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Research Article

COMPARATIVE MORPHOMETRY AND BIOGEOGRAPHY OF THE FRESHWATER TURTLES OF GENUS *PANGSHURA* (TESTUDINES: GEOEMYDIDAE: *PANGSHURA*)

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ABSTRACT

The present paper reports multivariate morphometric analyses for a total of 178 individuals of the Southeast Asian freshwater turtle genus *Pangshura* including 80 numbers of live and 98 numbers of museum specimens. Allometric change in the body size was examined in the live collected as well as compared with various reptile museums and private collections. The comparative study on live and museum specimens revealed that male and female individuals of all the four species of *Pangshura* can be identified by sexual dimorphism. The frequency of the morphometric measurements among and within *Pangshura* species reveales that distinct sexual dimorphism in each species of *Pangshura* is well observed. Males are always smaller in size than the females. The present observations have revealed that *P. sylhetensis* is the smallest species under the genus *Pangshura*, which may reach a carapace length up to 20.5 cm. The present study for the first time has been able to present a diagrammatic representation of *P. sylhetensis* with plastral formula. Support for recognition of these taxa provides a scenario of the systematics, distribution and natural history of the genus *Pangshura.*

Keywords: Biogeography, Conservation, Morphometry, Systematics.

INTRODUCTION

The family Geoemydidae comprises highly endangered species of Southeast Asia (Van Dijk *et al.*, 2000). The genus *Pangshura* under this family comprises small-sized turtles and at present four species of the genus *Pangshura* have been found in Southeast Asia. Fossils have also been recorded of this genus from the Pleistocene deposits of the Siwalik Hills and Narmada Valley. Recently, Walter and Tyler (2010) described a fifth species of fossil testudinoid from the Indian subcontinent i.e. *Pangshura tatrotia* sp. nov., which has been placed as sister relative to the extant turtle *P. tecta*.

Morphometric study as well as its variation plays an important role in physiological, evolutionary and ecological implication. Empirical relationships with turtle body size have been established for diverse properties such as body temperature (Spotila and Standora, 1985), growth rate (Bjorndal and Bolten, 1988). Morphometric analysis is an important tool since the rigidity of body structure facilitates in taking the specific measurement. Morphometric variation data has been documented in a few chelonian studies (Claude *et al.*, 2003) and are frequently being used to delineate stocks of several other organisms such as fish (Walker *et al.*, 1997). Range of distribution and the environmental fluctuations and effect of nutritional deficiency may cause minor variation in these measurements. Limited information is available on morphometric and current distribution range of the genus *Pangshura*. Therefore, in this study, an attempt has been made to reveal the distribution of *Pangshura* to define its deficient biogeographical information and the size related

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data for identification of sex as well as age of the species. The limitations of the earlier findings on the taxonomy and species identification from the four currently recognized species of *Pangshura* have been addressed in this study.The main objective of this study is to investigate the morphometric variation among selected populations of four currently recognized species under the genus *Pangshura*. This comparative study will generate necessary information for the support of recognition of the four *Pangshura* species (seven taxa) based on morphology and distribution, which will provide the information about the systematics, biogeography and natural history of this genus.

MATERIALS AND METHODS

The present study has been conducted in northeast India and northern India which has been recently recognized by the IUCN as a global turtle priority conservation area (Buhlmann *et al.*, 2009). The study was carried out during January, 2007 to March, 2011 with the aim to record the morphometric variation, distribution and conservation status of fresh water turtles under the genus *Pangshura* in northern and northeastern India. Field surveys were carried out randomly throughout the state and some selected observation sites in the state of Assam, West Bengal (WB) as well as in some location of Northern India specially Uttar Pradesh (UP) (Table 1). The turtles were searched in riverine forested areas under different habitat conditions such as hiding out or hideout under bushes, under leaf litters, in the gaps of large rock boulders (Crevices), gaps in roots of large trees or in hibernating form. Hill stream beds and river banks were also surveyed to search for the tracks of the turtle, through which sometimes collected the specimens. Besides, the fishermen and local communities of selected sites were interviewed using standard photosheet. Turtles under basking conditions were observed from a distance by using binoculars from boat or by walking along the river bank.

Turtles were collected from the Brahmaputra and Ganga river systems and the tributaries along with wetlands of northeast India and northern India including Tista River in West Bengal (Table 1, Plate 1) and identified the following by several workers (Smith, 1933; Pritchard, 1979; Daniel, 1983; Das, 1985, 1995, 2002; Hanfee, 1999; *et al.*, 2007a). The protocols used for recording morphological measurements were followed as per the standard guidelines for hard-shell turtle measurement. Measurements were taken using the dial vernier callipers: straight line of carapace length (CL), carapace width (CW), plastron length (PL), plastron width (PW) and shell height (SH) for all the captured specimens, which were later released. Turtle sex determination was done using the standard methodology adopted by Ernst *et al.* (1994). Juveniles were not separated by sex because turtles are not sexually dimorphic prior to maturity. Subsequently the live specimens were released in their respective natural habitat.

The plastral formula indicates relative lengths of the plastral scutes along the midline of adults. Scute abbreviations are: g = Gular, h = Humeral, p = Pectoral, ab = Abdominal, f = Femoral and a = Anal. The signs >, < and >< are respectively - greater than, less than and either may be the larger.

Allometric change in the body size of the collected live specimens were examined was examined and compared with various standard museum specimens, private collections, reptile expos, Zoos including the Bronx Zoo, New York. All available museum specimens were examined at the Chelonian Research Institute, 402 South Central Avenue, Oviedo, Florida 32765, USA. Sexual dimorphisms were observed.

As a major objective of the present work, present and past localities of *P. sylhetensis*, occurrences were recorded using Handheld Garmin 72 GPS and the locations were plotted on habitat map using the software ARCVIEW (Ormsby and Alvi, 1999) to know the extent of present and past distribution pattern as well as to find out the phylogeographic relations.

Table 1. Showing the collection date and place (80 specimens).

Taxon	Number of specimens	Date of observation	Place of observations	GPS locations
P. tecta	1	15.05.09	Kushiara River, Assam	24°52'37.5341"N; 92°31'5.1625"E
P. tecta	2	14.05.09	Gomrighat, Sonitpur district, Assam	26°44’47.93”N; 93°38’45.45”E
P. tecta	2	15.05.09	Hajo, Kamrup district, Assam	26°14’41.1’’N; 91°31’37.2’’E
P. tecta	3	12.06.09	Ganga river, UP	27° 12' 51.0"N; 79° 41' 33.6"E
P. tecta	2	19.12.10	Teesta river Jalpaiguri, WB	$26^0 30^/ 28.76^{//}$N; $88^0 44^/ 25.44^{//}$E
P. tecta	2	08.05.09	Orang National Park, Assam	26° 27' 00.1"N; 92° 15' 22.2" E
P. tecta	1	08.05.09	Futuri, Kamrup district, Assam	26º07’41.6’’N; 91º26’03.0”E
P. sylhetensis	2	28.08.08	Kushiara River at Bhangabazar, Karimganj district, Assam	24°51'39.38"N; 92°28'55.38.65" E

P. sylhetensis	2	06.08.08	Biswanath Ghat, Assam	26° 39′ 31.46″N; 93° 10′ 18.91″ E
P. sylhetensis	2	06.08.08	Jia Bharali River, Assam	26°57'09.24"N 92°49'05.40"E
P. sylhetensis	2	06.08.08	Kuruwa Ghat , Darrang district, Assam	26°13'32.79"N; 91°46'39.74"E
P. sylhetensis	2	15.12.10	Buxa Wildlife Sanctuary, WB	26°50'17.05"N; 89°50'13.83"E
P. sylhetensis	1	11.08.08	Subansiri river, Arunachal border	$27^0 26' 0.83''$N; $94^0 14' 4.96''$E
P. sylhetensis	2	10.08.08	Dikhowmukh, Sivasagar	$27^0 59' 0.12''$N; $94^0 26' 49.2''$ E
P. sylhetensis	2	10.08.08	Jiri river, Assam-Manipur border	24°48'13.93"N; 93°11'29.11" E
P. sylhetensis	2	08.05.09	Dholeswary River, Barakriver	24°41'21.03"N; 92°53'16.02" E
P. sylhetensis	2	12.06.09	Diffolu River, Kazirnaga National Park, Assam	26° 38′ 21.18″N; 93° 20′ 36.49″ E
P. sylhetensis	3	01.08.08	Umkiang, Jantia hills	25° 03' 60.5"N; 92° 22' 43.9" E
P. sylhetensis	2	04.05.09	Chandubi beel, Kulshi	25° 51' 0.79"N; 91° 21' 50.5" E
P. sylhetensis	4	18.04.10	Hajo, Kamrup, Assam	26 º 14'41.1''N; 91 º 31'37.2'' E
P. sylhetensis	1	17.09.09	Buri Khamar, Manas NP	$26^0 32' 41.24''$N; $90^0 53' 34.18''$ E
P. sylhetensis	2	19.12.10	Teesta river Jalpaiguri, WB	$26^0 31' 48.82''$N; $88^0 44' 32.23''$E
P. sylhetensis	1	29.03.09	Kulshi river, Assam	$26^0 03' 19.8''$N; $91^0 26' 52.3''$E
P. sylhetensis	1	14.12.10	Buxa Wildlife Sanctuary, WB	26°50'17.15"N; 89°50'13.73E"
P. sylhetensis	1	19.12.10	Teesta river Jalpaiguri, WB	26°32'43.58"N; 88°45'05.72E"
P. t.tentoria	3	06.08.08	Hajo, Kamrup, Assam	26º 14'41.1''N; E 91º 31'37.2''E
P. t. tentoria	2	25.03.09	Lahorighat, Morighaon district, Assam	26° 26' 31.5"N; 92° 16' 08.3"E
P. t. tentoria	2	04.04.10	Ganga river, Farrukhabad,UP	27° 14' 17.7" N ; E 79° 40' 27.1" E
P. t. tentoria	2	04.05.09	Ganga,U.P	27° 12' 51.0" N; 79° 41' 33.6" E
P. t. tentoria	2	11.05.09	Dimbur Char, Lahorighat, Morighaon district, Assam	26° 26' 31.5"N; 92° 16' 08.3" E
P. t. tentoria	1	07.08.08	Bohori , Barpeta	$26^0 14' 35.2''$N; $91^0 08' 11.2''$ E
P. t. tentoria	1	11.04.10	Orang National Park, Assam	26° 27' 40.1" N; 92° 15' 55.2" E
P. t. circumdata	3	04.05.09	Yamuna river, Etawah, UP	26°45'13.45"N; 79°0'28.21"E
P. tentoria circumdata	3	14.05.09	Yamuna river, UP	26°44'37.5749"N; 79°0'3.488"E
P. t. circumdata	1	11.05.09	Kalindri Ganga confluence, UP	27° 12' 51.5" N; 79° 41' 35.2" E
P. t. circumdata	1	06.08.08	Ganga river, UP	27° 13'23.3" N; 79° 43' 22.9" E
P. flaviventer	2	03.04.09	Buxa Wildlife Sanctuary, WB	26°50'16.05"N; 89°50'12.82E"
P. t. flaviventer	1	03.04.10	Lahorighat, Assam	26° 27' 00.1"N; 92° 15' 22.2"E
P. t. flaviventer	1	11.04.10	Biswanath Ghat, Assam	26° 39′ 32.46″N; 93° 10′ 17.92″ E
P. s. smithii	4	06.08.08	Hajo, Kamrup, Assam	26 º 14'41.1'' N; 91 º 31'37.2'' E
P. s. smithii	1	08.05.10	Burhachapari Wildlife Sanctuary, Assam	26°30'41.3"N ; 92°41'14.7"E
P. s. pallidipes	2	04.04.10	Ganga river, Farrukhabad,U.P	27° 12' 50.8" N; 79° 41' 34.6" E
P. s.pallidipes	1	12.06.09	Ganga river, UP	27° 13'23.3"N ; 79° 43' 22.9" E

Plate 1 (A-N)

A.

B.

C.

D.

E.

F.

G.

H.

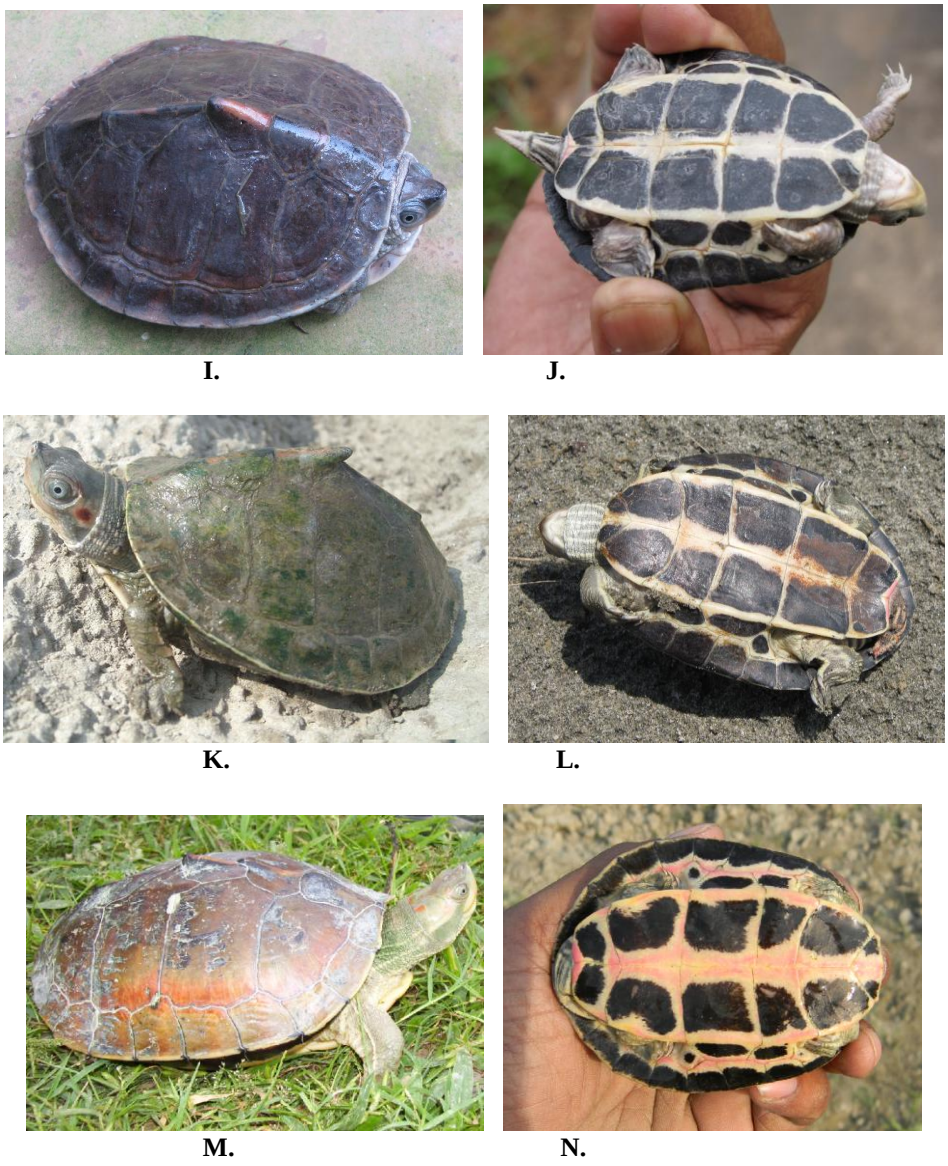


Plate 1. (A-N): Photographs of *Pangshura* species observed in the present study (Photographs by Chittaranjan Baruah). [A. *P. tectca* (Carapace), B. *P. tecta* (plastron), C. *P. sylhetensis* (Carapace), D. *P. sylhetensis* (plastron), E. *P. smithii pallidepes*(Carapace), F. *P. smithii pallidepes* (plastron), G. *P. smithii smithii* (Carapace), H. *P. smithii smithii* (plastron), I. *P. tentoria tentoria* (Carapace), J. *P. tentoria tentoria* (plastron), K. *P. tentoria tentoria flaviventer* (Carapace), L. *P. tentoria flaviventer* (plastron), M. *P. tentoria tentoria circumdata* (Carapace), N. *P. tentoria circumdata*(plastron)].

RESULTS

A total of 178 individuals including 80 nos of *Pangshura* from northeast India and northern India have been collected from different sites as shown in Table 1 as well as 98 number of museum specimens were analyzed to compare the different parameters of size and sexual dimorphism.

Live specimens: A total of of 80 *Pangshura* specimes were throughly examined during the field work (Table 2). The specimens include *Pangshura tecta* (13), *Pangshura sylhetensis* (34), *Pangshura smithi smithi* (5), *Pangshura smithi pallidepes* (3), *Pangshura tentoria tentoria* (13), *Pangshura tentoria circumdata* (8) and *Pangshura tentoria flaviventer* (4) (Plate 1 A-N).

Musueum specimens: A total of of 98 *Pangshura* specimes in museum were throughly examined at Dr.Peter C. H. Pritchard's Chelonian Research Institute, 402 South Central Avenue, Oviedo, Florida 32765, USA. *Pangshura smithi smithi* (22), *Pangshura smithi pallidepes* (6), *Pangshura sylhetensis* (1), *Pangshura tecta* (33), *Pangshura tentoria tentoria* (1), *Pangshura tentoria*

circumdata (16) and *Pangshura tentoria flaviventer* (19) (Table 3).

Key to the four Pangshura species

Fourth vertebral shield is pointed anteriorly, having a slight contact with the third vertebral and overlap five neural bones (Fig. 1).

A. 24 marginal shields are present; posterior margin of carapace is not or feebly serrated.

(i) Third vertebral shield elongate, quadrangular or pentagonal (in young) and with almost straight posterior border. The keel of the third vertebral shield terminated in a rounded projection..... *P. smithi*

(ii) Third vertebral shield is not much elongate, always pentagonal and pointed behind. The keel of the third vertebral shield terminates in a backwardly projecting spine.

Second vertebral shield longer than third..... *P. tecta*

Second vertebral shield shorter than third..... *P. tentoria*

B. 26 (13 pairs) marginal shields are present; posterior margin of carapace is strongly serrated..... *P. sylhetensis.*

Species description

I Indian Roofed Turtle - *Pangshura tecta* (Gray, 1831)

Description: The head is moderately small, pointed and shorter than the orbit. Carapace elevated, oval with a distinct vertebral keel that is spiked, especially on vertebral III; vertebral I as long as wide or longer than wide; vertebral II and III variable; vertebral IV longer than wide, flask-shaped; vertebral V wider than long; plastron truncated anteriorly, notched posteriorly; snout pointed, the skin of at the back of the forehead with irregular scales; upper jaw, unnotched, serrated; alveolar surface concave, with a serrated ridge along the border (Plate 1 A-B).

Plastral formula: abd > fem > an > < hum > an > gul.

Colour: Carapace brownish with a light brown, red or orange stripe along the first three vertebrals, the marginals with a narrow yellow border; plastron yellow or pink, with 2-4 black markings on each plastral scute; head with orange or reddish crescent-shaped postocular markings, curving up from below the eyes to meet on the forehead; neck dark with thin yellow stripes.

Sexual Dimorphism: Males are the smaller of the sexes and possess a comparatively longer tail that is thicker at the base. Males possess white bands on top of the tails, while females possess yellow bands. In addition, male carapaces are darker and the irises are red as opposed to the paler carapaces and pink irises of the females.

Habits and habitat: The species is fully aquatic and inhabits freshwater bodies with plenty of aquatic vegetation. It is a less active species and comparatively a poor swimmer. Not much is known about its breeding habits. Lay 4-10 eggs in the same clutch .They are herbivorous and feed Aquatic plants.

II. Assam Roofed Turtle - *Pangshura sylhetensis* (Jerdon, 1870)

Description: This is a small and rare species which hardly reaches to a length of 20.5 cm, observed in the present study. The head is moderately small, snout pointed, shorter than the orbit and projecting much beyond the lower jaw. Shell strikingly elevated, especially in juveniles and less so in adults, oval and markedly serrated posteriorly; vertebrals I as wider as long or wider than long, vertebrals II and V wider than long, vertebrals III and IV longer than wide, thirteen pairs of marginal scutes (the only Indian freshwater turtle to show marginal XIII), posterior of plastron with a weak notch or unnotched, snout slightly projecting, upper jaw weakly hooked. Olive brown above and 'S' shaped red stripe behind eye (Plate 1 C-D).

Plastral formula: fem > < abd > pect > hum > an > gul.

Colour: Carapace Olive brown with a pale brown vertebral keel, plastron is yellow coloured with larger black blotches on each scute. A narrow yellow stripe runs posteriorly from the eyes to the middle of the black of the head, another along the mandibles, curving to join the tympanum. Neck is surrounded with light stripes.

Sexual dimorphism: Males are smaller than females and possess relatively longer tails with thicker bases.

Habits and habitat: The species is fully aquatic and inhabits stagnant and slow running waters in the hilly terrain with plenty of aquatic vegetation. Bask communally on logs on water. They lay upto 6 -8 elongated eggs during October to February of a year (Baruah *et al.*, 2010).

III. Brown Roofed Turtle *Pangshura smithii* (Gray, 1863)

Description: Carapace oval and depressed, with or without a vertebral keel; vertebrals longer than wide, except vertebrals II and V, which are wider than long; plastron

truncated anteriorly, notched posteriorly; snout projecting beyond lower jaw; upper jaw with a weak notch, serrated; alveolar surface broad.The head is moderately small; snout is pointed, shorter than the orbit and projecting much beyond the lower jaw. Hatchlings measure 3.58-3.92 cm in carapace length.

Two subspecies are recognized, based on coloration of head, shell, limbs and penis: *smithii* (Gray, 1863) from northeastern India, northern India, Pakistan and Bangladesh, and *pallidipes* Moll, 1987 from northern India and Nepal.

(i) *P. smithii smithii:* It is the larger of the two subspecies and has black pigment on the sides of the head and on the anterior face of the limbs. There is a dark brown to reddish blotch behind each eye. The irides are pale blue-gray, and the mandibles yellowish. Black lines and triangles are present on the areolae of costals 2 and 3. The plastron is strongly marked with black, relieved only by the yellow edges (Plate 1 E-F).

(ii) *P. smithii pallidipes:* It posess very reduced pigmentation of the plastron and the much lighter coloration of the head and limbs. The shell is often less keeled, and the spur on the third vertebral scute is completely lacking. The head is light olive, light gray, or yellowish, and the reddish spot behind the eye is very attenuated or even absent. The irides are pale blue-gray. It has been observed in the present study that the patterning of this species is quite variable, some time individuals having reddish lines on the vertebral scutes and a more or less dark plastron (Plate 1 G-H).

Plastral Formula: abd > fem > hum > pect > an > gul.

Colour: The carapace is brownish-olive, with a dark brown vertebral stripe, the plastron yellow with or without dark blotches on each scute.

Sexual dimorphism: Males are smaller than females and possess relatively longer tails that are thicker at the base.

Habits and habitat: The species is entirely aquatic and is a rapid swimmer. It is omnivorous and devours flesh readily. Clutch size found with seven to nine elongated eggs on the sandy banks of the rivers in a single clutch eggs measure 3.3 cm in length and 2.4 cm in width.

IV. Indian Tent Turtle *Pangshura tentoria* (Gray, 1834)

Description: This is a small species in which the adult female is similar to *Pangshura tecta* in size. The head is moderately small and pointed, shorter than the orbit and feebly projecting beyond the lower jaw. Carapace elevated, oval with a distinct vertebral keel that is spiked, especially on vertebral III; vertebrals III and IV longer than wide, vertebral V wider than long, vertebrals I and II longer than wide or wider than long; plastron truncated anteriorly, notched posteriorly; snout pointed, the skin at the back of forehead with irregular scales; upper jaw unnotched, serrated; alveolar surface broad, with a single V-shaped ridge.

Three subspecies have been described: *tentoria* (Gray, 1834) from peninsular India, *circumdata* (Mertens, 1969) from the western tributaries of the Ganga and the rivers of Gujarat, and *flaviventer* (Gunther, 1864) from the northern tributaries of the Ganga.

(i) The typical subspecies grows to 23.0 cm straight carapace length. The carapace is brown with an amber or hazel stripe along the first three vertebrals; the plastron is yellow with large black blotches; and the head is olive or brownish, with a red postocular spot and an indistinct band behind the eye (Plate 1 I-J).

(ii) Subspecies *circumdata* grows to 26.5 cm straight carapace length. The carapace is brownish olive green with a pink pleuro-marginal ring; the plastron is yellow with large, dark blotches; the head is olive green with a pink postocular spot and pink bars behind the eyes (Plate 1 K-L).

(iii) Subspecies *flaviventer* grows to 20.3 cm straight carapace length. The carapace is brownish olive with a light-coloured stripe on the first three vertebrals; the plastron is yellow, unpatterned; the head is brownish olive, with a pink patch behind the eyes (Plate 1 M-N).

Plastral formula: abd > fem > pect > hum > an > gul.

Colour: Variable, depending on the subspecies.

Sexual dimorphism: Males are smaller, with comparatively longer and thicker tails.

Habits and habitat: The species is absolutely aquatic and inhabits in slow running water near the banks and still water pools on the river side. It is an active swimmer and is mainly herbivorous. Breeding habits is not known till now.

Distribution of Pangshura

***P. tecta*:** This species has a wide range in northern India, in the drainages of the Indus, Ganges, and Brahmaputra Rivers, from Pakistan to Bangladesh (and southern Nepal). Isolated populations exist in southern Pakistan and in west central India (Fig. 2 A).

***P. sylhetensis*:** India (Assam, Meghalaya, Arunachal Pradesh, Nagaland, West Bengal), Bhutan and Bangladesh (Ahmed *et al.*, 2009) (Fig. 2 B).

***P. smithii*:** The range of the species encompasses the drain-ages of the Indus, Ganga and Brahmaputra (Fig. 2 C).

(i) *Pangshura smithii smithii* is distributed in Bangladresh, India and Pakistan.In India, this sub-species has been reported from Assam (Manas National Park, Kaziranga National Park and Orang National Park), Bihar (Kapurthala, Sutlej river near Rupar), Punjab (Ludhiana, Ferozepur, Kapurthala, Sutlej river near Rupar), Uttar Pradesh (Gorakhpur, Katerniaghat).

(ii) *Pangshura smithii pallidipes* is distributed in Nepal and India. In India, this sub-species has been reported from Bihar (Bherihari Wildlife Sanctuary), Uttar Pradesh (Gangra River).

P. tentoria: The three subspecies together extend over a wide expanse of territory in the central and eastern parts of India and in Bangladesh, as well as in southern Nepal (Fig. 2 D). The known localities of occurrence for each subspecies are:

(i) *Pangshura tentoria tentoria:* Orissa (Tikarpara, Cuttack, Sambalpur, Nanaj, Puri), Andhra Pradesh (Manthani), Madhya Pradesh (Bilaspur), Mharashtra (Dhond, Pune), Assam (Praschag *et al.*, 2007).

(ii) *Pangshura tentoria circumdata:* Madhya Pradesh (Deogarh), Uttar Pradesh (Meerut, Lucknow, Etawah, Bateshwar), Gujarat (Surat), Rajasthan (River Gambir).

(iii) *Pangshura tentoria flaviventer:* Bihar (Sambharsa Ghat, Bettiah, Kahalgaon, saharsa), Uttar Pradesh (Katerniaghat, Gorakhpur), West Bengal and Assam.

In the hard shell turtle genus *Pangshura* of the present study, males are smaller across all measurements than females of the respective species and same could be observed in the museum collected specimens (Table 2 and 3). Relation among five carapace and plastron measures indicated strongest sexual dimorphism in the shell (carapace) height/length relationship. Size frequency distribution (CL-cm) demonstrated separation between size classes, presenting mode at 40cm, and another group formed by adults with accentuated increment at 115 and 100cm (Fig. 3 A-E). Juvenile with smallest medium values for all measured parameters, confirming observations of Sanches and Bellini (2002) and in accordance with Godley *et al.* (2002), who described a consistent pattern of sexual dimorphism in adult turtles. The critical observation was made by comparing the carapace length of the collected and museum specimen (Fig. 4 A and B) and observed that in all the three cases the data variable found was due to place variation.

In general, the observed tendencies were with adults demonstrating an accentuated disproportionality for weight increment, when associated to curved length. The only exception was the weight-curved length relationship in juveniles, which presented no significant differences in relative growth.

The present study on both live and museum collected specimens revealed that male and female individuals of all the four species of *Pangshura* can be identified by sexual dimorphism. Males are always smaller in size than the females. The frequency of the morphmetric measurements among and *Pangshura* species (Fig. 3 and 4) reveales distinct sexual dimorphism in each species of *Pangshura* are well observed.

In the genus *Pangshura*, males are always smaller than females. In *P. tecta*, adult males have carapace length (CL) 8.4-12.6 cm, Carapace width (CW) 7.5-8.5 cm, Plastron length (PL) 8.5-8.9 cm, Plastron width (PW) 5.2-7.1 cm and Shell hight (SH) 4.9-6.8. However, females are much larger than males with CL 15.5-19.6 cm, CW 11.8-14.2 cm, PL 14.5-19.1 cm, PW 7.1-9.2 and SH 6.5-8.9cm. The Juvenile studied in their respective natural habitat have CL 5.5-7.4 cm, CW 5.2-6.2 cm, PL 5.9-6.9 cm, PW 3.2-3.6 and SH 3.1-4.2. An adult female with CL 19.6 was weighed 1250 g. *Pangshura sylhetensis* was observed to be smallest in size among the species of *Pangshura*.In P. *sylhetensis*, females have been recorded CL 15.8-20.5 cm, CW 6.8-14.1 cm, PL 14.8 - 16.9 cm, PW 6.2-7.4 cm and SH 8.0-8.3 cm. Males are considerably smaller with CL 8.0- 9.8 cm, CW 5.85 -7.2 cm, PL 7.2-9.6 cm, PW 3.0-5.6 cm and shell hight 3.9 -6.1 cm. The largest individual (female) in the hajo was recorded a body weight of 1200g.

In *P. smithii*, females are larger than males with CL 13.4-21.6 cm, CW 11-12.7 cm , PW 6.9-8.2 cm and SH 7.3-8.4 cm. Males are having CL 9.4-12.8 cm, CW 7.1-7.5 cm, PL 7.6-7.8 , PW 4.2-4.4 cm and SH 7.3-8.4 cm. A female with CL 19.7 cm have a body weight of 1150 g. Comparision of morphometric parameters vi.z carapace length in the four species of *Pangshura* in live and museum specimens reveled that *P. tentoria circumdata* are larger than any othe species of *Pangshura* (Fig. 3 and 4). In *P. tentoria circumdata*, Males are smaller in size than females with CL 8.3-9.8 cm, CW 6.5-7.0 cm PL 8.17-8.5 cm, PW 4.3-5.6 cm and SH 3.6-4.3 cm. Females have CL 18.2-21.8, CW 14.6-15.2 cm, PL 16.5-19 cm, PW 9.2-9.6 and SH 9.7-9.9 cm. Both in *P. tentoria tentoria* and *P. tentoria flaviventer* adult males have a carapace length of 13.7- 14.9 c.m and females have carapace length of 15.5-22.8 cm, CW 11-16.5 cm, PL 14-20.3 cm, PW 7.2-10.4 cm and SH 9.5-11.1 cm (Table 2-3).

Table 2. Morphometric Measurements (cm) of live *Pangshura species* (n = 80).

Species	CL			CW			PL			PW			SH		
	M	F	J	M	F	J	M	F	J	M	F	J	M	F	J
P. tecta (4, 2, 7)	9.4± 0.01	17.2± 0.02	5.5± 0.01	7.5± 0.03	12.8± 0.1	6.2± 0.01	8.8± 0.03	15.4± 0.02	6.9± 0.02	5.4± 0.05	7.8± 0.10	3.4± 0.01	4.9± 0.02	8.2± 0.02	3.1± 0.001
P. sylhetensis (12, 8, 14)	9± 0.10	16.3± 0.12	4.5± 0.002	7.2± 0.01	11.3± 0.13	5.3± 0.001	9.4± 0.2	16.5± 0.12	6.9± 0.01	5.0± 0.01	7.1± 0.001	3.1± 0.01	5.6± 0.02	8.8±0. 001	3.0± 0.002
P.tentoria tentoria (3, 4, 6)	9.5± 0.02	20.4± 1.12	4.8±0. 02	8.6± 0.12	15.8± 0.12	5.8± 0.101	10.2± 0.10	20.1± 1.02	6.2± 0.01	5.9± 0.12	10.5± 0.03	3.3± 0.00 1	6.4± 0.02	10.9± 0.12	3.5± 0.001
P. tentoria circumdata (4, 3, 1)	9.7± 0.01	20.6± 1.01	5.5	8.7± 0.02	16.5± 1.00	6.2	10.7± 0.30	20.3± 0.37	6.1	5.9± 0.02	10.4± 0.03	3.1	6.6± 0.15	11.1± 0.12	3.4
P.tentoria flaviventer (3, 2, 0)	8.7± 0.02	19.3	-	9.0± 0.12	15.5	-	10.6± 0.09	19.9	-	5.8± 0.08	10.2	-	6.5± 0.08	10.8	-
P. smithii smithii (4, 2, 0)	7.8± 0.01	21.6	-	9.5± 0.11	14.2	-	7.4± 0.02	15.2	-	5.9± 0.04	8.6	-	4.4± 0.22	9.2	-
P. smithii pallidipes (2, 1, 0)	7.7	22.3	-	9.1	14.9	-	6.9	14.8	-	4.8	8.7	-	3.9	8.5	-

CL: Carapace length; CW: Carapace width; PL: Plastron length; PW: Plastron width; SH: Shell height; M: Male; F: Female; J: Juvenile (sub-adult). Figures in parentheses indicate nos. of M, F and J.

Table 3. Morphometric Measurements (cm) of *Pangshura species***.** Museum collected specimen (n= 98specimens).

Species	CL			CW			PL			PW			SH		
	M	F	J	M	F	J	M	F	J	M	F	J	M	F	J
P. tecta (15, 10, 8)	12.8± 0.02	15.9± 1.13	8.4± 0.05	9.9± 0.03	12± 0.1	6.7± 0.01	11.8± 0.03	14.8± 0.02	7.6± 0.02	6.1± 0.05	7.3± 0.10	3.6± 0.01	6.4± 0.02	7.5± 0.02	4.4± 0.001
P. sylhetensis (1, 0, 0)	9.5	-	-	7.2	-	-	8.2	-	-	3.7	-	-	5.0	-	-
P. tentoria tentoria (0, 0, 1)	-	-	8.2	-	-	6.6	-	-	7.8	-	-	3.8	-	-	4.2
P. tentoria circumdata (8, 5, 3)	18.5± 0.01	20± 1.01	8.2± 0.01	14.3± 0.02	14.9± 1.00	7.1± 0.13	17.8± 0.30	17.8± 0.37	7.4± 0.001	8.1± 0.02	9.4± 0.03	3.8± 0.2	9.4± 0.15	9.8± 0.12	4.5± 0.01
P.tentoria flaviventer (10, 7, 2)	15.5± 0.02	19.2± 0.14	9.7	11.9± 0.12	14.8± 1.08	7.9	15.4± 0.09	18..3 ±1.12	8.8	7.5± 0.08	9.2± 0.09	5.3	8.2± 0.08	9.3± 1.09	4.8
P. smithii smithii (12, 9, 1)	10.5± 0.01	13.5± 1.02	9.4	7.3± 0.001	11.8± 0.03	6.1	7.7± 0.1	14.8± 1.03	5.7	4.3±0 .01	7.1±0 .1	3.5	4.5±0 .002	7.7± 0.22	4.2
P. smithii pallidipes (3, 1, 2)	10.8	15.8	6.4	9.3	11.9	6.6	10.9	15.2	7.2	6.8	7.6	4.4	6.9	7.9	4.4

CL: Carapace length; CW: Carapace width; PL: Plastron length; PW: Plastron width; SH: Shell height; M: Male; F: Female; J: Juvenile (sub-adult). Figures in parentheses indicate nos. of M, F and J.

Table 4. Observations of *P. sylhetensis* in the study sites (Baruah *et al*., 2010).

Year	Jia Bharali River	Gomirighat	Biswanath Ghat	Kuruwa Ghat	Kulshi River
2006	8	6	6	4	-
2007	10	6	6	6	Shell
2008	14	8	10	6	Shell
2009	18	8	12	8	Shell
Total	50 (30 male, 20 female)	28 (17 male, 11 female)	34 (20 male, 14 female)	24 (14 male, 10 female)	-

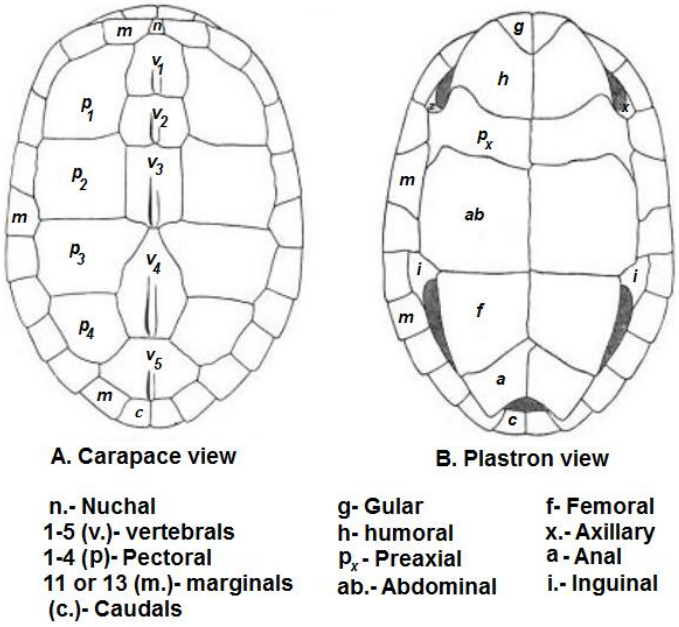


Figure 1. Diagrametic representation of (A) Carapace and (B) Plastron view of *Pangshura* species along with different body parts (Prepared during the present study, after Gunther, 1864).

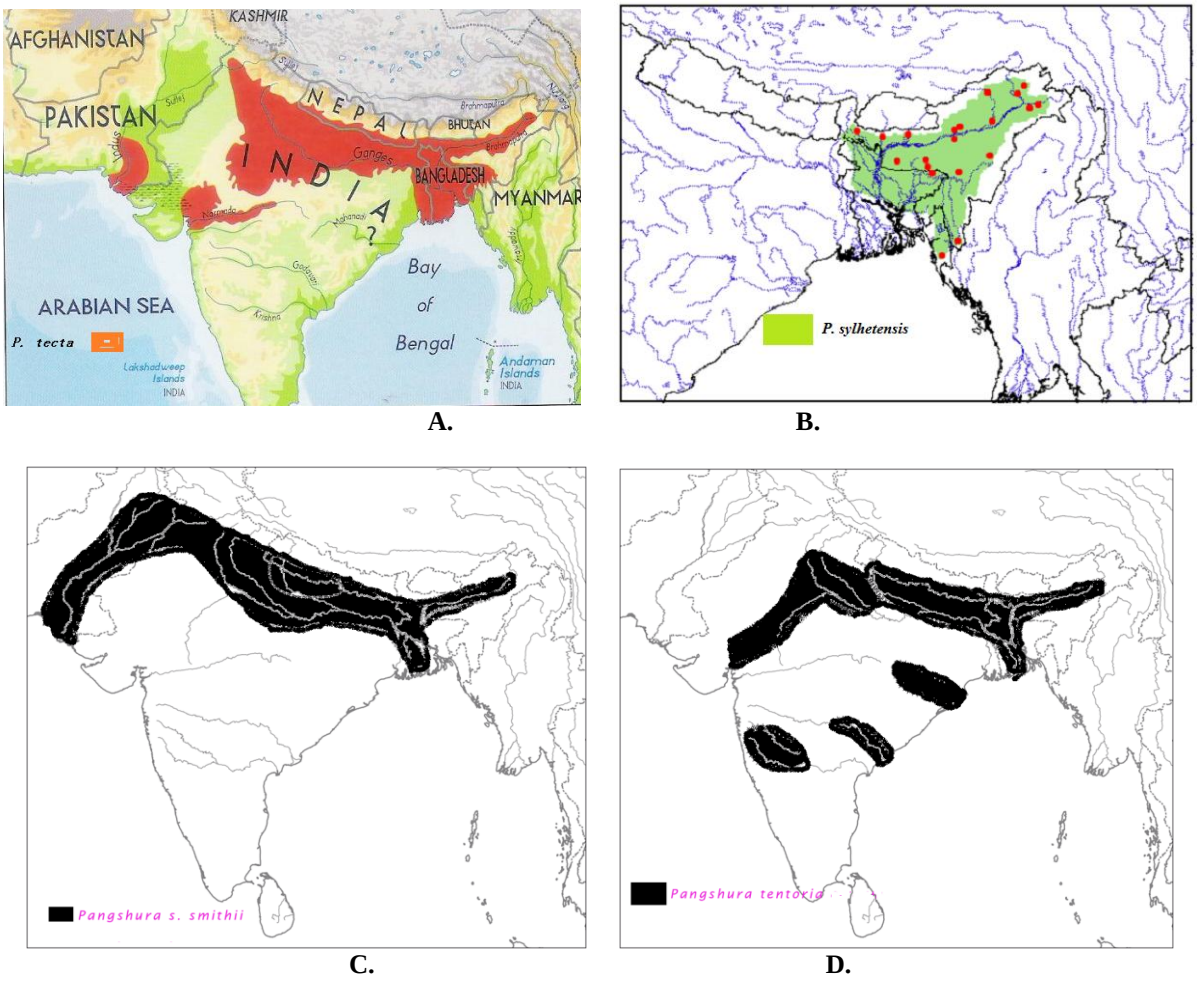
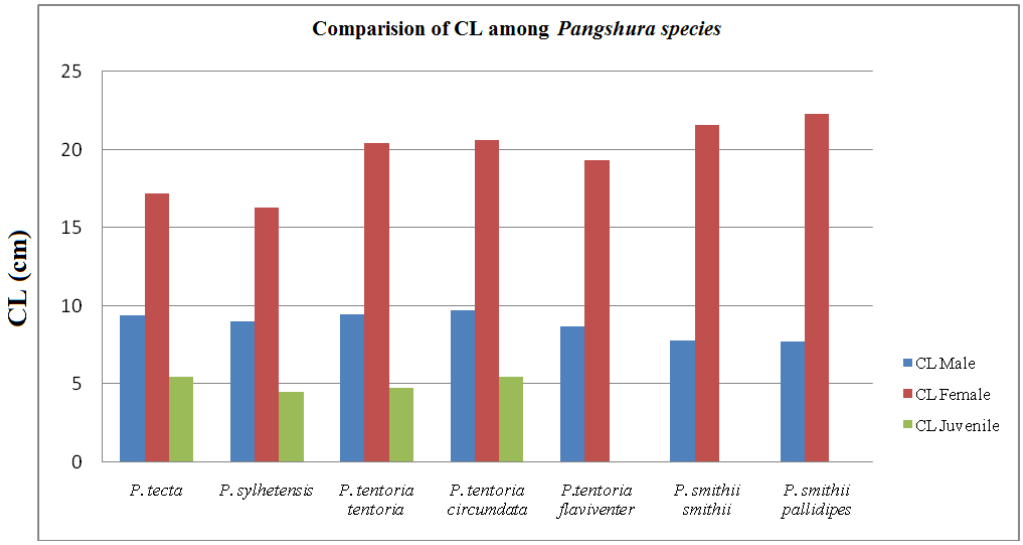
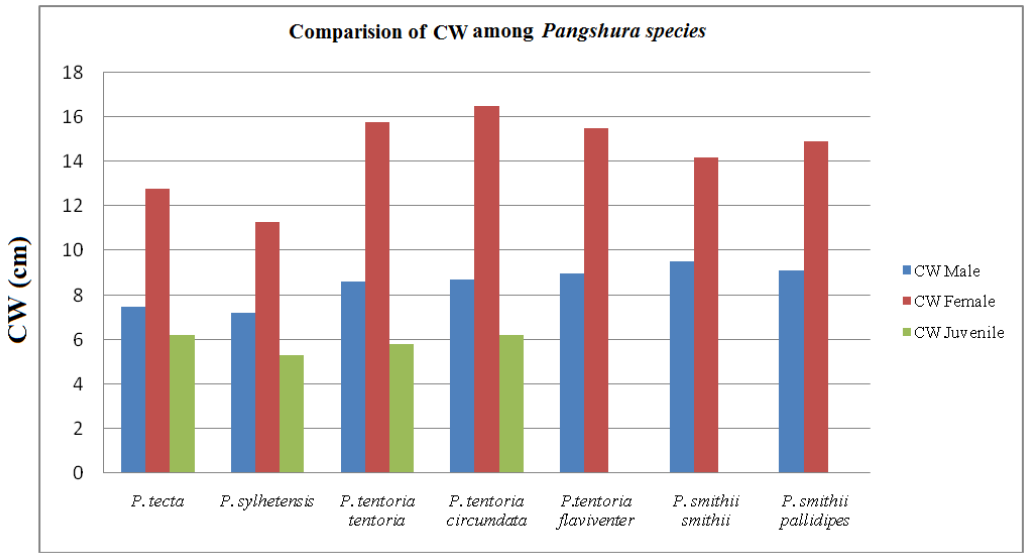


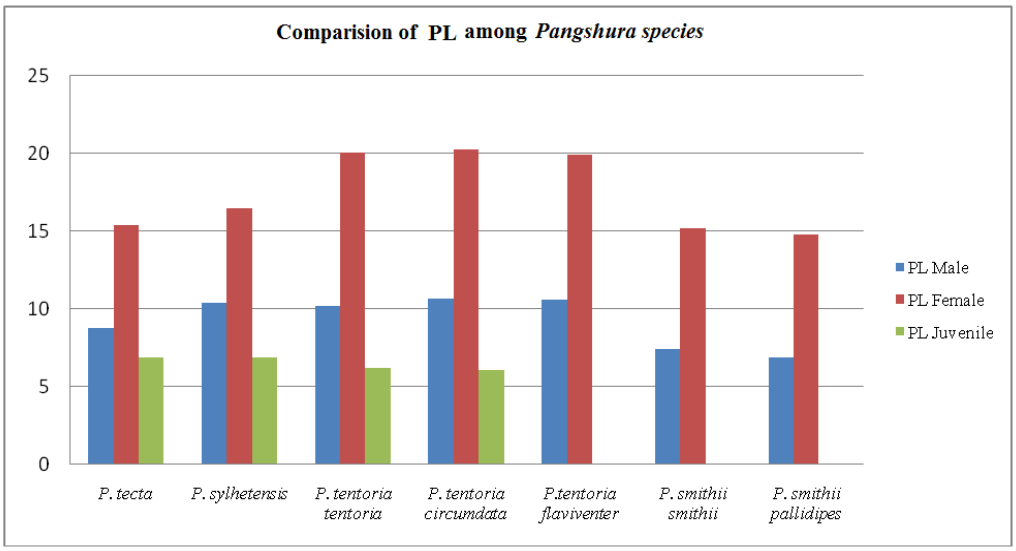
Figure 2. (A–D): Map of India showing the current distribution range of *Pangshura species* based on the observations in the present study along with literature record. [A. *P. tecta*, B. *P. sylhetensis*, C. *P. smithii*, D. *P. tentoria*].


Comparision of CL among Pangshura species
CL (cm)
25
20
15
10
5
0
P. tecta
P. sylhetensis
P. tentoria tentoria
P. tentoria circumdata
P.tentoria flaviventer
P. smithii smithii
P. smithii pallidipes
CL Male
CL Female
CL Juvenile

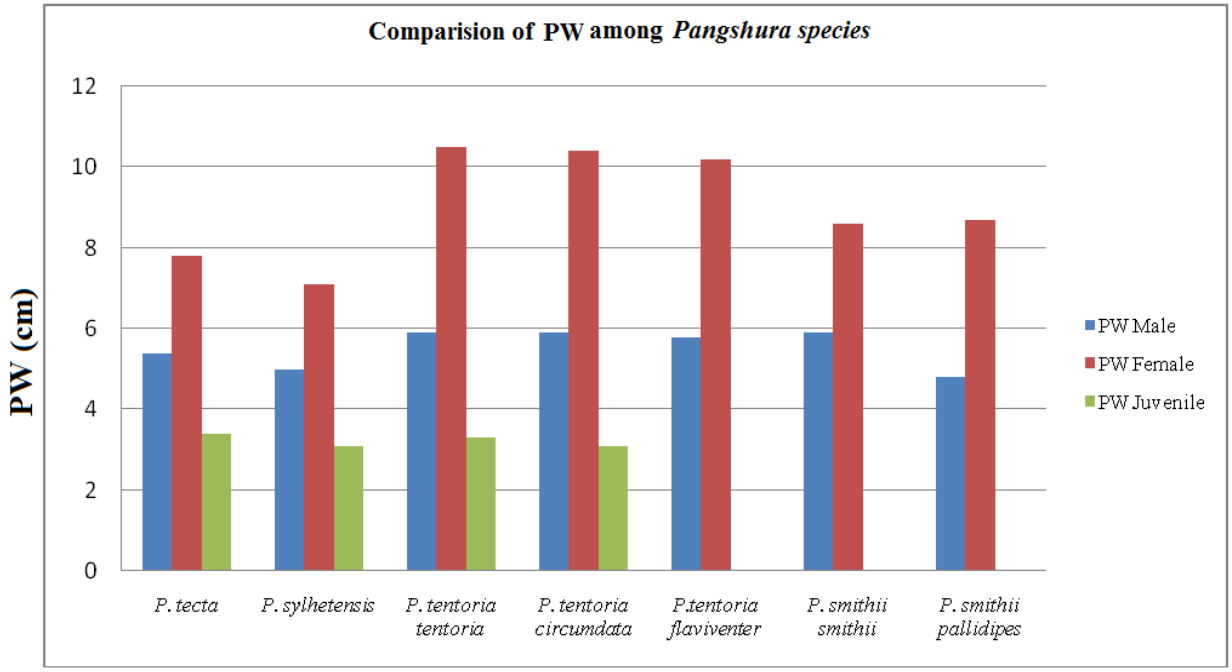
A.


Comparision of CW among Pangshura species
CW (cm)
18
16
14
12
10
8
6
4
2
0
P. tecta
P. sylhetensis
P. tentoria tentoria
P. tentoria circumdata
P.tentoria flaviventer
P. smithii smithii
P. smithii pallidipes
CW Male
CW Female
CW Juvenile

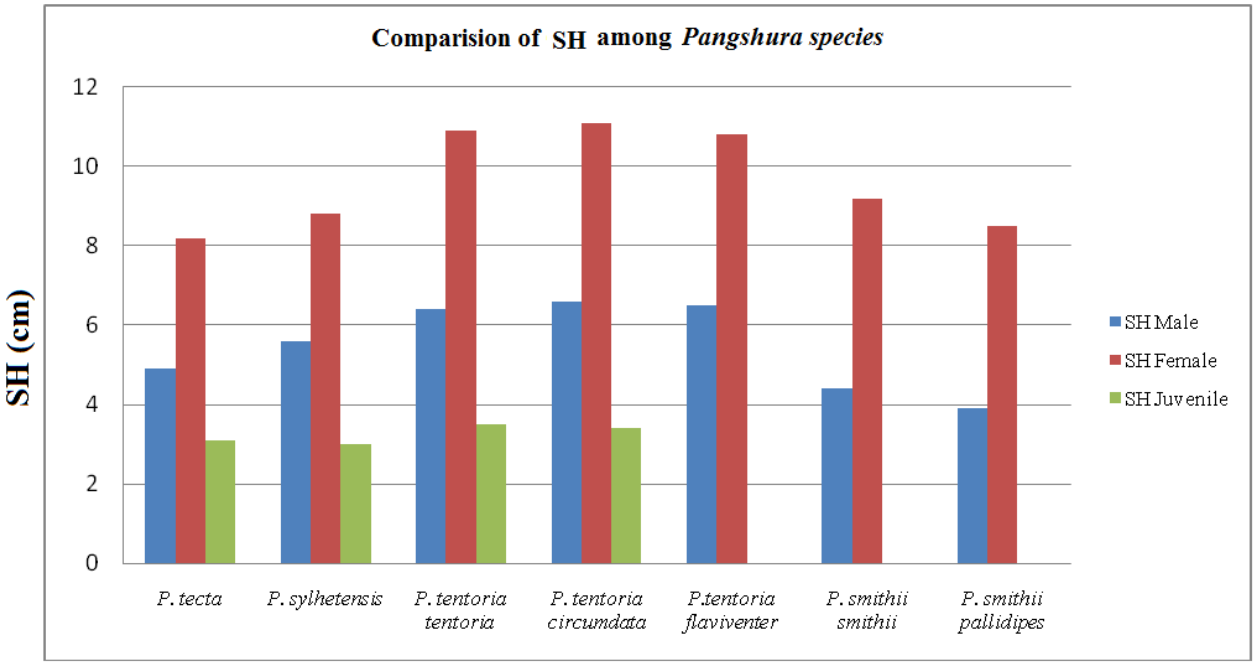
B.


Comparision of PL among Pangshura species
PL (cm)
25
20
15
10
5
0
P. tecta
P. sylhetensis
P. tentoria tentoria
P. tentoria circumdata
P.tentoria flaviventer
P. smithii smithii
P. smithii pallidipes
PL Male
PL Female
PL Juvenile

C.

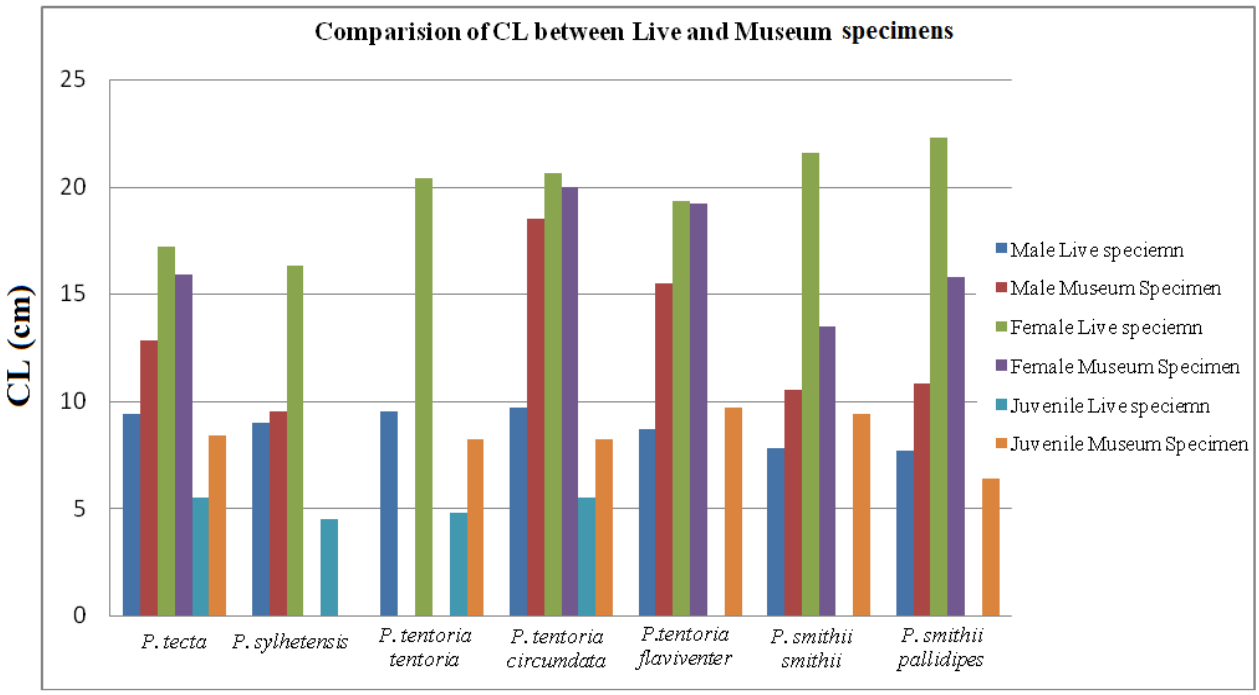


D.

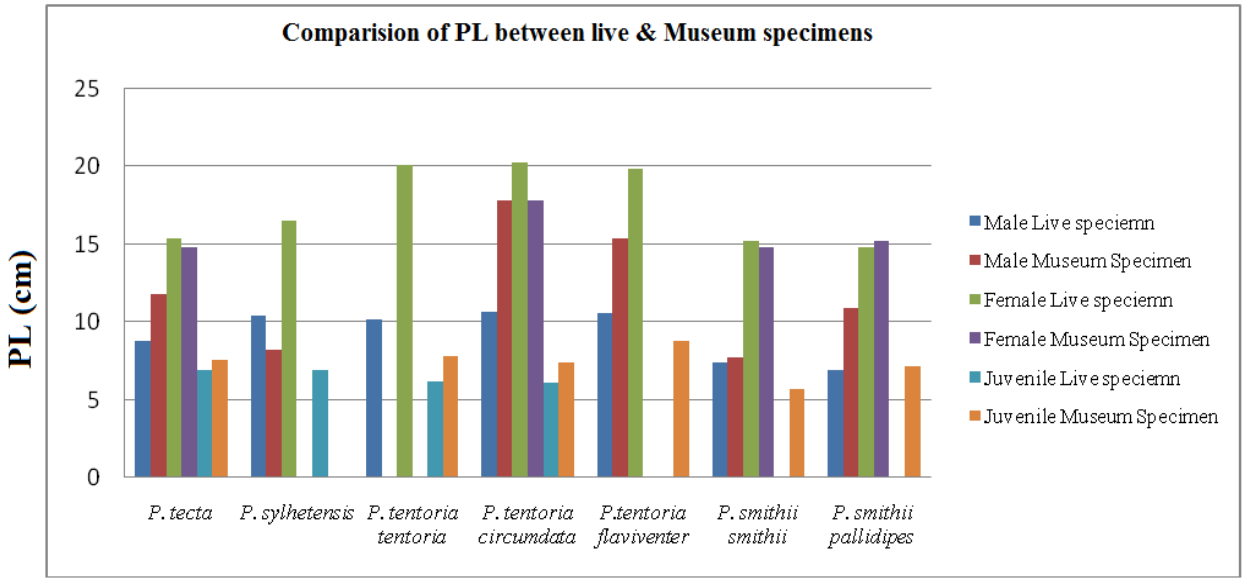


E.

Figure 3. (A – E): Chart showing the morphometric character with frequency. CL: Carapace length; CW: Carapace width; PL: Plastron length: PW: Plastron width: SH- Shell height.



A.



B.

Figure 4. (A – B): Chart showing the comparative Carapace length (CL) and planstron length (PL) between live and museum collected *Pangshura* specimens.

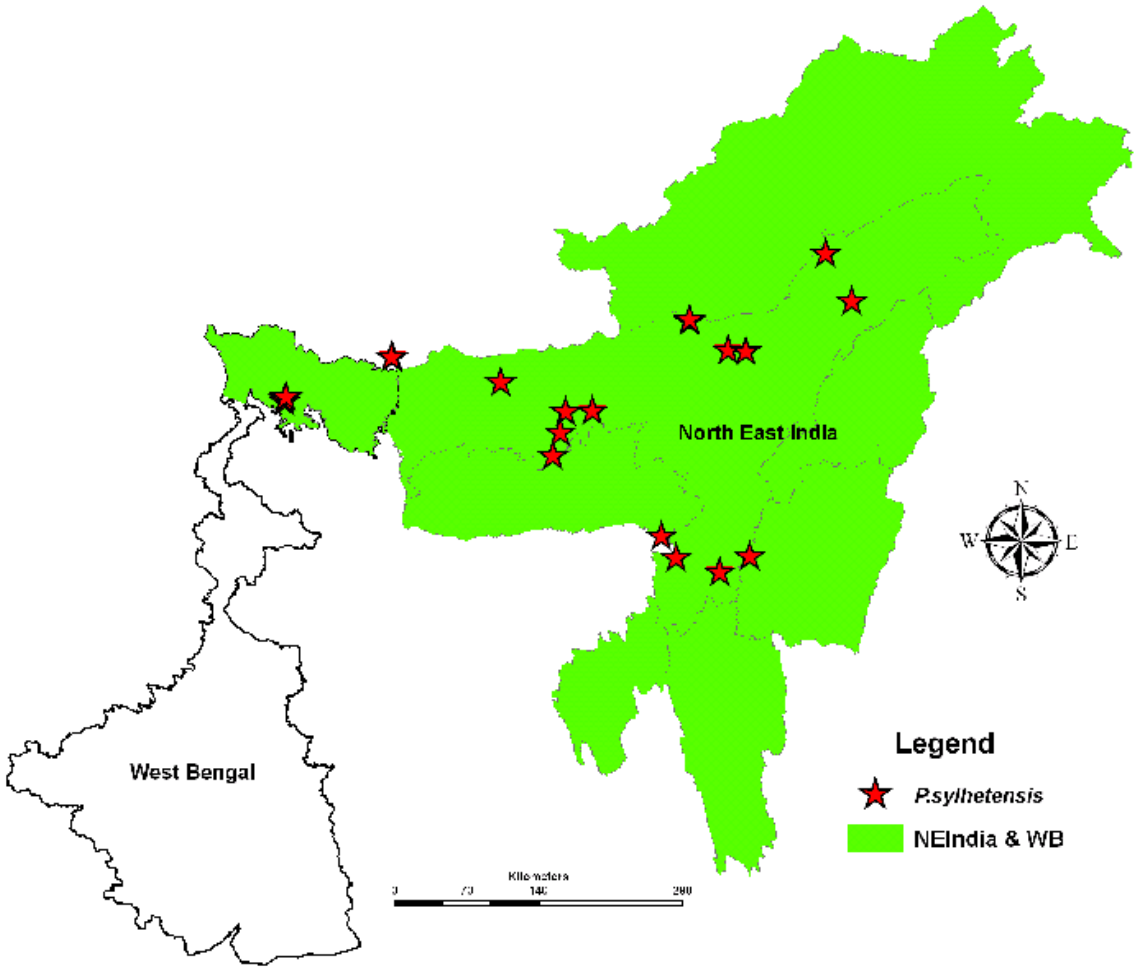


Figure 5. Distribution of *Pangshura sylhetensis* in northeast India and West Bengal. Green shading = projected distribution based on GIS-defined hydrologic unit compartments (HUCs) (Buhlmann *et al.*, 2009), and adjusted based on authors' data. Red stars = Observations and sample collection sites in the present study plus more recent and authors' data (Map prepared by Chittaranjan Baruah).

DISCUSSION

The present observations have reported that size of *Pangshura shylhetensis* may be larger (carapace length 18.5 cm) than that reported by Das *et al.* (2010). The present study reported a female individual from the temple tank of Hajo, Kamrup district, Assam having carapace length (CL) of 20.5 cm, carapace width (CW) 14.1 cm, plastron length (PL) 16.9 cm,plastron width (PW) 7.4 cm and shell hight (SH) 8.3 cm with weight of 1200g. The study also suggests that out of three sub-species of *P. tentoria, P.tentoria circumdata* is the largest in size. The present study has been able to present for the first time the diagrametic representation of *P. sylhetensis* with plastral formula and diagram (Fig. 1) modified after Gunther (1864).

The present survey is in conformity with Choudhury *et al.* (1997) and four species recorded were *P. smithii* (Gray, 1863), *P. tecta* (Gray, 1831), *P. tentoria* (Gray, 1834) and *P. sylhetensis* (Jerdon, 1870). In the present study, the subspecies of *P. smithii*, the typical *P. smithii smithii* and pale footed *P. smithii pallidipes* was previously recorded from northern India, Nepal (Moll, 1987), Kaziranga National Park (Das, 1995) and Brahmaputra Drainage (Choudhury *et al.*, 1997, 1999; Choudhury and Sengupta, 1998) .

A total of 136 *P. sylhetensis* (Table 4) was recorded by Baruah *et al.* (2010) (male -81 and female -55) and the habitat parameters were found to supports the suitability of the plains of the Brahmaputra valley. Further, the count of 50 nubers of male juvenile and 20 numbers of female juvenile during this study period (2006-2009) confirms the suitability of Brahmaputra floodplains as one of the proper breeding ground. Nests of *P. sylhetensis* were observed only during October-February at Biswanath Ghat (26° 39´ N; 93° 10´ E) and Kuruwa Ghat (26° 13´ N; 91° 46´ E) (Table-1) with 6 - 8 numbers of eggs per nest (Baruah *et al.*, 2010).

The present field survey has identified following potential habitats of *Pangshura species* in Assam, India i.e.

Nameri National Park, beel near Beseria village, near Gabharu river, Gahigaon wetland, Gohpur wetland of Sonitput district of Assam., Kaziranga National Park. *P. sylhetensis* is now found only in a few protected areas, including the Kaziranga, Nagaon and Nameri National Parks in the Brahmaputra River basin. The survey records of the year, 2009 demonstrated about the increased numbers of *P. sylhetensis* in the Jia Bharali River (Nameri National Park), Biswanath Ghat, Gomirighat and Kuruwa Ghat areas, probably due to the habitat conservation in protected areas (Sarma *et al.*, 2009).

Biogeography note on endangered P. sylhetensis

P. sylhetensis is one of the Asia's most endangered Freshwater Turtles (IUCN, 2007). *P. sylhetensis* was described by Jerdon, 1870, based on three syntypes that were deposited in the British Museum (Natural History), from the Khasi Hills of Sylhet District (at present in Bangladesh). Subsequently, Gray (1870) transferred the taxon to a new monotypic genus, *Jerdonella,* but Boulenger (1889) transferred it to the broad genus *Kachuga*. Moll (1986, 1987) revived *Pangshura* as a subgenus for this and several others small turtles that were still allocated to *Kachuga*. More recently, this species and its relatives have been reallocated to its original genus, *Pangshura* (Das 2002; Spinks *et al.*, 2004).

Moll (1986) had reported *Pangshura sylhetensis* (Jerdon, 1870) from Cherrapunji (Khasi hills) and Garo hills of Meghalaya, Cachar dist. of Assam. Choudhury (1995a,b) reported the new locality of *Pangshura sylhetensis* (Jerdon, 1870) in Sadiya, subdivision of Tinsukia district, Kolathua village of Sibsagar district, Assam. Choudhury *et al.* (1997) described the distribution of *P. sylhetensis* (Jerdon, 1870) in Assam. Praschag and Fachbach (2001) reported *P. sylhetensis* from Nameri National Park of Assam, India. Availability of the species in various location of the Northeastern region has been reported (Tikadar and Sharma 1985; Chaudhury, 1995a; Choudhury *et al.*, 1997). The species was collected from Manas National Park by Sarma from the Rupahi Bhumuk (Sarma, 2007; Sarma *et al.*, 2009), a perennial stream.

CONCLUSION

The present study revealed that 11 pairs of marginal shields are present in *P. tecta, P. tentoria and P. smithii*. However, *P. sylhetensis* posses 13 pairs of marginal shields with strongly serrated posterior marigin in the carapace. Distinct sexual dimorphism has been observed wihin the genus *Pangshura*, where males are smaller than females and posses relatively longer tails with thicker bases. The size of an adult female *P. sylhetensis* could be around 20.5 cm. The present study for the first time diagrametically represented the plastral formula of the *Pangshura* genus.

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