51.6–68.4)	–1.699, $P=0.089$	35.3±9.0 (23.9–48.2)	17.4±1.5 (14.3–21.6)
Plastron length (PL)	128.2±8.7 (101.1–141.7)	124.4±6.3 (105.4–132.2)	–3.339, $P<0.001$	68.4±19.8 (43.6–98.1)	33.1±3.0 (26.0–39.6)
Plastron width (PW)	75.8±3.6 (68.0–81.5)	74.0±3.3 (63.1–78.3)	–2.573, $P=0.010$	47.3±10.2 (35.2–62.0)	27.2±2.3 (22.5–30.9)
Plastron concavity	7.7±2.5 (2.4–12.0)	–		–	–
Weight (g)	461.5±82.5 (280.0–621.4)	382.5±54.5 (240.0–511.1)	–4.290, $P<0.001$	87.3±64.5 (20.7–195.2)	9.8±1.6 (8.2–14.5)

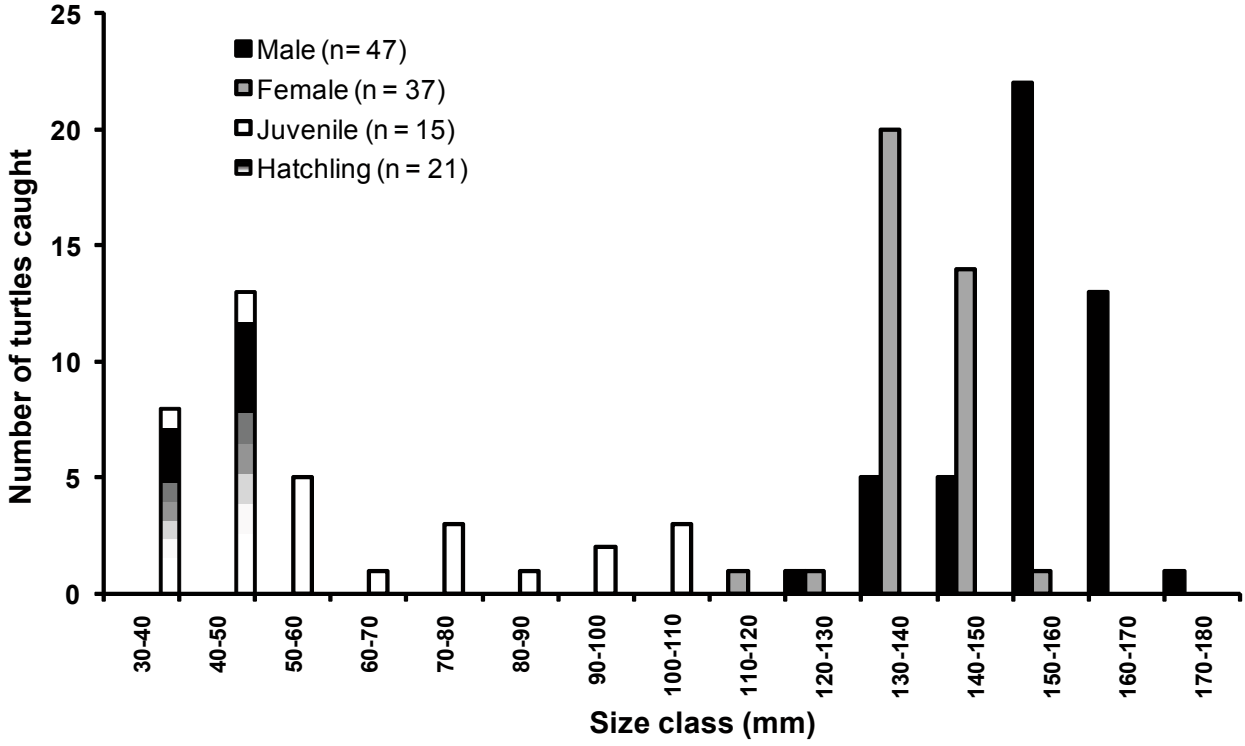

Fig. 6. Carapace length frequency of *Melanochelys tricarinata* between sexes and the unsexed juveniles and hatchlings.

154 mm (range 127–175 mm, *n*=47), and 138 mm (range 117–151 mm, *n*=37), respectively. Likewise, average weights of male and female turtles were 461.5 g (range 280.0–621.4 g, *n*=46) and 384.4 g (range 240.0–511.1 g, *n*=35), respectively. The smallest hatchling caught had an SCL of 33 mm and weighed around 8.0 g, while most other hatchlings were between 40 and 60 mm in length. A summary of morphometric measurements are presented in Table 2.

Sexual size dimorphism. Morphometric measurements presented in Table 2 suggest that male turtles are significantly larger and heavier than females in measurements including SCW and PL (Mann–Whitney *U*-test, $P< 0.001$; Table 2). The length–weight relationships for adult males and females were found to be significantly different from each other (ANCOVA, $F_{1,82}$=67.773, P<0.001; regression equation for males: y = 2.59x – 0.95; females: y = 2.62x – 0.95). Although male turtles are overall larger and heavier than females, at given lengths female turtles were found to be heavier than their male counterparts (Fig. 7).

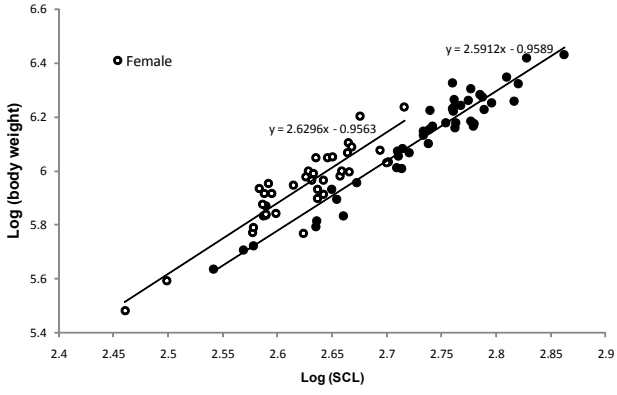

Fig. 7. Regression of log (body weight) on log (carapace length) for *Melanochelys tricarinata* from the Doon valley, northern India.

Table 3. Age estimation for seven male and four female turtles based on the number of annuli rings at first capture and at last recapture. Annuli rings in turtles over the age of 12 years appear less distinct.

	First capture		Last recapture		Expected number of annuli rings at last recapture year
Turtle ID	Year	No. of annuli rings	Year	No. of annuli rings	
♂ 9	2002	10	2008	12	16
♀ 13	2002	9	2008	12	15
♂ 10	2002	8	2008	12	14
♂ 8	2002	8	2007	12	14
♂ 26	2003	8	2008	11	13
♀ 22	2003	7	2008	10	12
♀ 34	2005	9	2008	10	12
♂ 14	2002	6	2007	12	12
♂ 15	2002	5	2008	11	11
♂ 23	2003	6	2007	10	10
♀ 37	2005	7	2008	10	10

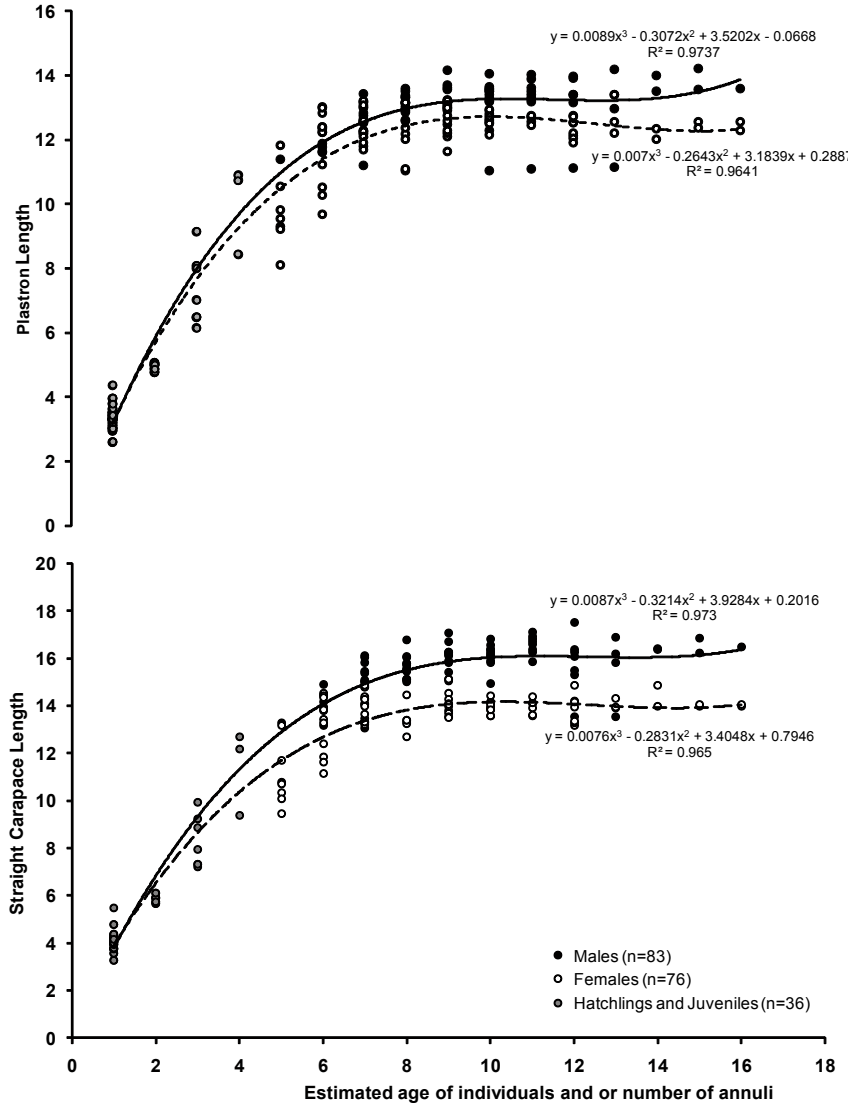

Fig. 8. Relationship between estimated age of individuals (based on count of annuli rings) to carapace and plastron lengths in male, female, juvenile and hatchling *Melanochelys tricarinata*. The relationship differed significantly between the sexes and size classes.

Age estimation and growth rate. The largest number of turtles caught (32%) fell into the seven to nine years age category. A comparison of the number of annuli rings from year of first capture and year of last capture for seven male and four female turtles is given in Table 3, providing evidence that from the age of 12 years onward the annuli appear less distinct. All unsexed juvenile turtles had five or fewer annuli rings, and hatchlings had a single ring. Four unsexed juveniles with five annuli rings at first capture were found to be males, showing a partial concavity of the plastron the following year. Also, in these young male turtles, the superciliary stripe was less prominent, starting to become paler.

An increase in SCL and PL with respect to age was observed (Fig. 8). A third order polynomial trend line fitted to the data showed that in both male and female turtles there is a steady increase in SCL and PL up to the age of 10, followed by a phase of very little or no growth. The regression values in the case of SCL and PL with respect to age were highly significant (SCL – male: R^2=0.973, female: R^2=0.965; PL – male: R^2=0.973, female: R^2=0.964; Fig. 8).

Diet

A total of 53 records were collected, 34 of which were direct feeding observations and the remainder based on turtle droppings. The majority of direct feeding observations involved earthworms; two observations relate to hatchlings trying to catch aquatic insects, and in one case an adult turtle attempted to ingest a fallen fruit of *Jasminum multiflorum*. On three occasions turtles were also observed feeding on garbage, and in one instance a turtle was feeding on human faeces outside the main study area. Analysis of turtle droppings showed a high representation of fruits of *J. multiflorum*, followed by (in decreasing order of occurrence) *Ficus* sp., *Cordia myxa*, *Ampelocissus*

latifolia, *Broussonetia papyrifera*, *Lantana camara* and *Sapium sebiferum*. Further, unidentified seeds, roots, tubers, vegetable waste in the form of tomato peel and a few animal remains in the form of feathers, crab shell fragments, millipedes, beetle elytra and termite wings were also recorded.

DISCUSSION

The capture–recapture data on the campus of WII suggest that the turtle population comprises about 30–40 individuals per year (Harihar, Kumar & Pandav, unpublished data). Despite an even sex ratio, males were encountered at a higher frequency than females in each of the survey years. We encountered only one pair of sparring males (two males in combat, 17 July 2005 at 1610) and five mating pairs (July to August). Based on the body size class information, both sparring males were of high SCL (160–170 mm) and weight (500–600 g). However, the males among the mating pairs were 8–10 years old, while female turtles were between 7 and 13 years old, suggesting that sexual maturity is attained at around 6–7 years of age. Supported by the fact that males in captivity were more active throughout the day during the monsoon months (Das, 1991, 2009), we feel that active mate search by males is probably the reason for higher encounter frequencies within our study area.

The periodicity in captures suggests that turtles are most active with the onset of the pre-monsoon showers in the area and then remain active until the onset of winter, following which they probably go through a long period of inactivity, possibly hibernating for six to seven months (October to April). On two occasions (17 October 2002 and 3 January 2009), turtles were found in burrows in the ground when they were accidentally dug up. Studies in captivity (Valentin & Gemel, 1999) observed the species laying eggs during the dry season (October–April), while we did not encounter any nest during the period of our study. However, we observed hatchlings (30–60 mm SCL) only during the peak monsoon period as opposed to observations made in captive situations where emergence occurred in the late dry period and early wet season (February to April). Based on the time of capture of individuals, the species appears to be crepuscular.

The body size structure shows that adults predominate (70%). This probably indicates that there could be higher mortality or dispersal of turtles in the younger stages as is reported among other terrestrial turtle species (Iverson, 1991). Given their cryptic coloration, we feel that juveniles and hatchlings could have been underrepresented in our samples, as sighting them in the dense leaf litter of the forest floor proved difficult. As we were unable to control for the biases in detectability, this could have resulted in the adult-biased population structure reported here.

Males were significantly larger than females, as is observed among most other terrestrial members of the family Testudinidae. Larger body size in male terrestrial turtles is proposed to have evolved as a result of sexual selection favouring better fighting ability during male–male combats (Berry & Shine, 1980), although Gibbons & Lovich (1990) describe a more general scenario, where body size is an outcome of natural selection to avoid predation or any other environmentally induced causes of mortality. It is likely that the larger body size of male *M. tricarinata* has also evolved as a result of both the selection forces mentioned above. Valentin & Gemel (1999) reported that male tricarinate turtles reach a longer carapace length and have different shell shapes than females, and as a result differ in size. Gibbons & Lovich (1990) also suggest that the smaller sex matures at a smaller size and at a younger age than the larger sex. In the case of *M. tricarinata*, the fact that females are heavier than males of the same length confirms that they probably mature earlier.

Individuals older than 12 years grew very slowly and did not have distinct annuli, as observed for other turtle species (Brookes et al., 1997; Chen & Lue, 1999). One male and one female turtle first captured in 2002 at the ages of 10 and nine years had only 12 countable rings at their last recapture in 2008, whereas two male turtles that were five and six years old at first capture in 2002 and 2003 had, in agreement with yearly additions in annuli, 11 and 10 rings when recaptured in 2008 and 2007, respectively. It is therefore important to note that the use of growth rings alone may not be a reliable method of estimating age in older individuals, as in other species (Wilson et al., 2003). In older turtles, the carapace coloration also changed, from dark coffee brown to pale brown.

While more data are clearly required to assess the feeding habits of these turtles, they appear to be omnivorous. The dependency of turtles on different food items in a given area appeared to be governed by availability. Fruits of *J. multiflorum* appeared to be the primary food item for turtles after their emergence. The arrival of rain then leads to the emergence of earthworms and other alternative food sources.

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