



Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Short communication

Market turtle mystery solved in Vietnam

Tri Ly^a, Huy Duc Hoang^a, Bryan L. Stuart^{b,*}^a Faculty of Biology, University of Science-Ho Chi Minh City, 227 Nguyen Van Cu Street, District 5, Ho Chi Minh City, Vietnam^b North Carolina Museum of Natural Sciences, 11 West Jones Street, Raleigh, NC 27601, USA

ARTICLE INFO

Article history:

Received 20 January 2011

Received in revised form 4 March 2011

Accepted 8 March 2011

Available online xxx

Keywords:

Asian turtle crisis

Cuora picturata

Market species

Overharvesting

Wildlife trade

ABSTRACT

Asian turtles are overharvested for food, medicinal purposes and pets, and most species are now at risk of extinction ('Asian turtle crisis'). As a result of high levels of trade, some species of Asian turtles are known to science mostly or only from animals found in trade. The Vietnamese box turtle (*Cuora picturata*) was described in 1998 and is known only from markets. This species is likely to be highly threatened, and identifying the origin of this "market species" is imperative if it is to be conserved. We used evidence from phylogeny, biogeography and trade patterns to focus field searches for this species, and in July 2010–January 2011 found it in the wild at three localities on the Langbian Plateau of southern Vietnam. This discovery provides the first opportunity to conserve the Vietnamese box turtle, and provides hope for determining the wild origin of other rare Asian turtles that remain known only from commercial trade.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

Turtles are harvested and traded throughout Asia for food, traditional medicine and pets (Compton, 2000). The demand for turtles, especially strong in China, now threatens the majority of Asian species with extinction in the wild (IUCN Red List of Threatened Species, 2010), a phenomenon known as the 'Asian turtle crisis'. The volume of this trade is very high (van Dijk et al., 2000; Cheung and Dudgeon, 2006; Gong et al., 2009; IUCN/SSC Tortoise and Freshwater Turtle Specialist Group, 2010), and although difficult to quantify, a minimum estimate of 13,000 metric tons of live turtles (equal to millions of individuals) are annually exported from South and Southeast Asia to China to meet demand (van Dijk et al., 2000).

The conspicuousness of turtles in markets, in contrast with the difficulty of finding turtles in the wild, means scientists know some Asian species mostly or only from animals observed in commercial trade (Parham et al., 2004). One case is that of the Vietnamese box turtle *Cuora picturata*, described to science in 1998 based on turtles obtained from markets in southern Vietnam (Lehr et al., 1998). Scientists have never observed *C. picturata* in the wild, and its origin remains unknown.

Some poorly known Asian turtles that were recently described as new species on the basis of trade animals have since been shown to be only recent hybrids of better known species, including inter-generic hybrids (Parham et al., 2001; Dalton, 2003; Stuart

and Parham, 2007). Some of these hybrids have a wild origin (Shi et al., 2005), while others originated from farming operations (where parental species are co-housed) that supply the Chinese turtle trade (Parham and Shi, 2001; Parham et al., 2001; Shi et al., 2008). Unlike such hybrids, *C. picturata* represents a unique evolutionary lineage that is genetically (Stuart and Parham, 2004; Spinks and Shaffer, 2007) and morphologically (Lehr et al., 1998; Stuart and Parham, 2004; Fritz et al., 2006) distinct from all other turtles, and hence is considered a valid species with a wild, but unknown, origin.

Cuora picturata may already be nearing extinction because it probably has a relatively small geographic range (given that it has never been encountered in the wild by scientists) and it, like other members of the genus *Cuora*, is in high commercial demand (Hendrie, 2000; Cheung and Dudgeon, 2006; Spinks et al., 2009; IUCN Red List of Threatened Species, 2010). Because the provenance of *C. picturata* is unknown, conservationists can rely only on captive-breeding of trade animals to ensure its persistence. However, these efforts are futile without knowing where captive-propagated turtles could eventually be re-established in the wild, and may be compromised by genetic admixture of animals obtained from trade (Fong et al., 2007). Clearly, identifying the wild origin of this "market species" is imperative to conserving it.

Most turtle biologists have assumed that *C. picturata* comes from somewhere in southern Vietnam or adjacent Cambodia based on its appearance in markets in southern Vietnam (e.g., Lehr et al., 1998; Stuart and Parham, 2004; Fritz et al., 2006). We used evidence from phylogeny, biogeography, and commercial trade patterns to narrow our field searches for this species to the Langbian Plateau of southern Vietnam. Molecular phylogenetic

* Corresponding author. Tel.: +1 919 733 7450; fax: +1 919 715 2294.

E-mail address: bryan.stuart@ncdenr.gov (B.L. Stuart).

analyses confirmed that *C. picturata* is evolutionarily most closely related to the morphologically similar Indochinese box turtle *C. galbinifrons* and Bourret's box turtle *C. bourreti* (Stuart and Parham, 2004; Spinks and Shaffer, 2007). *Cuora galbinifrons* and *C. bourreti* occur in upland, moist, closed canopy forest elsewhere in Vietnam, Laos and China, and we assumed that *C. picturata* occupies habitat similar to that of its closest relatives. Although turtles traded in markets in Vietnam come from a large geographic area, including the neighboring countries of Cambodia and Laos (Stuart et al., 2000), and market localities can be very distant from actual localities (Parham and Li, 1999), the Langbian Plateau is the most proximate locality to southern Vietnamese markets having upland, moist, closed canopy forest. Last, two primate clades, *Hylobates* gibbons and *Pygathrix* douc langurs, each have two species that co-occur with *C. galbinifrons* and *C. bourreti* in the northern and central Truong Son Mountains, with a third primate species occurring at the southern end of these mountains in the vicinity of the Langbian Plateau (Fooden, 1996; Groves, 2001; Stuart and Parham, 2004; Fig. 1). *Cuora picturata* and the southern species of gibbon and douc langur are concordant in being the sister taxon to a clade containing their central and northern relatives (Garza and Woodruff, 1992; Roos and Nadler, 2001; Stuart and Parham, 2004; Spinks and Shaffer, 2007), a pattern that may be explained by co-distributed taxa having shared responses to diversification factors in the landscape. Herein, we report the discovery of this “market species” in the wild, the essential first step in its conservation.

2. Materials and methods

Field surveys were carried out during 5–9 July 2010, 20–24 September 2010, and 6–10 January 2011 in forest at three localities in Khanh Hoa and Phu Yen Province, on the Langbian Plateau, Vietnam (Table 1). The field team consisted of one of us (TL), three

local villagers, and three dogs owned by the villagers that were skilled at finding wildlife, including turtles. Dogs are commonly used by hunters in Southeast Asia, and are more efficient than humans at locating terrestrial turtles (Stuart and Timmins, 2000; Platt et al., 2001b, 2003b, 2007). The joint human-canine team conducted surveys during the day from approximately 0730–1600 h by walking through forest and actively searching for turtles. The dogs tracked turtles by scent, and barked when they were located. Turtles were photographed, measured, and released at the site of capture.

3. Results and discussion

Eight *C. picturata* (three males, four females, and one unsexed juvenile) were found at the three surveyed localities in Khanh Hoa and Phu Yen Provinces on the eastern slopes of the Langbian Plateau in southern Vietnam (Fig. 1, Table 1, Appendix A). All were located by the dogs on the floor of broadleaf evergreen mixed with bamboo forest between 368 and 561 m elevation (Fig. 1, Table 1, Appendix A). The turtles were identified as *C. picturata* on the basis of having a highly domed carapace in adults, unpatterned anterior marginals, a wide brown band on the pleurals near to the marginals (rubbed off in some individuals), a plastron with black blotches, and yellow soft parts (Lehr et al., 1998; Stuart and Parham, 2004; Fig. 1; Appendix A).

The wild discovery of *C. picturata* on the Langbian Plateau of southern Vietnam provides the first opportunity to conserve these threatened turtles. Unfortunately, large areas of forest on the plateau are being rapidly converted to coffee plantations and other agricultural lands, and local residents harvest and sell the species to commercial traders. Only one of the three localities that was found to harbor *C. picturata* is currently protected (Deo Ca Protected Forest; Table 1). The Langbian Plateau is the site of one of the earliest herpetological expeditions to Vietnam (Smith, 1921), but the

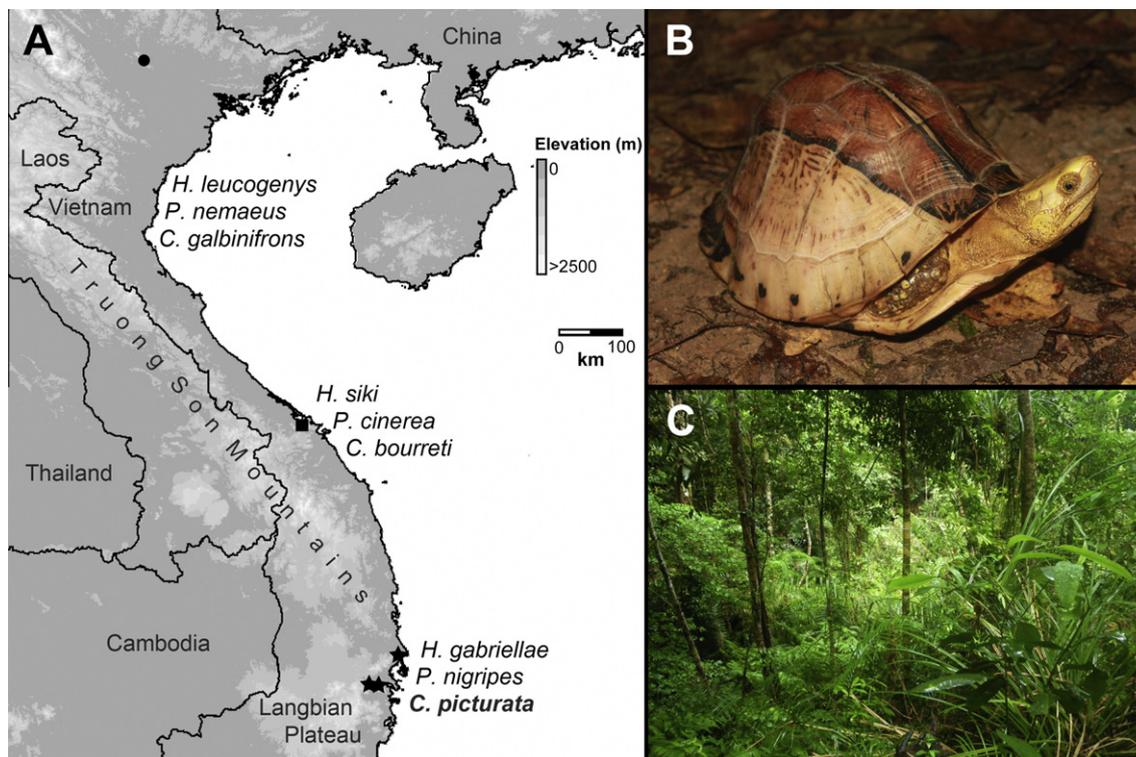


Fig. 1. (A) Map illustrating the north–south geographic partitioning of *Hylobates* gibbons, *Pygathrix* douc langurs, and *Cuora* box turtles, with the first localities of wild *C. picturata* (stars) and the type localities of its closest relatives, *C. bourreti* (square) and *C. galbinifrons* (circle); (B) a wild adult female *C. picturata* found 7 July 2010; and (C) its habitat on the Langbian Plateau, Khanh Hoa Province, Khanh Vinh District, Vietnam.

Table 1
Capture data on the Vietnamese box turtle, *Cuora picturata*, found in the wild in 2010–2011 in Vietnam.

Measurement	Individual							
	1	2	3	4	5	6	7	8
Date	5 July 2010	7 July 2010	22 September 2010	22 September 2010	22 September 2010	22 September 2010	7 January 2011	7 January 2011
Time (h)	1347	0940	1020	1023	1030	1440	0915	0950
Province	Khanh Hoa	Khanh Hoa	Khanh Hoa	Khanh Hoa	Khanh Hoa	Khanh Hoa	Phu Yen	Phu Yen
District	Khanh Vinh	Khanh Vinh	Khanh Vinh	Khanh Vinh	Khanh Vinh	Khanh Vinh	Dong Hoa	Dong Hoa
Commune	Khanh Dong	Khanh Dong	Khanh Hiep	Khanh Hiep	Khanh Hiep	Khanh Hiep	Hoa Xuan Nam	Hoa Xuan Nam
Protected area	None	None	None	None	None	None	Deo Ca protected forest	Deo Ca protected forest
Coordinates (WGS84)	12°24'11.55"N 109°00'33.68"E	12°23'44.57"N 109°01'46.16"E	12°26'26.88"N 108°53'54.37"E	12°26'26.98"N 108°53'54.52"E	12°26'28.49"N 108°53'53.60"E	12°26'21.51"N 108°53'27.23"E	12°51'14.25"N 109°18'31.37"E	12°51'05.84"N 109°18'30.87"E
Elevation (m)	437	561	423	422	430	368	449	484
Weather	Dry, sunny	Light rain, cloudy	Dry, sunny	Dry, sunny	Cloudy	Dry, sunny	Cloudy	Cloudy
Microhabitat temp. (°C)	30.3	25.8	26.9	26.4	28	28.7	21.4	21.4
Microhabitat humidity (%)	80.5	92.4	90.2	95	90.8	90.8	89.5	90.1
Microhabitat	Under dry leaf litter at base of rattan bush on hill slope (~30°)	On moist forest floor among tree seedlings and a large rock, at base of decaying 30-m hardwood tree	On moist forest floor with sandy substrate among small trees on hill slope (~45°)	On moist forest floor under rock ledge on hill slope (~45°), ~1 m away from No. 3	On moist forest floor with sandy substrate under rattan bush, ~50 m away from Nos. 3 and 4	On moist forest floor with sandy substrate under rattan bush	On wet forest floor among tree seedlings and rocks at base of a 7-m hardwood tree on hill slope (~30°)	On wet forest floor at base of a 6-m palm tree on hill slope (~30°)
Sex	Female	Female	Female	Male	Male	Male	Unsexed juvenile	Female
Carapace length (mm)	157.0	176.3	169.9	168.8	167.7	170.7	86.6	145.1
Carapace width (mm)	120.1	135.0	128.1	123.1	130.1	133.9	75.4	110.80
Weight (g)	690	970	835	885	830	920	100	430
Plastral growth rings (No.)	20	22	20	Worn	20	20	6	9

plateau has received minimal herpetological attention since, and no focused field surveys for turtles have been conducted there prior to ours. Additional field surveys on the plateau are needed to determine whether *C. picturata* occurs within any additional established protected areas that will safeguard it from deforestation and over-harvesting, and if not, what can be done to mitigate its extinction in the wild. *Cuora picturata* is readily harvested with the assistance of hunting dogs but difficult to find without them, and effective *in situ* conservation management of this species will require curbing the use of hunting dogs within its habitat. Publishing detailed localities for commercially valuable species can inadvertently facilitate their exploitation (Stuart et al., 2006), but trade networks are already established for *C. picturata* at their confirmed localities and are unlikely to be affected by this report.

The discovery of a persisting population of *C. picturata* in the wild offers some hope in the 'Asian turtle crisis.' The dire conservation status of most Asian turtle species (IUCN Red List of Threatened Species, 2010) may tempt conservationists to give up on finding and protecting Asian turtles in the wild, and instead rely on captive-breeding to keep them extant. However, field surveys still yield rare Asian turtles (Platt et al., 2001a,b, 2003a,b,c, 2010; Diesmos et al., 2004), and as we have demonstrated, even when it is uncertain where to look. Three other species of very rare Asian box turtles, Zhou's box turtle *C. zhoui*, McCord's box turtle *C. mccordi*, and the Yunnan box turtle *C. yunnanensis*, are found in commercial trade in China but remain unknown in the wild (Parham and Li, 1999; Parham et al., 2001, 2004; Zhou and Zhao, 2004). Like *C. picturata*, both *C. zhoui* and *C. mccordi* are known to science only from animals obtained in trade (Parham et al., 2001). A reported provenance for *C. mccordi* based solely on interviews of turtle hunters and traders (Zhou et al., 2008) is unreliable without field observations given that traders are motivated to hide localities of commercially valuable turtles (Parham and Li, 1999; Parham et al., 2001). *Cuora yunnanensis* was known only from 12 museum specimens that were obtained by natural history dealers prior to 1908 in Yunnan, southern China (Parham et al., 2004), and was considered extinct until it reappeared in trade in 2004 (Zhou and Zhao, 2004; Zhou, 2005). It is hoped that focused field efforts such as ours will soon identify the mysterious origins of these other rare species that are known to scientists only by turtles bearing price tags.

Acknowledgements

Permission for fieldwork was provided by the University of Science-Ho Chi Minh City and the local authorities of Khanh Dong, Khanh Hiep, and Hoa Xuan Nam Communes and Deo Ca Protected Forest. The project benefited from the assistance of Le Thi Thuy Duong, Phung Ba Thinh, Nguyen Thi Anh Minh, Nguyen Thanh Hung, and Nguyen Dinh Hien. The manuscript was improved by three anonymous reviewers and discussion with James Parham. The work was supported by grants from the Turtle Conservation Fund, IDEA WILD, and The John D. and Catherine T. MacArthur Foundation.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2011.03.004.

References

Cheung, S.M., Dudgeon, D., 2006. Quantifying the Asian turtle crisis: market surveys in southern China, 2000–2003. *Aquatic Conserv. Mar. Freshw. Ecosyst.* 16, 751–770.
 Compton, J., 2000. An overview of Asian turtle trade. *Chel. Res. Monogr.* 2, 24–29.
 Dalton, R., 2003. Mock turtles. *Nature* 423, 219–220.

Diesmos, A.C., Gee, G.V.A., Diesmos, M.L., Brown, R.M., Widmann, P.J., Dimalibot, J.C., 2004. Rediscovery of the Philippine forest turtle, *Heosemys leytenis* (Chelonia; Bataguridae), from Palawan Island, Philippines. *Asiatic Herpetol. Res.* 10, 22–27.
 Fong, J.J., Parham, J.F., Shi, H., Stuart, B.L., Carter, R.L., 2007. A genetic survey of heavily exploited, endangered turtles: caveats on the conservation value of trade animals. *Anim. Conserv.* 10, 452–460.
 Fooden, J., 1996. Zoogeography of Vietnamese primates. *Int. J. Primatol.* 17, 845–899.
 Fritz, U., Petzold, A., Auer, M., 2006. Osteology in the *Cuora galbinifrons* complex suggests conspecificity of *C. bourreti* and *C. galbinifrons*, with notes on shell osteology and phalangeal formulae within the Geoemydidae. *Amphibia-Reptilia* 27, 195–205.
 Garza, J.C., Woodruff, D.S., 1992. A phylogenetic study of the gibbons (*Hylobates*) using DNA obtained noninvasively from hair. *Mol. Phylogenet. Evol.* 1, 202–210.
 Gong, S.-P., Chow, A.T., Fong, J.J., Shi, H.-T., 2009. The chelonian trade in the largest pet market in China: scale, scope and impact on turtle conservation. *Oryx* 43, 213–216.
 Groves, C., 2001. *Primate Taxonomy*. Smithsonian Institution Press, Washington D.C. and London.
 Hendrie, D.B., 2000. Status and conservation of tortoises and freshwater turtles in Vietnam. *Chel. Res. Monogr.* 2, 63–73.
 IUCN Red List of Threatened Species, 2010. v. 2010.4. <www.iucnredlist.org>.
 IUCN/SSC Tortoise & Freshwater Turtle Specialist Group, 2010. A study of progress on conservation of and trade in CITES-listed tortoises and freshwater turtles in Asia. In: *Cop15, Inf. 22. Convention on international trade in endangered species of wild fauna and flora. Fifteenth meeting of the conference of the parties, Doha (Qatar). 13–25 March.* <http://www.cites.org/common/cop/15/inf/E15i-22.pdf>.
 Lehr, E., Fritz, U., Obst, F.J., 1998. *Cuora galbinifrons picturata* subsp. nov., eine neue Unterart der Hinterindischen Scharnierschildkröte. *Herpetofauna* 20, 5–11.
 Parham, J.F., Li, D., 1999. A new locality for *Cuora pani* Song 1984 with comments on its known range. *Asiatic Herpetol. Res.* 8, 111–113.
 Parham, J.F., Shi, H., 2001. The discovery of *Mauremys iversoni*-like turtles at a turtle farm in Hainan Province, China: the counterfeit golden coin. *Asiatic Herpetol. Res.* 9, 71–76.
 Parham, J.F., Simison, W.B., Kozak, K.H., Feldman, C.R., Shi, H., 2001. New Chinese turtles: endangered or invalid? A reassessment of two species using mitochondrial DNA, allozyme electrophoresis and known-locality specimens. *Anim. Conserv.* 4, 357–367.
 Parham, J.F., Stuart, B.L., Bour, R., Fritz, U., 2004. The evolutionary distinctiveness of the extinct Yunnan box turtle (*Cuora yunnanensis*) revealed by DNA from an old museum specimen. *Proc. R. Soc. Lond. B. (Biol. Lett. Suppl.)* 271, S391–S394.
 Platt, S.G., Kalyar, Win Ko Ko, Khin Myo Myo, Lay Lay Khaing, Rainwater, T.R., 2007. Notes on the occurrence, natural history, and conservation status of turtles in central Rakhine (Arakan) State, Myanmar. *Hamadryad* 31, 202–211.
 Platt, S.G., Khin Myo Myo, Win Ko Ko, Aung Maung, Rainwater, T.R., 2010. Field observations and conservation of *Heosemys depressa* in the Rakhine Yoma Elephant Range of western Myanmar. *Chel. Conserv. Biol.* 9, 114–119.
 Platt, S.G., Lee, R.J., Klemens, M.W., 2001a. Notes on the distribution, life history, and exploitation of turtles in Sulawesi, Indonesia, with emphasis on *Indotestudo forstenii* and *Leucocephalon yuwonoi*. *Chel. Conserv. Biol.* 4, 154–159.
 Platt, S.G., Saw Tun Khaing, Win Ko Ko, Kalyar, 2001b. A tortoise survey of Shwe Settaw Wildlife Sanctuary, Myanmar, with notes on the ecology of *Geochelone platynota* and *Indotestudo elongata*. *Chel. Conserv. Biol.* 4, 172–177.
 Platt, S.G., Stuart, B.L., Heng, S., Long, K., Kalyar, Heng, K., 2003a. Rediscovery of the critically endangered river terrapin, *Batagur baska*, in Cambodia, with notes on occurrence, reproduction, and conservation status. *Chel. Conserv. Biol.* 4, 691–695.
 Platt, S.G., Win Ko Ko, Lay Lay Khaing, Khin Myo Myo, Thanda Swe, Tint Lwin, Rainwater, T.R., 2003b. Population status and conservation of the Critically Endangered Burmese star tortoise *Geochelone platynota* in central Myanmar. *Oryx* 37, 464–471.
 Platt, S.G., Win Ko Ko, Kalyar, Myo Myo, Lay Lay Khaing, Rainwater, T.R., 2003c. Ecology and conservation status of the Arakan forest turtle, *Heosemys depressa*, in western Myanmar. *Chel. Conserv. Biol.* 4, 678–682.
 Roos, C., Nadler, T., 2001. Molecular evolution of the douc langurs. *Zool. Garten N. F.* 71, 1–6.
 Shi, H., Parham, J.F., Fan, Z., Hong, M., Yin, F., 2008. Evidence for the massive scale of turtle farming in China. *Oryx* 42, 147–150.
 Shi, H., Parham, J.F., Simison, W.B., Wang, J., Gong, S., Fu, B., 2005. A report on the hybridization between two species of threatened Asian box turtles (Testudines: *Cuora*) in the wild on Hainan Island (China) with comments on the origin of 'serrata'-like turtles. *Amphibia-Reptilia* 26, 377–381.
 Smith, M.A., 1921. New or little-known reptiles and batrachians from southern Annam (Indo-China). *Proc. Zool. Soc. London* 1921, 423–440.
 Spinks, P.Q., Shaffer, H.B., 2007. Conservation phylogenetics of the Asian box turtles (Geoemydidae, *Cuora*): mitochondrial introgression, numts, and inferences from multiple nuclear loci. *Conserv. Genet.* 8, 641–657.
 Spinks, P.Q., Thomson, R.C., Shaffer, H.B., 2009. A reassessment of *Cuora cyclornata* Blanck, McCord and Le, 2006 (Testudines, Geoemydidae) and a plea for taxonomic stability. *Zootaxa* 2018, 58–68.
 Stuart, B.L., Parham, J.F., 2004. Molecular phylogeny of the critically endangered Indochinese box turtle (*Cuora galbinifrons*). *Mol. Phylogenet. Evol.* 31, 164–177.
 Stuart, B.L., Parham, J.F., 2007. Recent hybrid origin of three rare Chinese turtles. *Conserv. Genetics* 8, 169–175.
 Stuart, B.L., Rhodin, A.G.J., Grismer, L.L., Hansel, T., 2006. Scientific description can imperil species. *Science* 312, 1137.

- Stuart, B.L., Timmins, R.J., 2000. Conservation status and trade of turtles in Laos. *Chel. Res. Monogr.* 2, 58–62.
- Stuart, B.L., Timmins, R.J., Hendrie, D.B., Lieng, S., Chun, S., Hout, P., Heng, K., Touch, T.S., Prak, H.L., Chul, T., Compton, J., Holloway, R., 2000. Turtle trade in Indochina: regional summary (Cambodia, Laos, and Vietnam). *Chel. Res. Monogr.* 2, 74–76.
- van Dijk, P.P., Stuart, B.L., Rhodin, A.G.J., 2000. Asian turtle trade: proceedings of a workshop on conservation and trade of freshwater turtles and tortoises in Asia. Executive summary. *Chel. Res. Monogr.* 2, 13–14.
- Zhou, T., 2005. Discovery of a living male Yunnan box turtle, *Cuora yunnanensis* Boulenger [sic], 1906. *Sichuan J. Zool.* 24, 345–346.
- Zhou, T., Blanck, T., McCord, W.P., Li, P.-P., 2008. Tracking *Cuora mccordi* Ernst, 1988: the first record of its natural habitat: a re-description; with data on captive populations and its vulnerability. *Hamadryad* 32, 57–69.
- Zhou, T., Zhao, E.-M., 2004. On the occurrence of living *Cuora yunnanensis* since 58 years, and its description. *Sichuan J. Zool.* 23, 325–327.

Appendix A. Supplementary Material

Ly, Hoang & Stuart, "Market turtle mystery solved in Vietnam"

Biological Conservation

Fig. S1. *Cuora picturata* Individual 1 (see Table 1 for details).

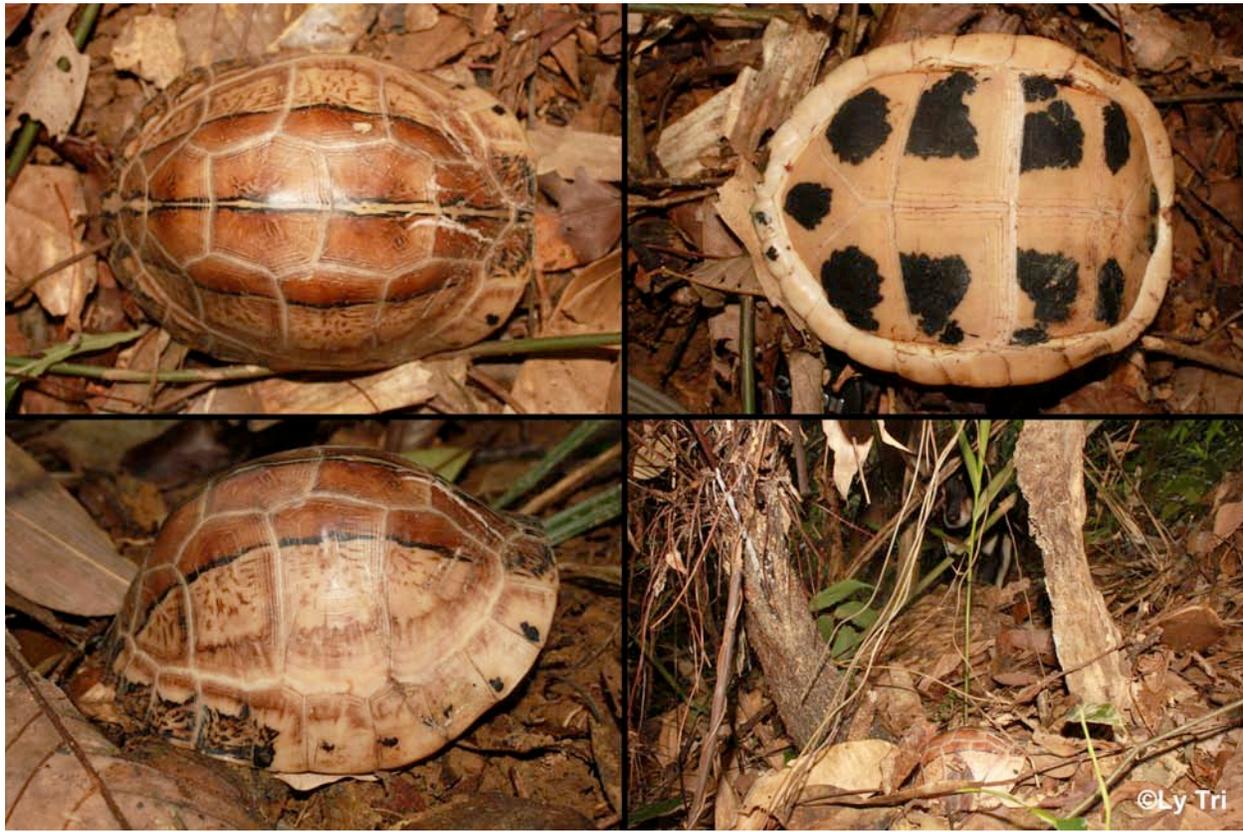


Fig. S2. *Cuora picturata* Individual 2 (see Table 1 for details). This individual is also shown in Fig. 1B–C.



Fig. S3. *Cuora picturata* Individual 3 (see Table 1 for details).



Fig. S4. *Cuora picturata* Individual 4 (see Table 1 for details).



Fig. S5. *Cuora picturata* Individual 5 (see Table 1 for details).



Fig. S6. *Cuora picturata* Individual 6 (see Table 1 for details).



Fig. S7. *Cuora picturata* Individual 7 (see Table 1 for details).

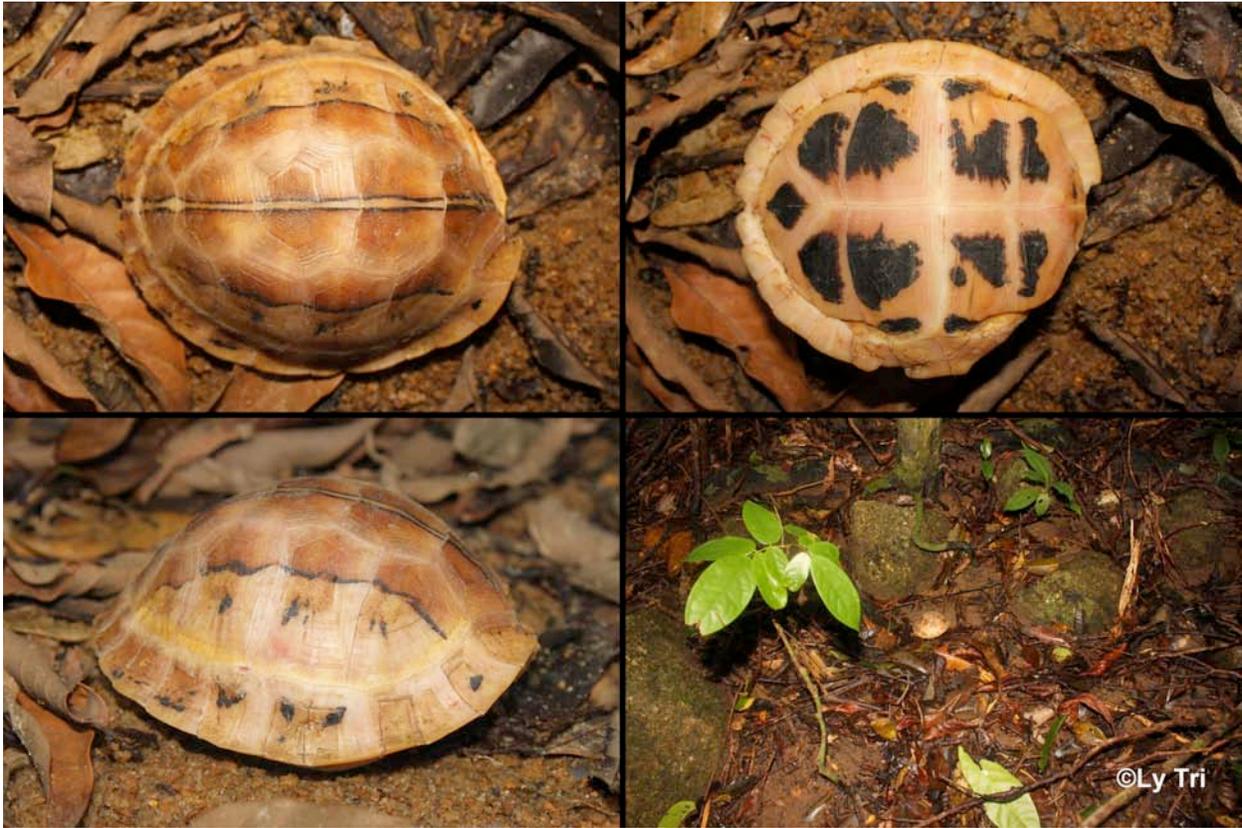


Fig. S8. *Cuora picturata* Individual 8 (see Table 1 for details).

