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Estimating identification uncertainties in CITES 'look-alike' species

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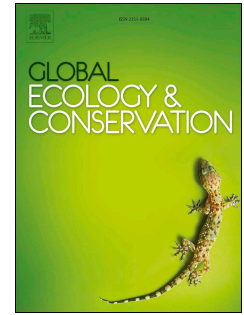
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1 **Short Communication**

2

3 **Title:** Estimating identification uncertainties in CITES 'look-alike' species

4

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6

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14

15

16 **Abstract**

17 Achieving sustainability in international wildlife trade encompasses a series of  
18 challenges, such as identification uncertainty for taxonomically complex groups.  
19 Although CITES has developed a 'look-alike' policy to collectively manage trade in  
20 morphologically similar species and thus facilitate enforcement, its effective  
21 application with regards to the export quota system is questionable. We used a  
22 multidisciplinary approach to provide an understating of the trade in a taxonomically  
23 complex genus of Malagasy chameleons. An online systematic survey of trade was  
24 undertaken to identify which species of *Calumma* have been the subject of trade. A  
25 matching task was employed to calculate identification error rates among species in  
26 the genus. Results suggest that the online market for *Calumma* is thriving, including  
27 species with long-standing zero quotas. Identification error rates varied widely,  
28 reaching high levels of error for some species pairs here identified as 'look-alike'  
29 species. Findings suggest manual identification technique has varying reliability,  
30 potentially resulting in misidentification by stakeholders within the trade. Such errors  
31 have negative consequences for both chameleon conservation and the long-term  
32 socio-economic development of Madagascar. An understanding of the patterns of  
33 identification error can help tailor future management and policy plans.

34

35 **Keywords:** accuracy; *Calumma*; chameleon; enforcement; Madagascar; wildlife  
36 trade

37

## 38 1. Introduction

39 Halting biodiversity loss is one of the ambitious objectives set by the United Nations'  
40 Sustainable Development Goals agenda (United Nations 2015). Under this framework,  
41 concerns have been raised regarding the overexploitation in the wildlife trade (Robinson et  
42 al. 2015a). However, the aim of achieving sustainability in the wildlife trade has many  
43 challenges, one of which, identification uncertainty, has proven to be a major obstacle  
44 (Elphick 2008, Schlaepfer et al. 2005). Species misidentifications impact the accurate  
45 estimation of viable harvest levels for wildlife resources, as well as the detection of illegal  
46 trade. This can have serious negative impacts on the efficacy of management and policy  
47 plans (e.g. Beerkircher et al. 2009, Zhou et al. 2016). Scientific research on species  
48 identification has recently focused on reducing such biases by incorporating error rates in  
49 estimating population size (e.g. Lee et al. 2015, Runge et al. 2007) or by developing  
50 innovative tools to genetically identify traded wildlife products (e.g. Nithaniyal et al. 2016,  
51 Xiong et al. 2016). Further research is required to provide a greater understanding of the  
52 issues around misidentification, including levels of accuracy, and thus contribute to the  
53 prevention or reduction of errors (Elphick 2008, Shea et al. 2010). Such understandings of  
54 identification error rates among different stakeholders (e.g. Austen et al. 2016, White et al.  
55 2014) as well as between different species (Austen 2018) helps decision makers foster the  
56 development of problem-adequate solutions (Gehring and Ruffing 2008).

57  
58 Under the Convention on International Trade in Endangered Species of Wild Fauna and  
59 Flora (CITES), species that are threatened through international trade are listed on one of  
60 three appendices that are aimed at monitoring, regulating and if required banning trade in  
61 specific taxa (cites.org). As a result, the issuance of a permit by the management authority  
62 of a member State requires findings that the trade is not be detrimental to the species (i.e.  
63 Non-Detriment Finding) and that the item in question has been legally acquired (i.e. Legal

64 Acquisition Finding). With this increased burden of proof and the cost associated with  
65 applying for a permit there may be an incentive for laundering as taxa that are less  
66 regulated. Due to the issues of misidentification and thus the potential for laundering,  
67 CITES applies the so-called 'look-alike' principle when it comes to listing taxa. Under the  
68 'look-alike' principle, taxa deemed to look similar are listed together within the same  
69 Appendix if one or more of the taxa are threatened through international trade (CITES  
70 2016). Specifically, under criterion A of Annex 2 b it states that species can be included in  
71 Appendix II if "The specimens of the species in the form in which they are traded resemble  
72 specimens of a species included in Appendix II ... or in Appendix I, so that enforcement  
73 officers who encounter specimens of CITES-listed species are unlikely to be able to  
74 distinguish between them" (CITES 2016). For example, the entire orchid family  
75 (Orchidaceae) was listed in the CITES appendices and account for over 70% of species  
76 listed under CITES. While some species of orchids, such as those within the genus  
77 *Paphiopedilum* (South East Asian slipper orchids), are serious threatened with extinction  
78 through the international horticulture trade, many other species are rarely if ever traded.  
79 However, due to the difficulty in identification of orchids, particularly when not in flower, the  
80 entire family was listed (Hinsley et al. 2017).

81

82 While CITES provides a mechanism for monitoring, regulating and if required banning  
83 trade in specific taxa, a mechanism exists through which international trade can be further  
84 regulated in the form of a quota system. Quota systems allow for the setting of annual  
85 export quotas for specific species, provided that the relevant member States produce  
86 adequate non-detrimental findings (CITES 2016). As a result, if concerns exist then the  
87 quota may be set at zero, effectively banning the trade. This has the potential to lead to  
88 laundering of these control species through those species for which a non-zero quota

89 exists. Currently it remains unclear to what extent the 'look-alike' principle is taken into  
90 consideration when setting quotas.

91

92 The trade in chameleons for the exotic pet and specialist reptile keeper market is a thriving  
93 global trade, which has led to concerns of overexploitation (Carpenter et al. 2004).

94 *Calumma*, a genus of Malagasy chameleons, is diverse and taxonomically complex with  
95 new species continuing to be discovered through integrative taxonomy (Glaw 2015,  
96 Prötzel et al. 2015). This increasing diversity in often cryptic species makes identification,

97 challenging, particularly for non-specialists such as customs officers. The genus has a

98 varied history of regulations under CITES, as well as through European Union (EU)

99 opinions (Carpenter et al. 2004, UNEP-WCMC 2015). Listed on CITES Appendix II in

100 1977, the genus underwent a 19-year trade suspension when Madagascar failed to

101 implement recommendations from the CITES Significant Trade Process (CITES 1995).

102 After the suspension was withdrawn in 2014, a quota system was implemented through

103 which species slowly entered the market under quota while others had a quota of zero

104 (e.g. *C. globifer*). Due to the rapidly expanding trade in *Calumma*, illegal trade in wild-

105 sourced zero quota species has been reported (Todd 2011, UNEP-WCMC 2015, DL

106 Roberts pers. obs.). The trade in *Calumma*, as well as other reptiles and amphibians, has

107 important implication, not just to their conservation, but also in terms of collection of these

108 species as a livelihood strategy (Robinson et al. 2018).

109

110 Here we use *Calumma* as a model system to explore the look-alike issue under a quota

111 system. Specifically, we conduct a systematic survey of online trade to identify potential

112 cases of illegal trade in zero quota species of *Calumma*. We then use match-mismatch

113 experiment to compare the variation in error rate in identification between different species

114 of *Calumma* with the aim of identify those species pairs that are most likely to be confused.

115 The results of the matching task are compared with identified cases of potential illegal  
116 trade.

117

## 118 **2. Materials and Methods**

119 The study received ethical approval from the ethics committee of the School of  
120 Anthropology and Conservation, University of Kent.

121

### 122 **2.1 Systematic survey of online trade**

123 An systematic survey of online trade was conducted over a 21-day period, between the 3<sup>rd</sup>  
124 and 23<sup>rd</sup> May 2017. The search terms '*Calumma*' and 'for' and 'sale' were entered into the  
125 Google search engine (google.co.uk), the first 200 resulting hits were scrutinised.  
126 Snowball sampling was then used to further investigate the content of each websites  
127 identified through the systematic survey as containing trade for additional records. Details  
128 of the specimens found for sale (species and origin i.e. wild or captive bred) and  
129 characteristics of the sale (year of sale, country of sale, type of seller (i.e. private or  
130 commercial), website and price) were recorded. By consulting trade legislation through the  
131 UNEP World Conservation Monitoring Centre website Species+ (speciesplus.net), we  
132 identified whether the species offered for sale was subject to a zero-export quota. All sale  
133 prices were converted to US dollars using the exchange rate (xe.com) during the period of  
134 the study (July 2017). Median prices for legally and potentially illegally traded species were  
135 compared using a Mann-Whitney *U* test. All data were analysed in Microsoft Excel 2016  
136 and IBM SPSS Statistics 24 package for Windows.

137

### 138 **2.2 Match-mismatch experiment**

139 Following the study of Austen (2018) on variation in error rate in identification between  
140 different species of bumblebee, images of 19 species of *Calumma*, representing 61.3% of



141 the genus, were collected through a search of online public websites. A matrix of all  
142 possible comparison combinations among the 19 species was developed. The species'  
143 selection depended on the availability of images of side viewed, adult, male specimens, as  
144 well as one colour morph for *C. parsonii*, to avoid biases. Due to the potential for errors in  
145 identification of images on public websites, an expert on chameleons was used to  
146 confirmed the identification to reduce this error as far as practically possible. A match-  
147 mismatch experiment was then designed in Microsoft PowerPoint 2016 (Supplementary  
148 Material 1). Participants were recruited from the University of Kent. After obtaining  
149 informed consent, participants were asked to provide basic demographic information and a  
150 self-assessment of experience in chameleon identification. The match-mismatch  
151 experiment consisted of 190 randomised stimuli, that is paired images of the same species  
152 (n=19) and of different species (n=171). On completion of the survey, participants were  
153 asked to indicate characteristics used in differentiating species. We then calculated the  
154 identification error rate for each stimulus, as well as the median (as data was not normally  
155 distributed) identification error rate among the presented species of *Calumma*. All analyses  
156 were conducted in Microsoft Excel 2016.

157

### 158 **3. Results**

#### 159 **3.1 Online trade in *Calumma***

160 The systematic survey of online trade identified 128 advertisements of *Calumma* for sale  
161 across 12 different websites; most were online forums (n=7) or commercial breeders and  
162 traders' websites (n=4). Most advertisements were from the USA (n=78, 60.9%), while  
163 others were from the UK (n=34, 26.6%) and Ukraine (n=2, 1.6%). A total of 13 *Calumma*  
164 species were found for sale, *C. parsonii* being the most common (n=68, 53.1%), followed  
165 by *C. oshaughnessyi* (n=18, 14.1%), *C. globifer* (n=11, 8.6%), *C. brevicorne* (n=8, 6.2%),  
166 *C. malthe* (n=6, 4.7%), *C. nasutum* (n=4, 3.1%), *C. gastrotaenia* (n=3, 2.3%), *C. boettgeri*

167 (n=2, 1.6%) and *C. crypticum*, *C. glawi*, *C. guillaumeti*, *C. hilleniusi* and *C. marojezense*  
168 (each n=1, 0.8%). Wild caught specimens (39.1%, n=50) were more common than captive  
169 bred (18.7%, n=24) and long-term captive (5.5%, n=7) specimens. A substantial number of  
170 advertisements (36.7%, n=47) did not report the source of the specimens. Only 6  
171 advertisements (4.7%) mentioned CITES permits. According to information on quotas  
172 (speciesplus.net), *C. globifer* and *C. parsonii* were traded during years of trade  
173 suspension. We therefore identified 16 potentially questionable advertisements (12.5% of  
174 all advertisements), in which the source of the specimen for sale was not reported. In a  
175 further 16 advertisements, captive bred was reported as the source, although this cannot  
176 be confirmed. A Mann-Whitney *U* test showed sale prices for *C. globifer* (median =  
177 \$1,401.05, n=9), under zero quotas since 1996, were not significantly different from prices  
178 for *C. parsonii* (median=\$1,324.50, n=56,  $U=250.5$ ,  $p=0.977$ ), but significantly different  
179 from those for *C. oshaughnessyi* (median = \$600, n=16,  $U=29$ ,  $p=0.140$ ), *C. brevicorne*  
180 (median=\$400, n=7,  $U=6$ ,  $p=0.005$ ) and *C. nasutum* (median=\$175, n=4,  $U=0$ ,  $p=0.003$ ).

181

### 182 **3.2 Species identification error rate**

183 A total of 21 participants, of 13 different nationalities, all reporting good or corrected-to-  
184 normal vision, took part in the match-mismatch experiment. Nineteen participants reported  
185 having no experience in identifying chameleons, whereas two participants stated having a  
186 little experience of respectively 4 and 5 years. The median identification error rate for  
187 matching tasks was 14.3%, although error rates varied widely among paired images  
188 (Table 1). For example, 43 species pairs scored 0% for species identification error with no  
189 participant misidentifying these pair, whereas others had extremely high levels of  
190 misidentification error, scoring 95.3% (n=1, *C. globifer* and *C. ambreense*), 90.5% (n=5, *C.*  
191 *brevicorne* and *C. amber*, *C. brevicorne* and *C. crypticum*, *C. crypticum* and *C. amber*, *C.*  
192 *nasutum* and *C. fallax*, *C. oshaughnasseyi* and *C. marojezense*) and 76.2% (n=1, *C.*

193 *globifer* and *C. oshaughnasseyi*). Also, overall error rates were higher for mismatches  
194 (14.3%) than for matches (4.8%). Participants described the nose (90.5%, n=19) and head  
195 shape (90.5%, n=19) as the trait used in identification, followed by colour pattern (57.2%,  
196 n=12), body shape (42.8%, n=9), presence of spikes (28.6%, n=6) and feet shape (23.8%,  
197 n=5). Most participants (52.4%, n=11) stated mixed sexes and different life stages were  
198 presented during the task.

199

#### 200 **4. Discussion**

201 Only three years after the lifting of the trade suspension on *Calumma*, there has been a  
202 rapid growth in the trade of *Calumma* species under quotas totalling 9 species (*C.*  
203 *boettgeri*, *C. brevicorne*, *C. gastrotaenia*, *C. guillaumeti*, *C. malthe*, *C. marojezense*, *C.*  
204 *nasutum*, *C. oshaughnessyi*, *C. parsonii*). The USA remains the main importer, while  
205 Ukraine has been suggested to constitute a route for illegal wildlife trade to access the  
206 European market (Carpenter et al. 2004, UNEP-WCMC 2015). We identified species that  
207 are subject to a zero quota (speciesplus.net) but for which trade was identified through an  
208 online systematic survey. Most notably, *C. globifer* was found in trade during years in  
209 which a zero quota was set and held a significant market value, with prices comparable  
210 with those for the highly desirable *C. parsonii*. Given the presence of an open online trade  
211 in species of questionable origin, greater effort in the monitoring of such trade is required  
212 (Harrison et al. 2016, Hinsley et al. 2016).

213

214 The question remains as to why zero-quota species are appearing in trade.

215 Misidentification among *Calumma* species appears to be heterogeneous, with particularly  
216 high error rates among certain species, here identified as 'look-alike' species. Variation in  
217 species misidentification using the same methodology has previously been shown to occur  
218 for bumblebees, with potential implications for selecting target species in pollinator surveys

219 (Austen 2018). In the case of *Calumma*, we suggest that zero quota species recorded in  
220 the online trade could be attributed to two, potentially co-occurring, factors. One is  
221 accidental collection of non-target species due to errors in identification. The other is  
222 deliberate laundering (Xiong et al. 2016). In the case of *C. globifer*, which was found in the  
223 trade but with zero quota, it had high levels of misidentification with two species that have  
224 quotas, *C. oshaughnessyi* and *C. parsonii* (76.2% and 61.9% misidentification respective).  
225 However, *C. globifer* is only sympatric with *C. parsonii*, therefore misidentification could  
226 occur during collection of *C. parsonii*. The high market demand for the larger species of  
227 chameleons, such as *C. parsonii*, may incentivize traders to illegally export specimens of  
228 morphologically similar species, such as *C. globifer*. This is particularly of concern when  
229 two species with a high rate of misidentification (e.g. 76.2% for *C. globifer* vs *C.*  
230 *oshaughnessyi*) also have significant disparity in price (e.g. *C. globifer* median price =  
231 \$1,401.05 vs *C. oshaughnessyi* median price = \$600). Future research could take  
232 advantage of market research methods (e.g. Hinsley et al. 2015) to further analyse the  
233 consumption behaviour of importing countries, such as the demand for either  
234 morphologically similar or dissimilar species, thus evaluating desirable traits (e.g. body  
235 size, colour patterns, ornamentation, skin softness, behaviour, rarity, Angulo et al. 2009).  
236  
237 Capacity building through targeted training may help reduce incidences of  
238 misidentification, particularly among customs officers, as well as other stakeholders.  
239 Match-mismatch experiments as well as other methods from psychology have the potential  
240 to provide a more rigorous test base for training, beyond mere gestalt of those providing  
241 the training. Training will, however, only be successful if good governance is in place  
242 (Ewers and Smith 2007, Gehring and Ruffing 2008). Beyond training, the application of  
243 such methodologies can also help provide a stronger evidence base for listing species on  
244 CITES appendices under the look-alike principle, as well as managing the quota system.

245

246 In sum misidentification cannot be ruled out as a cause of zero-quota species entering the  
247 wildlife trade and the extent to which CITES export quota systems take into account the  
248 issue of 'look-alike' taxa remains unclear. Taxonomic complexity of the genus *Calumma*  
249 constitute an obstacles to effective enforcement of CITES quotas. Both unintentional  
250 substitution or intentional laundering of zero quota species risks overexploitation. For  
251 example, here we found that *C. parsonii*, for which as quota exists, was frequently  
252 misidentified with *C. globifer*, a species with a zero quota but appearing in trade. As both  
253 species co-occur in nature, misidentification could have occurred during the process of  
254 collection. However, *C. globifer* was most frequently misidentified with the significantly  
255 cheaper *C. oshaughnessyi*, indicating a financial incentive to launder within the quota  
256 system. It is important to note that a recent Review of Significant Trade suggested wild  
257 populations of *C. globifer* cannot sustain collection for the pet trade (Jenkins et al. 2010).  
258 Based on our survey of online trade, the limited availability of captive bred specimens, due  
259 to a zero quotas policy since 1995, and the comparatively higher mortality rates of  
260 chameleons in captivity (Robinson et al. 2015b), suggest supply is likely to rely on wild  
261 sourcing. We therefore suggest a precautionary approach be applied to future decisions to  
262 relaxation of the quotas to avoid unexpected and detrimental consequences. An  
263 understanding of heterogeneity in identification error rates among *Calumma* species  
264 (Table 1) provides a useful, adaptable framework for effective management and policy  
265 plans related to changes in the quota. Further the matrix of identification error rates  
266 presented here can help inform more targeted future training of customs officers and other  
267 stakeholders. However, with an increase in taxonomic complexity (Isaac et al. 2004),  
268 manual identification is likely to remain error prone (Alenezi et al. 2014, Austen 2018,  
269 Austen et al. 2016). Machine learning solutions using image processing or DNA barcoding

270 techniques could support more robust identifications by stakeholders (Nithaniyal et al.  
271 2016, Sacchi et al. 2010, Xiong et al. 2016).

272

## 273 **6. Acknowledgments**

274 We would like to thank Dr. Angus Carpenter for information on the trade in chameleons in  
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278

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- 388

389 **8. Tables and Figures with Captions**

390

391 Table 1. Identification error rates among 19 species of *Calumma*, calculated as the  
392 percentage of the number of wrong answers given per stimulus, divided by the number of  
393 participants<sup>1,2</sup>

394

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| Species <sup>3</sup> | <i>C. amb</i> | <i>C. ambr</i> | <i>C. and</i> | <i>C. boe</i> | <i>C. bre</i> | <i>C. cry</i> | <i>C. cuc</i> | <i>C. fal</i> | <i>C. fur</i> | <i>C. gal</i> | <i>C. gas</i> | <i>C. gla</i> | <i>C. glo</i> | <i>C. hil</i> | <i>C. mal</i> | <i>C. mar</i> | <i>C. nas</i> | <i>C. osh</i> | <i>C. par</i> |
|----------------------|---------------|----------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| <i>C. amb</i>        | 23.8%         |                |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |
| <i>C. ambr</i>       | 23.8%         | 4.8%           |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |
| <i>C. and</i>        | 14.3%         | 19.1%          | 14.3%         |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |
| <i>C. boe</i>        | 0.0%          | 0.0%           | 0.0%          | 0.0%          |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |
| <i>C. bre</i>        | 90.5%         | 19.1%          | 0.0%          | 23.8%         | 4.8%          |               |               |               |               |               |               |               |               |               |               |               |               |               |               |
| <i>C. cry</i>        | 90.5%         | 52.4%          | 0.0%          | 4.8%          | 90.5%         | 14.2%         |               |               |               |               |               |               |               |               |               |               |               |               |               |
| <i>C. cuc</i>        | 9.5%          | 4.8%           | 28.6%         | 0.0%          | 19.1%         | 4.8%          | 0.0%          |               |               |               |               |               |               |               |               |               |               |               |               |
| <i>C. fal</i>        | 14.3%         | 28.6%          | 9.5%          | 52.4%         | 9.5%          | 38.1%         | 14.3%         | 52.4%         |               |               |               |               |               |               |               |               |               |               |               |
| <i>C. fur</i>        | 0.0%          | 19.1%          | 9.5%          | 40.8%         | 9.5%          | 4.8%          | 4.8%          | 19.1%         | 0.0%          |               |               |               |               |               |               |               |               |               |               |
| <i>C. gal</i>        | 4.8%          | 0.0%           | 4.8%          | 19.1%         | 14.3%         | 0.0%          | 0.0%          | 14.3%         | 4.8%          | 4.8%          |               |               |               |               |               |               |               |               |               |
| <i>C. gas</i>        | 23.8%         | 23.8%          | 80.9%         | 0.0%          | 9.5%          | 9.5%          | 28.6%         | 19.1%         | 33.3%         | 4.8%          | 0.0%          |               |               |               |               |               |               |               |               |
| <i>C. gla</i>        | 0.0%          | 28.6%          | 71.4%         | 0.0%          | 4.8%          | 4.8%          | 33.3%         | 23.8%         | 14.3%         | 4.8%          | 57.1%         | 9.5%          |               |               |               |               |               |               |               |
| <i>C. glo</i>        | 33.3%         | 95.3%          | 28.6%         | 0.0%          | 33.3%         | 42.9%         | 0.0%          | 9.5%          | 0.0%          | 0.0%          | 19.1%         | 0.0%          | 4.8%          |               |               |               |               |               |               |
| <i>C. hil</i>        | 47.6%         | 38.1%          | 14.3%         | 14.3%         | 19.1%         | 14.3%         | 19.1%         | 4.8%          | 9.5%          | 0.0%          | 33.3%         | 23.8%         | 33.3%         | 4.8%          |               |               |               |               |               |
| <i>C. mal</i>        | 52.4%         | 9.5%           | 0.0%          | 23.8%         | 57.1%         | 61.9%         | 14.3%         | 4.8%          | 4.8%          | 4.8%          | 4.8%          | 0.0%          | 9.5%          | 9.5%          | 4.8%          |               |               |               |               |
| <i>C. mar</i>        | 0.0%          | 0.0%           | 23.8%         | 0.0%          | 33.3%         | 0.0%          | 0.0%          | 0.0%          | 28.6%         | 0.0%          | 38.1%         | 9.5%          | 0.0%          | 19.1%         | 0.0%          | 19.1%         |               |               |               |
| <i>C. nas</i>        | 14.3%         | 23.8%          | 9.5%          | 61.9%         | 33.3%         | 42.9%         | 38.1%         | 90.5%         | 9.5%          | 9.5%          | 23.8%         | 14.3%         | 23.8%         | 19.1%         | 28.6%         | 9.5%          | 38.1%         |               |               |
| <i>C. osh</i>        | 47.6%         | 61.9%          | 19.1%         | 9.5%          | 52.4%         | 66.7%         | 0.0%          | 14.3%         | 19.1%         | 0.0%          | 4.8%          | 9.5%          | 76.2%         | 9.5%          | 14.3%         | 90.5%         | 19.1%         | 0.0%          | 18            |
| <i>C. par</i>        | 28.6%         | 14.3%          | 0.0%          | 23.8%         | 14.2%         | 23.8%         | 4.8%          | 28.6%         | 0.0%          | 0.0%          | 0.0%          | 0.0%          | 61.9%         | 4.8%          | 19.1%         | 0.0%          | 23.8%         | 42.9%         | 0.0%          |

396 <sup>1</sup> Identification error rates have been classified as low if below 25% (white), medium-low if  
397 comprised between 25 and 50% (light grey), medium-high if comprised between 50 and  
398 75% (dark grey) and high if above 75% (black).

399 <sup>2</sup> Species for which trade is allowed under a quota system are highlighted

400 <sup>3</sup> Species abbreviations: *C. amb* = *C. amber*; *C. ambr* = *C. ambreense*; *C. and* = *C.*  
401 *andringitraense*; *C. boe* = *C. boettgeri*; *C. bre* = *C. brevicorne*; *C. cry* = *C. crypticum*; *C.*  
402 *cuc* = *C. cucullatum*; *C. fal* = *C. fallax*; *C. fur* = *C. furcifer*; *C. gal* = *C. gallus*; *C. gas* = *C.*  
403 *gastrotaenia*; *C. gla* = *C. glawi*; *C. glo* = *C. globifer*; *C. hil* = *C. hilleniusi*; *C. mal* = *C.*  
404 *malthe*; *C. mar* = *C. marojezense*; *C. nas* = *C. nasutum*; *C. osh* = *C. oshaughnessyi*; *C.*  
405 *par* = *C. parsonii*

406

407 **9. Supplementary Materials**

408 **Supplementary Material 1.** Questionnaire-based survey, consisting of a demographic  
409 research, an assessment of experience in chameleon's identification and a photographic  
410 matching task, for which an example of matching and mismatching stimuli is here  
411 presented.

412

413 ***Calumma* Chameleons Photographic Matching Task**

414 Welcome to the survey!

415

416 My name is XXX and I am a Conservation and International Wildlife Trade MSc student at  
417 the University of Kent in the UK, researching wildlife trade. Your response to this survey  
418 will form an important contribution towards my research and is very much appreciated.

419

420 The survey is designed to preserve respondents' anonymity. Please answer questions in  
421 the knowledge that you are doing so as an anonymous contributor.

422

423 Collated (anonymous) survey outcomes may be submitted for publication in peer-reviewed  
424 scientific journals.

425

426 Once started, you have the option to withdraw from completing the survey at any time.

427

428 **Question 1)** Please select the **YES** option in question number one to confirm:

429

- You have read and understood why this survey is being conducted

430

- You understand that data from it may be published

431

- You understand that you may withdraw from survey completion at any time

432

- You are aged 18 years or over

- 433
- You consent to complete this survey

434 Alternatively, please select the **NO** option should you NOT wish to complete the survey.

435

436 **Question 2)** To which **sex** do you assign yourself?

- 437
- Female
- 438
- Male
- 439
- Other
- 440
- Decline to specify

441

442 **Question 3)** What **age bracket** do you belong to?

- 443
- 18 to 24
- 444
- 25 to 34
- 445
- 35 to 44
- 446
- 45 to 54
- 447
- 55 to 64
- 448
- 65 to 74
- 449
- 75 or older
- 450
- Decline to specify

451

452 **Question 4)** What is your **nationality**?

453

454 **Question 5)** Do you consider yourself to have a **normal vision**?

- 455
- Yes
- 456
- No, but my vision is corrected to normal with glasses or contact lenses
- 457
- No, I have a visual impairment

458

459 **Question 6)** Please select which of the below best describes your **experience** in  
460 identifying chameleons:

- 461 • No experience
- 462 • Little experience
- 463 • Some experience
- 464 • Experienced
- 465 • Competent

466

467 **Question 7)** If you have any experience, approximately how many **years** have you being  
468 identifying chameleons for?

469

#### Photographic Matching Task

470 You will now be shown a series of pictures consisting in two photographs of *Calumma*  
471 chameleons.

472 You will be asked to tell if these represent the same species.

473 Please note that this is a **forward only** survey. You will NOT be able to modify your  
474 answers once moved forward.

475

476 **Example match (*C. oshaughnessyi*)**

|                                  |                                  |
|----------------------------------|----------------------------------|
| Image of <i>C. oshaughnessyi</i> | Image of <i>C. oshaughnessyi</i> |
|----------------------------------|----------------------------------|

477

478 Do you think that the above photographs represent the **same species**?

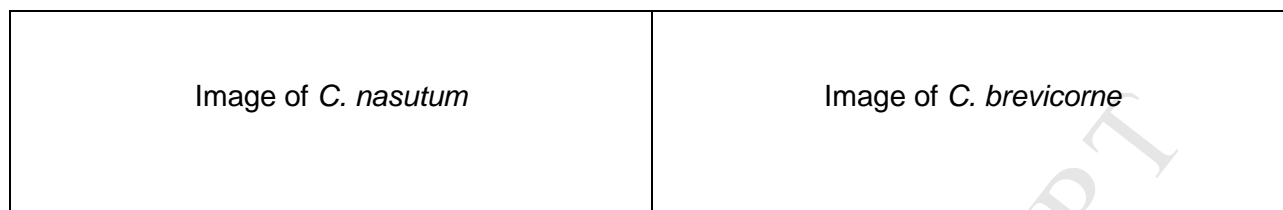
- 479 • Yes
- 480 • No



- 481
- I do not know

482

483 **Example mismatch (*C. nasutum* vs *C. brevicorne*)**



484

485 Do you think that the above photographs represent the **same species**?

- 486
- Yes
- 487
- No
- 488
- I do not know

489

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