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A likely new natural hybrid form of "*Cuora serrata*" (*Cuora picturata* x *Cuora mouhotii obsti*) and its presence in the wild in Phu Yen province, Vietnam

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"*Cuora serrata*" was originally described as a subspecies of *Cuora galbinifrons* (Iverson and McCord, 1992) and later elevated to full species status (Obst and Fritz, 1997). However, shortly after, it was proven to be a hybrid (Parham et al., 2001). Based on the genetic fingerprints of specimens originating from the wild and the pet trade, "*C. serrata*" appears to be a hybrid of *Cuora mouhotii* x *Cuora galbinifrons* or *Cuora mouhotii* x *Cuora bourreti* (Stuart and Parham 2004; Shi et al., 2005). *"Cuora serrata*" is nowadays considered a collective noun for hybrids between members of the *galbinifrons*-complex and *C. mouhotii* sensu lato. Until recently, no records of hybridization between *C. mouhotii* and the third member of the *galbinifrons*-complex, *Cuora picturata*, were known and this species was long supposed to occur outside the natural range of *C. mouhotii* (Shi et al., 2005). However, *C. picturata* was recently discovered in the wild on the Langbian Plateau in the southern Vietnamese provinces of Khanh Hoa and Phu Yen (Ly et al., 2011; Van Ha and McCormack 2012; Nguyen and McCormack 2012). At the time, this record was about 300 km south of the most southern record of *C. mouhotii* in Vietnam's Quang Nam province (Ly et al., 2013). However, simultaneously, *C. mouhotii* was also discovered in this area and classified as the southern subspecies *C. m. obsti* (Ly et al., 2013). Shortly after, both *C. m. obsti* and *C. picturata* were found within only a few hundred meters of each other at Deo Ca–Hon Nua Special Use Forest (SUF), Dong Hoa District, Phu Yen province (Vietnam) (Blanck and Braun, in prep). This demonstrates sympatric occurrence, making hybridization geographically feasible - as also speculated by Ly et al. (2013).

Between 2011 and 2014 photos of nine "*C. serrata*"-like specimens with clear *C. picturata* resemblance appeared on Chinese online pet reptile fora. These animals consisted of one subadult and eight adults. All originated from the Chinese turtle trade, therefore lack any locality. In addition, on 18 August 2014 an adult female was encountered in Suoi Dua village, Sông Hinh district, Phu Yen province, Vietnam (Nguyen et al., in prep) (Fig. 1). It had recently been caught by local hunters in Song Hinh forest. Although this turtle was encountered in the local trade, the circumstances and detailed information given by the hunter that actually caught it, lend credence to the locality's accuracy. The female was sold to a trader for €85 who planned to sell it with profit.

Cuora picturata is characterized by high domed carapace. It lacks dorsal and lateral keels and a mahogany brown-reddish dorsal band is present (Fig. 2). Sporadically this colouration tends toward dark purple brown. The plastron is horn coloured with large solid black markings on each scute (Fig. 2). The soft parts display a unique reticulated pattern. Head coloration is lime yellow and the irises display black markings surrounding the pupil, making the pupil seem as not roundish but usually somewhat star shaped. Such iris markings are typical and unique for *C. picturata* and do not appear in *C. galbinifrons* and *C. bourreti* (Lehr et al., 1998) nor do they usually occur in "*C. serrata*" specimens without *C. picturata* parentage.

Cuora mouhotii is characterised by dorsal and ventral keels and serrated hind marginals. It is dorsally more

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Figure 1. Wild caught likely hybrid (*Cuora picturata* x *Cuora mouhutii obsti*) from Suoi Dua village, Sông Hinh district, Phú Yên province, Vietnam 18-8-2014 (Photos by T.L. Nguyen).

or less flattened and usually chestnut to caramel brown in colour (Fig. 2). From the lateral keels downwards a radiating black pattern often occurs on the costalia. The soft parts are dark grey, though the neck region and head may display pinkish to yellowish colour and be finely reticulated. Two subspecies are currently recognized which are basically distinguished by their shape (*mouhotii* being more elongated, *obsti* more rounded) and particularly by their plastral pattern (*mouhotii* usually shows black bar-like markings along the outer edges; *obsti* shows radiating black markings which often form triangles, frequently extending to the plastrons center and in most cases black gulars and partly black patterned humerals (Fig. 2)).

For phenotypic comparisons of putative hybrids we obtained one to six photos for each of the ten specimens,

Figure 2. Dorsal and plastral views of *Cuora picturata* (top), *Cuora mouhotii obsti* (middle), *Cuora mouhotii mouhotii* (bottom) (Photos by R. Struijk and J. Stumpel).

though quality and photo positioning differed per specimen. For all, the soft parts and carapace were visible in these photos, but plastron photos were only visible from seven. Each individual was compared to the most characteristic features of both suspected parental species (Table 1). Due to the fact of the limited number of photos it was impossible to analyse every feature for each specimen.

In all ten specimens, multiple *C. picturata* features could be noticed, e.g. a high domed carapace, mahogany brown-reddish dorsal band, unique reticulations on the soft parts and yellowish top of head (Fig. 3). All nine specimens in which the eyes were visible in the photos, displayed black iris markings surrounding the pupils.

Characteristics indicative of *C. mouhotii* parentage include serrated hind marginals and the presence of

Table 1. Characteristics for ten likely hybrids between *Cuora picturata* and *Cuora mouhotii* (*obsti*) (ad = adult; sub = subadult; + = present; ± = intermediary; - = absent; ? = undeterminable from photos).

	SPECIMEN									
	1	2	3	4	5	6	7	8	9	10
General data										
Year	2014	2014	2014	2014	2014	2014	2014	2011	2014	2013
Sex	unknown	unknown	unknown	female	female	unknown	unknown	female	unknown	unknown
Stage	adult	adult	adult	adult	adult	subadult	adult	adult	adult	adult
Locality data available	yes	no	no	no	no	no	no	no	no	no
Photos available	4	6	1	6	4	4	6	6	3	1
C. picturata characteristics										
High domed carapace	+	+	+	+	+	+	+	+	+	+
Black iris markings	+	+	+	+	?	+	+	+	+	+
Reticulations soft parts	+	+	+	+	+	+	+	+	+	+
Head (top) colour	+	±	+	+	+	+	+	+	±	+
Mahogony dorsal band	+	+	?	+	+	+	+	+	+	+
C. mouhotii characteristics										
Serrated hind marginals	+	±	+	+	+	+	+	+	+	?
Keels	+	+	+	±	+	+	+	+	+	-
Costal pattern	+	+	+	+	+	+	+	+	+	+
Plastral pattern	+	?	?	+	+	+	+	+	+	?

dorsal and lateral keels. Also, the black radiating costal pattern is present in all specimens (Fig. 3). Feature which in some cases are interpreted as intermediate are e.g. the keels, serrated hind marginal and the orange/pink neck region, in one case extremely intense in color. Remarkably, in all cases the shape of the plastral pattern can possibly be linked to the subspecies *Cuora mouhotii obsti*. It displays a more radiating pattern, triangular shapes and the large percentage of the gular and intergular scutes that is covered by black markings. This pattern is typical for *C. m. obsti* and differs greatly from that of *C. m. mouhotii* (Fritz et al., 1998; Struijk et al., in prep.). Also the only (small) subadult specimen (6) displayed the very typical *C. m. obsti* plastral pattern.

Based on the combination of multiple features for each specimen in the available photos, we believe that *C. picturata* genes are present in all ten specimens and *C. mouhotii* genes are present in at least nine specimens. In at least seven specimens indications of *C. m. obsti* genes are apparent. However, the analysis given is purely based on phenotypic features. In order to truly confirm the suspected parental lineages, genetic studies should be conducted, comparable to studies that revealed the *galbinifrons*- and *bourreti* lineage in other "*C. serrata*" (Parham et al., 2001; Shi et al., 2005). This might, however, prove difficult since, to the best of our knowledge, all specimens, if still alive, are within the trade or in private hobbyist collections.

All ten specimens were encountered in turtle trade and locality data is only available for one. There is no real evidence to establish the origin of the other nine. Given the massive scale of farming in China, it can no longer be concluded that turtles sold at markets or within the trade in general, originate from the wild (Shi, 2002; Shi et al., 2004). Shi et al. (2005) provided evidence that "*C. serrata*" occurs in the wild but also stated that captive origin cannot be excluded. We agree that some captive breeding could have occurred, and in fact did occur at least once in Europe (Struijk and Blanck, 2015), however, we believe that an origin in the wild is most plausible for "*C. serrata*" in general, and this putative hybrid combination in particular.

First, members of the *galbinifrons*-complex and *C. mouhotii* are of low economic value, highly susceptible to stress, very hard to breed and have a very low fecundity, especially *C. picturata* (Struijk, unpublished data; Blanck, unpublished data) - and do not fit into the Chinese turtle farm models. The presence of any species in a farm at the same time that it is abundant and cheaply available in the wild-collected trade, may simply mean that the farms recently stocked up on that species. Therefore, the presence in a farm does not in

Figure 3. Lateral views of likely hybrid (*Cuora picturata* x *Cuora mouhotii obsti*) (labelled as specimens 7 (top left), 9 (top right), 5 (bottom left) and 8 (bottom right) in table 2). (Photos by T. Blanck, T.M. Chan and Anonymous).

any way imply that the species actually breeds in the farm. Even farm hatchlings may be 'captive hatched' rather than 'captive bred', thus originating from gravid wild caught females. Shi et al. (2002, 2008) indicate the presence of one of the parental species, i.e. *C. mouhotii*, in large numbers in Chinese farms. However, these data were derived indirectly through questionnaires and it is questionable how reliable the identifications were (Shi et al. 2008). Zhou et al. (2008), who visited the farms themselves, could not find significant numbers of *C. mouhotii* (and *C. galbinifrons*) and no breeding success of this species at all. Zhou and Blanck visited dozens of farms within the last decade but only saw a handful of *C. galbinifrons* and *C. mouhotii*, all of which were in bad health and therefore in non-breeding condition. In Chinese turtle farms, many specimens are kept together in rather small enclosures, and their focus lies on species that either have a good reproduction rate (e.g., *Mauremys reevesi*) and/or a high economic value (e.g., *Cuora trifasciata* and *Cuora cyclornata*) or are reasonably hardy (e.g., *Cuora flavomarginata*). Outwardly this suggests captive production of *Cuora picturata* and *Cuora mouhoti* hybrids in Chinese farms is unlikely. Even farmers admit that their sporadic "*C. serrata*" all originate from the trade in wild caught turtles (Zhou, pers. comm.; Blanck, pers. obs.).

Second, nearly all "*C. serrata*" show consistent 'natural' growth which results in hard and smooth shells. The captive rearing of hatchlings and juveniles within the *galbinifrons*-complex, even by experienced keepers, often result in visible deformations in comparison to specimens from the wild (e.g. a more flattened shell or curled marginalia). If many "*C. serrata*" would be of captive origin, these deformaties might be expected. The ten *picturata* "*serrata*" specimens in this study all exhibit natural growth without any abnormalities that possibly could have been caused due to (improper) captive husbandry.

Finally, and most convincingly, the only specimen with locality data originates from within the range

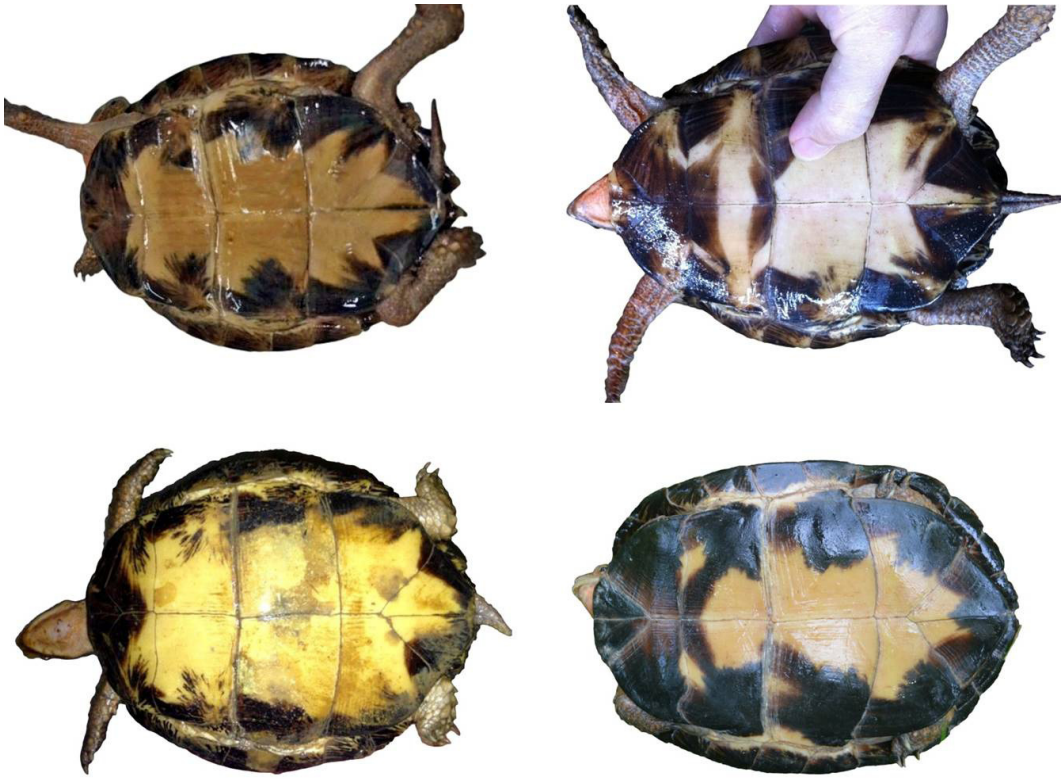

Figure 4. Plastral views of likely hybrid (*Curora picturata* x *Cuora mouhotii obsti*) (labelled as specimens 9 (top left), 8 (top right), 7 (bottom left) and 4 (bottom right) in table 2). (Photos by T. Blanck, T.M. Chan and Anonymous).

of putative parentals in Vietnam. The locality of this specimen (Song Hinh forest) is located near the only very few *C. picturata* localities known to science, and in a zone where it occurs in sympatry with *C. m. obsti*. That characteristics of *C. m. obsti* are present in at least six specimens under examination here, lending further support to a wild origin. Plastral markings in *galbinifrons "serrata"*, which only sympatrically occur with *C. m. mouhotii* from further north in Vietnam and Southern China, show different markings (see Stuart and Parham, 2004; Struijk and Blanck, 2015).

This said the possibility of captive origins for some specimens cannot be completely ruled out. The low economic value of parental species does not necessarily mean that crossings are of low value too. "*C. serrata*" initially was sold for the same prices as its parental species. After its 'description' prices increased, but decreased sharply again when its hybrid status was revealed (Stuart and Parham 2004). However, due to the interest by Chinese hobbyists in hybrid specimens, prices started to increase again since 2005. Indonesian turtle traders were then offering "*C. serrata*" for prices which were threefold of that of *C. galbinifrons*, €330 and €110 per animal, respectively (Struijk pers. obs.). Nowadays prices reach up to approximately €1.000-2.000 with a maximum of €5.000 in September 2011 (Blanck, pers. obs.) and males are especially sought after. These data indicate that it could be commercially interesting to produce these hybrids in captivity. Theoretically this would probably be the best motivation to explain (some) captive origin. Still, we consider it highly unlikely that farmers have the capability to produce these extremely difficult to breed parental species in such numbers and rear hatchlings to adulthood.

Despite thorough market surveys during the last two decades, no *picturata* "*serrata*" were seen in the Chinese trade even when large quantities of both parental species

Figure 5. Plastral views of different "*Cuora serrata*" hybrids: *Cuora galbinifrons* x *Cuora mouhotii mouhotii* (top); *Cuora bourreti* x *Cuora mouhotii mouhotii* (bottom, see Struijk & Blanck, 2015) (Photos by T. Blanck and B. Sturlese).

and other "*C. serrata*" varieties were being offered. It seems unlikely that hunters could recognize and ignore such hybrids, and instead collected pure specimens (until recently). Even the reasons behind the hybridization, and a possible increase in the detection rate of hybrids, are unknown. One hypothesis might be that the drastic decline in turtle densities reducing oppurtunities to find compatible counterparts for mating- as has been described in Teleostei (Crapon de Caprona and Fritzsch, 1984). Additional fieldwork and molecular studies may shed light on this question.

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