Differences in hatching success between nests having northern, southern, and western slope orientations suggests that the exposure influences development and survival of the embryo, but the nest temperatures in the three orientations were not significantly different. There were some differences in nest temperatures in different slope orientations but lack of statistical significance could be due to insufficient samples. There was no increase in nest temperatures after a period of low and fluctuating temperatures and this might cause intermittent development of the embryo (Ewert, 1984). After the month of May, the nest temperatures exceeded 35°C and such heat is not conducive for development of the embryo; the optimal period for development would have been between March and May. The increase in number of NDE/IF eggs in nests 6 and 10 (Table 3) suggests that disturbance of the eggs could have adverse effects on further development. In southern facing nests the numbers of welldeveloped but dead embryos were high (Table 3), probably due to high temperatures experienced by these eggs during incubation. The yolk volume remaining in dead hatchlings was greater than that in live hatchlings. It could be inferred that the embryos died well before hatching and that the fullydeveloped embryo aestivates, using some of the yolk reserves until hatching. Soil moisture varied considerably in the nests during the incubation period. During summer, low soil moisture could have caused mortality of embryos by desiccation.

Hatching, even of nests laid at different times, took place simultaneously when there were rains after summer in July. It is probable that moisture acts as a "hatching releaser." Results from the locomotion study suggest that hatchlings orient themselves by the gradient of the substrate, moving downwards until they reach water. Thus, nesting on slopes (banks) would be advantageous to the hatchlings. Hatchlings that had to make a long journey to the river took intermittent refuge under bushes and cracks in the soil; when water flowed during subsequent rains they were swept into the river.

From this study it would be reasonable to recommend protection of nests in order to increase hatching success in the wild population, since predation of nests is high. These measures may be taken to augment the natural population in the wake of large scale collection of nests for re-introduction programs.

Acknowledgments. — I thank WWF - India for providing me a honorarium through the Conservation Corps Volunteer (CCV) program and J.W. Lang for financial support through the "Reptile Egg and Incubation Project." My heartfelt thanks to D. Basu and other staff of the Uttar Pradesh Forest Department for their help. Thanks are also due to H. Andrews, I. Das, and R. Whitaker for their encouragement.

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Received: 28 August 1997 Reviewed: 26 April 1998 Revised and Accepted: 30 May 1998

> Chelonian Conservation and Biology, 1998, 3(1):99-102 © 1998 by Chelonian Research Foundation

Morphometrics of the Fossil Box Turtle, *Terrapene innoxia* Hay 1916, from Florida

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The fossil turtle species *Terrapene innoxia* was described by Hay (1916) from a series of shell elements collected by E.H. Sellards from Wisconsin (Rancholabrean) Pleistocene deposits at "Vero, St. Lucie County, Florida" (the site is actually in Indian River County). The series consists of a complete carapace, the holotype (Florida Geological Survey [FGS] 7080, now United States National Museum of Natural History, Smithsonian Institution [USNM] 8824), a second almost complete carapace (FGS 7079), several carapacial fragments (FGS 7081–84), and two plastral elements (FGS 5471, 7085). Hay's (1916) description of *T. innoxia* was vague and barely separates it from other North American box turtles: "Carapace thin, relatively narrow, highest at middle of length, sloping hardly more rapidly backward than forward; nuchal bone not excavated; hinder

peripherals little or not at all flared outward; vertebral scutes of moderate width; hinder marginal scutes of moderate height." Further, the only taxon to which Hay compared T. innoxia was the extant subspecies T. carolina major (Agassiz, 1857), the Gulf Coast box turtle, which presently ranges along the west coast of Florida and is not found near the east coast type locality of T. innoxia (Conant and Collins, 1991; Ernst and McBreen, 1991). Why Hay did not compare T. innoxia with T. carolina bauri Taylor, 1895, the Florida box turtle, which presently occurs throughout the eastern half of peninsular Florida (Ashton and Ashton, 1985; Iverson and Etchberger, 1989; Conant and Collins, 1991; Ernst and McBreen, 1991) is not known. However, Auffenberg (1958), in discussing differences between T. innoxia and several taxa of larger fossil Terrapene, was under the opinion that Hay had used modern specimens of populations now assigned to T. c. bauri.

The first revision of *T. innoxia* was by Barbour and Stetson (1931) who placed it in the synonymy of the fossil species *T. canaliculata* Hay, 1907 (Type locality: Whitemarsh Island or Skedaway Island, Chatham County, Georgia) on the basis of its carapacial shape and small size, believing it could only be regarded as the young of the latter taxon. Milstead (1956) accepted this view, and placed *T. innoxia* in the synonymy of *T. canaliculata* without further examination of the problem, but Auffenberg (1958) relegated *T. innoxia* to the synonymy of *T. c. bauri* on the basis of its small size, lack of an axillary scute, carapace shape, slightly less excavated nuchal bone at the anterior rim, and welldeveloped nuchal scute. Milstead (1969) and Ernst and McBreen (1991) also listed *T. innoxia* as a primary synonym of *T. c. bauri*, agreeing with Auffenberg (1958).

The above studies presented no quantitative data for synonymizing *T. innoxia* with other taxa of *Terrapene*, although Milstead (1956) and Auffenberg (1958) alluded to having made such comparisons. In this study we statistically compare the holotype and 17 additional fossil specimens of *T. innoxia* (Florida Museum of Natural History [UF] 248, 2106, 2618, 2627, 1640-46, 1648, 1655, 1663, 1700, 1704, 1709), with 102 specimens of extant *T. c. bauri* from the USNM collection, including the holotype, USNM 8352. Measurable data from FGS 7079 listed by Hay (1916) was also used in the comparisons.

Methods. - Straight-line measurements of the following characters were taken with dial calipers accurate to 0.1 mm on all specimens of T. c. bauri, and as many as possible of the same characters were measured on fossil specimens of T. innoxia, a number of which were incomplete: 1) greatest carapace length, 2) carapace width and height at the level of the seam separating vertebrals 2 and 3, 3) marginal width [the difference between the carapace width and the width across the costals taken between the points of juncture of the marginal and costal scutes at the level of the seam between vertebrals 2 and 3], 4) greatest length and width of the nuchal scute and the five vertebral scutes, 5) greatest plastron length, 6) greatest length and width of both plastral lobes, 7) least bridge length, and 8) lengths of all plastral scutes along their medial seams. Notes were also recorded as to the point of greatest carapace height and width, the condition of the median vertebral keel, the slope of the posterior portion of the carapace, and whether or not the posterior marginals were flared.

Carapace variation was assessed by a principal components analysis (PCA) of the variance-covariance matrix of carapace length, carapace width, carapace height, and the lengths and widths of vertebrals 1–5. Our PCA was limited to the carapace measurements listed above so as to include the greatest number of measurements without excluding fossil specimens of *T. innoxia* because of missing observations. Bivariate plots with 75% confidence ellipses were made for characters that contributed at least 10% of the total variance to the first principal component. The mean of x and y for *T. c. bauri* and *T. innoxia* is shown in each bivariate plot as the intersection of the standard error bars for each of the plotted variables.

Results and Discussion. — Milstead (1969) reported that the lateral carapacial shape of *T. c. bauri* separates it from all other *Terrapene*, and described the carapace as elongated and highly vaulted posteriorly. The greatest height and width occur well behind both the bridge and the midpoint of the carapace, giving an overall impression of a turtle with its bulk badly skewed to the rear. The posterior marginals are flared and somewhat recurved. The holotype of *T. innoxia* (USNM 8824), a complete carapace, closely matches this description, as do the complete carapaces of UF 278,

Table 1. Measurements (in m	m) of shell characters for T. innoxia and	T. c. bauri (n. mean, standard	deviation [SD] and range [Min_Ma	x De
CH = carapace height, CL = ca	rapace length, CW = carapace length, V11	L-V5L = length of vertebrals 1	-5, V1W–V5W = width of vertebrals 1	1-5.

	Terrapene innoxia			Terrapene carolina bauri						
Character	n	Mean	SD	Min	Max	n	Mean	SD	Min	Max
CH	8	50.69	6.31	41.5	61.1	80	65.67	6.48	44.3	77 7
CL	8	125.60	5.23	118.4	135.8	88	131.97	13.86	82.7	165.7
CW	7	86.97	4.80	80.8	93.7	88	92.26	10.37	58.5	115.0
VIL	9	25.92	2.54	22.0	29.7	85	26.96	3.17	19.5	35.2
V1W	11	25.73	2.59	22.9	32.0	85	25.77	3.66	17.0	30 3
V2L	7	29.06	3.86	25.6	37.0	77	29.56	3 38	18.0	36.6
V2W	7	31.67	3.47	26.9	38.2	76	33.10	3.46	25.3	40.6
V3L	7	28.44	3.71	23.1	33.9	74	28.75	3 50	18.2	35.4
V3W	7	36.70	3.62	32.0	40.7	73	37.27	3.79	26.5	46.4
V4L	9	33.00	4.60	25.2	40.0	76	32.69	1.07	10.1	40.4
V4W	9	29.12	4.59	24.1	35.6	76	33.12	4.97	24.2	45.0
V5L	11	23.41	4.07	17.7	30.4	80	23.34	3.20	12.0	40.2
V5W	11	29.02	3.32	22.5	35.2	81	30.87	4 09	19.6	33.5

Table 2. Coefficients of the first four principal components (PC I - IV) for seven measurements taken on *T. c. bauri* (n = 70) and *T. innoxia* (n = 7) (see Table 1 for character abbreviations).

Character	PC I	PC II	PC III	PC IV
CL	0.742686	-0.408336	-0.505673	-0.071708
CW	0.527668	-0.022382	0.821826	-0.190393
CH	0.309601	0.897381	-0.201407	-0.066585
V1W	0.111916	-0.017148	0.147076	0.901331
VIL	0.119369	0.084063	-0.032786	0.302622
V5W	0.182613	0.137777	0.003198	0.065610
V5L	0.118367	0.033547	-0.074938	0.214227
% Variation	80.4	7.7	5.0	2.7

1640, 1642, 1645, and 1648. On the basis of carapacial shape these specimens of *T. innoxia* may be assigned to *T. c. bauri*, as was done by Auffenberg (1958).

The number of T. c. bauri and T. innoxia examined for each character, and the means, standard deviations, and ranges of the measurements are presented in Table 1. Few specimens of T. innoxia were complete for all carapacial characters measured. However, all of the characters examined are highly correlated to one another and therefore need consideration in the context of the others for comparison. The first component of the PCA can be viewed as a weighted average of the overall body size because all the characters used had a positive sign (Table 2). The signs are both positive and negative in the second component and therefore may be viewed as an index of carapace shape. Carapace height has a high positive loading for component two indicating that individuals with coefficients below zero have a low domed carapace for their overall carapace size. The majority (88%) of the total carapacial variation was explained by the first two components, thus only these two components were plotted. The bivariate plot of the first two components (Fig. 1) shows T. innoxia to have a lower than expected carapace height given its overall body size.

Bivariate plots with 75% confidence ellipses indicate that carapace height of *T. innoxia* plotted as a function of carapace width is well within the expected allometric limits of *T. c. bauri* (Fig. 2A). However, carapace height is much lower than expected for a given carapace width (Fig. 2B) or carapace length (Fig. 2C). The carapace length of *T. innoxia* as a function of carapace width, however, is well within the expected allometric limits of *T. c. bauri* (Fig. 2A).

Our results indicate a difference in shell height between *T. innoxia* and *T. c. bauri*, with *T. innoxia* being more flattened. Since the specimens of *T. innoxia* examined all came from eastern Florida, this difference might not be explained by introgression of genes from the more flattened *T. c. major* population now present in west Florida. Therefore, the referral of *T. innoxia* to the synonymy of *T. c. bauri* is in doubt. Further analysis of variation within *T. c. bauri* and *T. c. major* will be necessary to determine whether *T. innoxia* is distinct enough to warrant taxonomic recognition.

Acknowledgments. — We thank Robert Purdy of the USNM and Marc Frank and Erica Simos of the FU for their permission and help in examining fossil *Terrapene innoxia*.



Figure 1. Plot of first two principal components for characters given in Table 2; *Terrapene innoxia* = *, *T. c. bauri* = \circ .



Figure 2. Bivariate plots of character measurements with 75% confidence ellipses: A. CL vs. CW, B. CH vs. CW, C. CH vs. CL. See Table 1 for abbreviations; *Terrapene innoxia* = *, *T. c. bauri* = \circ .

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Received: 19 September 1997 Reviewed: 26 April 1998 Revised and Accepted: 15 May 1998

> Chelonian Conservation and Biology, 1998, 3(1):102-104 © 1998 by Chelonian Research Foundation

Use of Passive Integrated Transponder (PIT) Tags for Marking Small Freshwater Turtles

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Internally injected passive integrated transponder (PIT) tags have been used in recent studies on a wide variety of animal species, including salmonid fishes (Prentice et al., 1990; McCutcheon et al., 1994; Peterson et al., 1994), crustaceans (Pengilly and Watson, 1994), birds (Elbin and Burger, 1994), and mammals (Thomas et al., 1987; Barnard, 1989; Ball et al., 1991). In amphibian and reptile studies, PIT tags have been used on salamanders (J.A. Ott and D.E. Scott, *pers. comm.*), snakes (Keck, 1994; Jemison et al., 1995), lizards (Germano and Williams, 1993), crocodilians (Dixon and Yanosky, 1993), freshwater turtles (Camper and Dixon, 1988), and sea turtles (Fontaine et al., 1986). Loss incidence of

internally injected PIT tags appears to be low. Reported tag loss has been attributed to inability to detect the tag in large animals (Steyermark et al., 1996) or to faulty implantation (Freeland and Fry, 1995). PIT tag retention of 100% has been reported in pine snakes (*Pituophis melanoleucus*) by Elbin and Burger (1994) and in leatherback turtles (*Dermochelys coriacea*) by McDonald and Dutton (1996).

Internal injection of PIT tags has been successfully implemented with large sea turtles but has not yet received popular application with small freshwater turtles. Although hard-shelled turtles are easily marked for long-term studies by notching carapacial marginal scutes (Cagle, 1939; Gibbons, 1986), the use of PIT tags might have several valuable applications and advantages. Scute notching is remarkably reliable and permanent when used on adult and subadult turtles, but PIT-tagged juveniles could be positively identified upon recapture when the interval in years is large and scute notches difficult or impossible to identify.

Also, if PIT tags could be injected into the body cavity without adverse effects, species that are difficult to mark, such as soft-shelled turtles (Trionychidae), could be better studied. Movement patterns of PIT-tagged turtles could be monitored with remote scanners over frequently used or established routes, such as openings in drift fences or entrances to tortoise (Gopherus spp.) burrows, where a scanner could be positioned within close range of a passing turtle. This technique was employed to study the use of highway culverts by desert tortoises (W. Boarman, pers. comm.) and has been successfully used with other taxa such as fish and mammals (Prentice et al., 1990; McCutcheon et al., 1994; Harper and Batzli, 1996). PIT tags are very useful for longterm marking of captive animals, particularly where physical disfigurement caused by carapacial notching is undesirable (B. Tryon, pers. comm.). Also, there is potential use for PIT tags in wildlife law enforcement and in detecting illegal trafficking of endangered species. Our goal was to determine if PIT tags are suitable for individual identification of small turtles, specifically freshwater emydids.

Methods. - We injected PIT tags (American Veterinary Identification Devices [AVID], Norco, CA) (12 x 2 mm, 0.096 g) into 7 Trachemys scripta elegans ranging in size from 86 to 131 mm plastron length (PL). We chose three injection sites into the inguinal region of the body cavity: A) anteriorly and parallel to the bridge of the shell (n = 3 turtles), B) anteriorly and perpendicular to the spine (n = 2), and C) posteriorly and parallel to the carapace edge (n = 2) (Fig. 1). Due to the small size of our turtles, we did not inject PIT tags into the legs to avoid damage to neurovascular structures and impairment of muscle movement. After cleansing the skin with 70% isopropyl alcohol, we inserted the 12-gauge injection needle swabbed with antibiotic ointment into the body cavity only far enough to puncture the skin and all muscle layers. Following implantation we covered the insertion wound with New Skin Liquid Bandage (Medtech Laboratories, Inc., Jackson, WY). We measured PL to the nearest mm and X-rayed each turtle (Gibbons and Greene, 1978) immediately following implantation on 26 July 1995 (time = T1).