

**Table 2.** Remigration numbers and percentages for loggerheads nesting on Senri Beach in Minabe, Wakayama, Japan.

Year	Identified Females (No.)	Remigrations				
		1991 (No.) (%)	1992 (No.) (%)	1993 (No.) (%)	1994 (No.) (%)	1995 (No.) (%)
1990	50	0	3	4	0	0
		0.0	6.0	8.0	0.0	0.0
1991	60	—	0	11	2	4
			0.0	18.3	3.3	6.7
1992	89	—	—	1	13	9
				1.1	14.6	10.1
1993	114	—	—	—	3	18
					2.6	15.8
1994	76	—	—	—	—	0
						0.0

surveys are needed to quantify this relationship and its possible causes.

Kamezaki et al. (1997) reported on 2219 marked loggerhead turtles from 16 nesting beaches from Ryukyu Archipelago to Shizuoka of Japan, and documented that 37 (1.7%) of these were incidentally captured by fisheries. Nine of these 37 turtles were tagged on Senri Beach in Minabe. The impact of the fisheries industry on the population of loggerheads nesting on Senri Beach, and on other beaches in Japan, is not well investigated, and further quantification of this impact is needed.

**Acknowledgments.**—Nightly patrols over 6 years were facilitated by 96 volunteers. Although we cannot list all of their names here, we would like to express special thanks to all of them. We especially thank F. Fukuhara for tagging many turtles. We are grateful to the Japan Sea Turtle Association for supplying tags and tagging pliers. Information on the incidental recapture of tagged loggerhead turtles was gathered by I. Miyawaki, Kushimoto Marine Park. This work was financially supported by grants from the Ministry of Education, Science, Sports and Culture (No. 05454093) and the Research Fellowships of the Japan Society for the Promotion of Science (JSPS) for Young Scientists (KS, YM, and HT).

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## A Comparison of Plastral Scute Lengths Among Members of the Box Turtle Genera *Cuora* and *Terrapene*

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The turtle shell is one of the most conservative derived vertebrate structures known, having remained substantially unchanged since the Triassic (Romer, 1956, 1966). The arrangement of the epidermal scutes on the shell of turtles belonging to the families Bataguridae and Emydidae is particularly uniform, especially those of the plastron (Cherepanov, 1989), and provides few systematically important variants. However, research by Lovich and Ernst (1989) demonstrated that a great deal of variability occurs in the relative lengths of plastral scutes and plastral formulae in several emydid species. Later research indicated that closely related species could be differentiated from each other, as well as more distant relatives, by using the length relationships of plastral scutes (Lovich et al., 1991).

Several genera of "box turtles" belonging to the families Bataguridae (*Cuora*, *Cyclemys*, *Notochelys*, *Pixidea*,

etc.) and Emydidae (*Emydoidea*, *Emys*, *Terrapene*) occur in different parts of the world; these turtles have a more or less vaulted carapace and a single moveable hinge on the plastron situated between the pectoral and abdominal scutes that allows the two plastral lobes to close the shell. We have chosen to concentrate our studies on two genera of "box turtles" that contain species which are the most superficially similar and that occupy ranges on opposite sides of the globe; the Asian genus *Cuora* (Bataguridae; Gaffney and Meylan, 1988) ranges marginally from the Indian subcontinent and southeastern Asia through Indonesia to Sulawesi and the Philippine Islands, while the North American genus *Terrapene* (family Emydidae) occurs from the northeastern USA southwestward to southern Mexico (Ernst and Barbour, 1989; Ernst and McBreen, 1991). Our objective was to compare the relative lengths of those scutes positioned along the plastral midline and their corresponding plastral formulae of selected species in *Cuora* and *Terrapene*. Similarity of these genera at one time led to confusion and erroneous placement of some relatively vaulted *Cuora* in the genus *Terrapene* (McCoy and Richmond, 1966). The shells of *Terrapene carolina*, *T. ornata*, *Cuora amboinensis*, *C. evelynae*, *C. flavomarginata*, and *C. galbinifrons* in particular, are morphologically very similar. Our hypothesis was that the above species of the two genera would be morphometrically distinguishable using the technique of Lovich et al. (1991) to analyze plastral scute formulae in spite of other superficial anatomical similarities.

**Materials and Methods.** — A total of 783 specimens was examined from various museum collections (BMNH, CAS, HMCZ, CMNH, FMNH, GMU, MNHN, USNM, a list of specimens examined is available upon request from CHE), including the species *Terrapene carolina*, *T. ornata*, *Cuora amboinensis*, *C. evelynae*, *C. flavomarginata*, and *C. galbinifrons*. Island and mainland populations of *C. amboinensis* (corresponding to the subspecies *C. a. kamaroma*, *C. a. amboinensis*, and *C. a. couro* of Rummeler and Fritz, 1991) were analyzed as separate taxonomic entities since unpublished studies by Ernst et al. (in prep.) indicate that *C. a. couro* is synonymous with *C. a. amboinensis*. Straight-line measurements were taken along the midline contacts of the six paired plastral scutes (gular [G], humeral

[H], pectoral [P], abdominal [Ab], femoral [F], and anal [An]) with dial calipers to the nearest 0.1 mm (Table 1).

The plastral scute length data were standardized for carapace length and analyzed separately for males and females. Multivariate normality was verified using chi-square quantile plots (Johnson and Wichern, 1992). A MANOVA was used to determine significant differences between species. The specimens were then classified to predicted taxa using quadratic discriminant function analysis with crossvalidation. Techniques generally followed those of Lovich et al. (1991). The first two canonical variables of a canonical discriminant function were used to generate graphs showing separation of the genera. All statistical analyses were done with SAS software (SAS Institute, 1989). Plastral formulae were also derived from these data and analyzed separately for males and females.

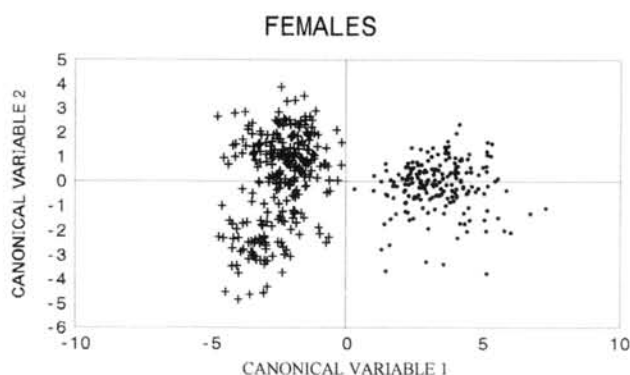
**Results and Discussion.** — Multivariate analysis of variance on females confirmed the difference among the species examined using all six plastral scute measurements simultaneously (Wilks' lambda = 0.036;  $F = 62.97$ ;  $p < 0.0001$ ). The discriminant function correctly classified 80% of the female sample to species (Table 1). Perfect classification was achieved between the species examined within the two genera, as misclassifications occurred only within genera. Within the genus *Terrapene* just over 3% were misclassified, within *Cuora* 43% were misclassified. Separation of genera on the first two canonical discriminant axes is shown in Fig. 1.

Multivariate analysis of variance on males also showed the difference among species using all six plastral scute measurements simultaneously (Wilks' lambda = 0.036;  $F = 42.16$ ;  $p < 0.0001$ ). The discriminant function correctly classified 89% of the male sample to species (Table 2). With one exception, perfect classification was achieved between genera; only a single *T. ornata* was incorrectly classified with the island group of *C. amboinensis*. Slightly fewer than 3% of the male *Terrapene* were misclassified, while 22% of the male *Cuora* were misclassified. Separation of taxa on the first two discriminant axes is shown in Fig. 2.

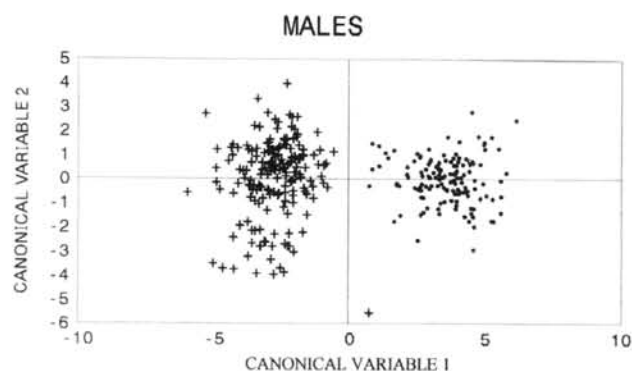
The fact that the analysis resulted in almost perfect separation of these members of the two genera is interesting given their apparently similar plastral morphology. We conclude that in spite of the influence of plastral anatomy,

**Table 1.** Classification of female turtles, based on plastral scute dimensions. Correctly classified individuals in bold numbers.

Actual Taxon	Classified as							Total
	<i>Terrapene</i>		<i>Cuora</i>					
	<i>carolina</i>	<i>ornata</i>	<i>amboinensis</i> (mainland)	<i>amboinensis</i> (island)	<i>evelynae</i>	<i>flavomarginata</i>	<i>galbinifrons</i>	
<i>T. carolina</i>	<b>191</b>	4	0	0	0	0	0	195
<i>T. ornata</i>	5	<b>69</b>	0	0	0	0	0	74
<i>C. amboinensis</i> (mainland)	0	0	<b>0</b>	11	1	0	0	12
<i>C. amboinensis</i> (island)	0	0	5	<b>90</b>	6	10	2	113
<i>C. evelynae</i>	0	0	0	10	<b>6</b>	2	0	18
<i>C. flavomarginata</i>	0	0	2	24	1	<b>15</b>	1	43
<i>C. galbinifrons</i>	0	0	0	7	0	2	<b>2</b>	11
Total	196	73	7	142	14	29	5	466



**Figure 1.** Plot of first two canonical variables for females of species groups representing *Cuora* (•) and *Terrapene* (+).



**Figure 2.** Plot of first two canonical variables for males of species groups representing *Cuora* (•) and *Terrapene* (+).

the two genera have significant morphometric differences in their relative plastral scute lengths.

Examination of the corresponding plastral formulae generated by the differences in plastron scute lengths also revealed major differences between the compared species of *Cuora* and *Terrapene* (Tables 3 and 4). Thirty-nine formulae were recorded from the plastron of female *Cuora* and *Terrapene*, of which 34 (87.2%) were not shared across genera. Thirty-six plastral scute formulae were recorded from males of these genera; 33 (91.7%) did not overlap between genera. When combining the plastron formulae of female and male *Terrapene*, 86.8% of the individuals (388 of 447) had one of six formulae: An>Ab>G>P>H>F (146), An>G>Ab>P>F>H (97), An>G>Ab>P>H>F (48), An>Ab>G>P>F>H (40), An>G>Ab>F>P>H (29), and An>Ab>G>H>P>F (28). Similarly, 66.4% of the individual *Cuora* (223 of 336) had one of only four formulae: Ab>An>P>G>F>H (79), An>Ab>P>G>F>H (68), Ab>An>P>G>H>F (44), and An>Ab>P>G>H>F (32). Rummeler and Fritz (1991) reported variation in plastral formulae among populations of *Cuora amboinensis* which they believed to be associated with subspecific variation. This may be correct (see above comment regarding *C. a. couro*), but they did not compare the various island populations of the currently recognized *C. a. amboinensis*. Such comparisons are necessary to assess total subspecific or other variation in this complex. This has been done by Ernst et al. and will be presented in a later paper.

The major differences between the two genera lie in the relative lengths of the gular and pectoral scutes and their positions in the formulae (Tables 3 and 4; Fig. 3). The gular is always one of the three longest scutes in *Terrapene*, but one of the shortest three in *Cuora*; the reverse is true regarding the pectoral (Ernst and Barbour, 1989). Observed intraspecific variation in plastral formulae within *Cuora* may influence current taxonomic designations, and will be addressed in a later paper.

*Cuora* and *Terrapene* are not ecological equivalents in habitat requirements or behavior (CHE, pers. obs.). Neither subspecies of *Terrapene ornata* enter water for extended periods of time, possibly due to a scarcity of water in much of their habitat, and should be considered terrestrial. Individuals of *T. carolina* more readily enter water; however, the subspecies *carolina*, *triunguis*, *mexicana*, and *yucatanensis* should probably be regarded as primarily semiterrestrial. On the other hand, the subspecies *bauri* and *major* require more water than the former four and could be considered semi-aquatic. In fact, *T. c. major* spends considerable time in water, often feeding and mating there (Ernst, 1981), and is the most aquatic *Terrapene* next to the fully aquatic, specialized, Mexican species *T. coahuila* (Ernst and Barbour, 1989).

Of the *Cuora* examined in this study, *C. galbinifrons* and *C. flavomarginata*, and probably also the latter's sister species *C. evelynae* (Ernst and Lovich, 1990), are highly terrestrial (Ernst and Barbour, 1989), usually entering water only to drink or occasionally to soak in extremely hot

**Table 2.** Classification of male turtles, based on plastral scute dimensions. Correctly classified individuals in bold numbers.

Actual Taxon	Classified as							Total
	<i>Terrapene</i>		<i>Cuora</i>					
	<i>carolina</i>	<i>ornata</i>	<i>amboinensis</i> (mainland)	<i>amboinensis</i> (island)	<i>evelynae</i>	<i>flavomarginata</i>	<i>galbinifrons</i>	
<i>T. carolina</i>	<b>146</b>	2	0	0	0	0	0	148
<i>T. ornata</i>	3	<b>26</b>	0	1	0	0	0	30
<i>C. amboinensis</i> (mainland)	0	0	<b>0</b>	4	1	0	0	5
<i>C. amboinensis</i> (island)	0	0	0	<b>104</b>	1	2	0	107
<i>C. evelynae</i>	0	0	0	9	<b>1</b>	0	0	10
<i>C. flavomarginata</i>	0	0	0	9	0	<b>4</b>	0	4
<i>C. galbinifrons</i>	0	0	0	3	0	1	<b>0</b>	4
Total	149	28	0	130	3	7	0	317

**Table 3.** Ratio of plastral scutes to plastron length for females of the taxa examined.

Taxa	Plastral Scute					
	G	H	P	Ab	F	An
<i>T. carolina</i>	0.186	0.089	0.127	0.203	0.068	0.328
<i>T. ornata</i>	0.222	0.055	0.134	0.172	0.120	0.297
<i>C. amboinensis</i> (mainland)	0.173	0.054	0.193	0.261	0.069	0.251
<i>C. amboinensis</i> (island)	0.170	0.053	0.206	0.260	0.061	0.249
<i>C. evelynae</i>	0.160	0.049	0.207	0.273	0.051	0.260
<i>C. flavomarginata</i>	0.160	0.060	0.205	0.251	0.065	0.258
<i>C. galbinifrons</i>	0.160	0.078	0.201	0.253	0.072	0.236

weather (CHE, pers. obs.). *Cuora amboinensis*, however, is much more aquatic and spends considerable time in water, particularly to feed, sleep, or migrate, and possibly to mate. In this respect it more closely resembles the North American wood turtle, *Clemmys insculpta*, in its behavior (Ronald I. Crombie, pers. comm.). Another major difference between the two genera is the period of daily activity. *Terrapene* species are almost exclusively diurnal except for nesting females, while *Cuora amboinensis*, *C. flavomarginata*, and *C. galbinifrons* are often active at night (CHE, pers. obs.).

Plastral kinesis, or the ability to flex the plastron, has evolved independently in several lineages apart from the two

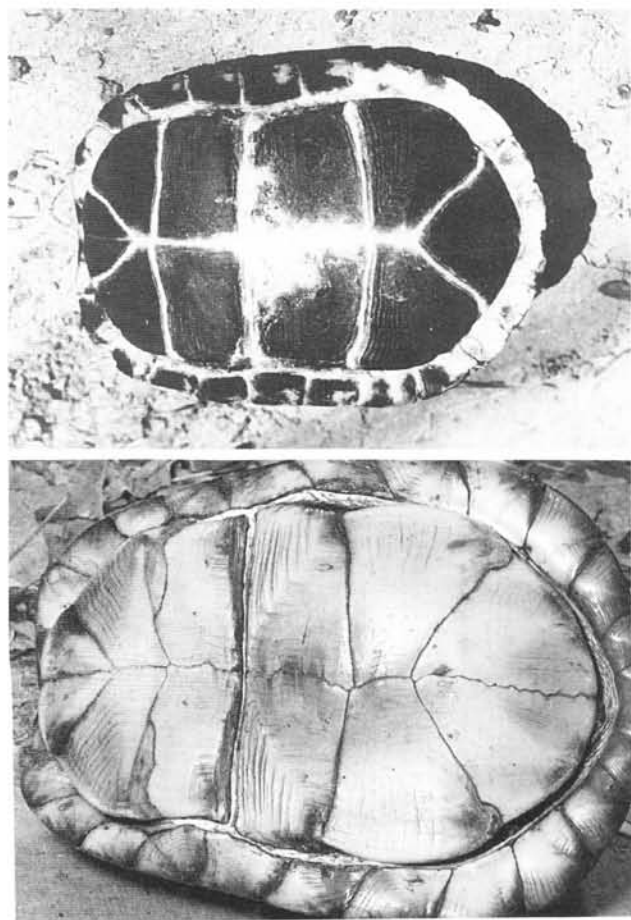
**Table 4.** Ratio of plastral scutes to plastron length for males of the taxa examined.

Taxa	Plastral Scute					
	G	H	P	Ab	F	An
<i>T. carolina</i>	0.187	0.088	0.129	0.196	0.072	0.326
<i>T. ornata</i>	0.220	0.060	0.131	0.174	0.131	0.284
<i>C. amboinensis</i> (mainland)	0.187	0.048	0.194	0.241	0.065	0.264
<i>C. amboinensis</i> (island)	0.175	0.054	0.213	0.245	0.067	0.246
<i>C. evelynae</i>	0.170	0.049	0.203	0.271	0.056	0.251
<i>C. flavomarginata</i>	0.163	0.069	0.196	0.240	0.071	0.261
<i>C. galbinifrons</i>	0.148	0.070	0.212	0.252	0.083	0.236

genera examined (Bramble, 1974; Ernst and Barbour, 1989). In Asian *Cuora*, closure of the anterior plastral lobe is controlled by the hypertrophied testoscupularis muscle. The scapulo-carapacial articulation is modified to allow dislocation of the joint during shell closure, thus accommodating displacement of the pectoral girdle as the shell is closed (Bramble, 1974). In contrast, in American *Terrapene* a portion of the main cervical retractor muscle raises the anterior end of the plastron and a segmented scapula permits effective accommodation of the pectoral girdle (Bramble, 1974). These architectural differences are reflected in the bony structure of the plastron and may be translated into the lengths of the epidermal scutes.

John B. Iverson (pers. comm.) has suggested an interpretation of the differences in the plastral formulae in relation to the hinge-closing arrangement in the two species. His interpretation of the long interpectoral seam is as follows. In *Cuora* the force (i.e., the pull) generated to close the plastral forelobe is exerted via the acromion process which is connected by a ligament to the entoplastron. In *Terrapene*, a significant part of the force (pull) generated to close the plastral forelobe is exerted via the cervico-plastral ligament, which is attached to the epiplastra (much farther anterior on the forelobe). Thus in *Cuora*, the tug is on the entoplastron, whereas in *Terrapene* it is on the epiplastra. Under this arrangement, it would be logical to expect a strengthening of the ento-hyoplastral suture in *Cuora* to prevent the chance of buckling of that suture during closing, but to expect a strengthening of the interepiplastral suture and the anterior epi-entoplastral suture in *Terrapene* to prevent buckling in the more anterior part of the plastral forelobe during closing. The functional, or adaptive, significance of the large pectoral scutes in *Cuora* may thus simply be to strengthen the ento-hyoplastral connection in that genus, whereas the larger gular scutes of *Terrapene* may simply strengthen the sutures among the epiplastra and the entoplastron.

In conclusion, the results of analysis of variation in the relative plastral scute lengths and plastral formulae of turtles of the genera *Cuora* and *Terrapene* are congruent with phylogenetic hypotheses based on the separate evolution of other characters (Bramble, 1974; Gaffney and Meylan, 1988) in the presence of superficially striking morphological similarities. Although the two genera may have converged in several ways, they have not done so in plastral formulae.

**Figure 3.** Plastra of *Cuora galbinifrons* (top) and *Terrapene carolina* (bottom).



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## An Ecotourism Initiative to Increase Awareness and Protection of Marine Turtles in Brazil: the Turtle by Night Program

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The Brazilian Sea Turtle Conservation Program (TAMAR) was founded in 1980. Its main goal has been to protect sea turtle populations along the coast by trying to stop the slaughter of nesting females and egg poaching as well as accidental capture in fishing gear. It is affiliated with the Brazilian Environmental Agency (IBAMA) and co-managed by Fundação Pró-TAMAR, an NGO. Local fishermen, who used to hunt turtles, were hired to patrol the nesting areas and feeding grounds. Throughout the years, TAMAR has raised the awareness of local people for endangered sea turtles and developed new, alternative sources of income for coastal communities. Each of the 22 stations of TAMAR has its own characteristics and particular community-based conservation work. One example is the pioneering work in the states of Espírito Santo and Sergipe, where TAMAR has helped organize women's groups for making handicrafts, such as embroidery and T-shirts with sea turtle motifs. Today, around 30% of TAMAR's budget comes from the sale of its products. Integrating local villagers into TAMAR's work also helps spread the message of conservation to neighboring villages and to tourists who visit some of its stations.

TAMAR also raises funds and awareness for conservation of Brazilian marine turtles through its Sea Turtle Adoption Campaign. By "adopting" a sea turtle for US \$50 people can give one more hatchling the opportunity to reach the safety of the sea. Adopters receive an exclusive T-shirt, an adoption certificate, and a participation sticker. Another attractive aspect of the campaign is that participants enter a special raffle that provides a one-week trip for two to Praia do Forte or to Fernando de Noronha Archipelago, with air tickets sponsored by Varig, the Brazilian Airlines, along with food and hotel accommodations.

TAMAR's National Headquarters is based at Praia do Forte beach (12°34' S, 38°00' W), on the northeastern coast of Brazil, 80 km north of Salvador, Bahia (Marcovaldi and Laurent, 1996). Praia do Forte beach has become, during the past 10 years, a major tourist beach, receiving many visitors, especially during the high season summer months of December to February.

At Praia do Forte, where ecotourism is becoming a common activity, adopters have the option of choosing