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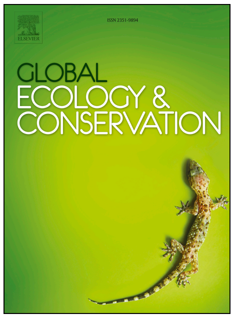

Estimating identification uncertainties in CITES ‘look-alike’ species

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Short Communication

Title: Estimating identification uncertainties in CITES ‘look-alike’ species

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Abstract

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

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

1. Introduction

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

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

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

While CITES provides a mechanism for monitoring, regulating and if required banning trade in specific taxa, a mechanism exists through which international trade can be further regulated in the form of a quota system. Quota systems allow for the setting of annual export quotas for specific species, provided that the relevant member States produce adequate non-detrimental findings (CITES 2016). As a result, if concerns exist then the quota may be set at zero, effectively banning the trade. This has the potential to lead to laundering of these control species through those species for which a non-zero quota exists. Currently it remains unclear to what extent the ‘look-alike’ principle is taken into consideration when setting quotas.

The trade in chameleons for the exotic pet and specialist reptile keeper market is a thriving global trade, which has led to concerns of overexploitation (Carpenter et al. 2004). *Calumma*, a genus of Malagasy chameleons, is diverse and taxonomically complex with new species continuing to be discovered through integrative taxonomy (Glaw 2015, Pröetzel et al. 2015). This increasing diversity in often cryptic species makes identification, challenging, particularly for non-specialists such as customs officers. The genus has a varied history of regulations under CITES, as well as through European Union (EU) opinions (Carpenter et al. 2004, UNEP-WCMC 2015). Listed on CITES Appendix II in 1977, the genus underwent a 19-year trade suspension when Madagascar failed to implement recommendations from the CITES Significant Trade Process (CITES 1995). After the suspension was withdrawn in 2014, a quota system was implemented through which species slowly entered the market under quota while others had a quota of zero (e.g. *C. globifer*). Due to the rapidly expanding trade in *Calumma*, illegal trade in wild-sourced zero quota species has been reported (Todd 2011, UNEP-WCMC 2015, DL Roberts pers. obs.). The trade in *Calumma*, as well as other reptiles and amphibians, has important implication, not just to their conservation, but also in terms of collection of these species as a livelihood strategy (Robinson et al. 2018).

Here we use *Calumma* as a model system to explore the look-alike issue under a quota system. Specifically, we conduct a systematic survey of online trade to identify potential cases of illegal trade in zero quota species of *Calumma*. We then use match-mismatch experiment to compare the variation in error rate in identification between different species of *Calumma* with the aim of identify those species pairs that are most likely to be confused.

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

2. Materials and Methods

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

2.1 Systematic survey of online trade

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

2.2 Match-mismatch experiment

Following the study of Austen (2018) on variation in error rate in identification between different species of bumblebee, images of 19 species of *Calumma*, representing 61.3% of the genus, were collected through a search of online public websites. A matrix of all possible comparison combinations among the 19 species was developed. The species' selection depended on the availability of images of side viewed, adult, male specimens, as well as one colour morph for *C. parsonii*, to avoid biases. Due to the potential for errors in identification of images on public websites, an expert on chameleons was used to confirmed the identification to reduce this error as far as practically possible. A match-mismatch experiment was then designed in Microsoft PowerPoint 2016 (Supplementary Material 1). Participants were recruited from the University of Kent. After obtaining informed consent, participants were asked to provide basic demographic information and a self-assessment of experience in chameleon identification. The match-mismatch experiment consisted of 190 randomised stimuli, that is paired images of the same species (n=19) and of different species (n=171). On completion of the survey, participants were asked to indicate characteristics used in differentiating species. We then calculated the identification error rate for each stimulus, as well as the median (as data was not normally distributed) identification error rate among the presented species of *Calumma*. All analyses were conducted in Microsoft Excel 2016.

3. Results

3.1 Online trade in *Calumma*

The systematic survey of online trade identified 128 advertisements of *Calumma* for sale across 12 different websites; most were online forums (n=7) or commercial breeders and traders' websites (n=4). Most advertisements were from the USA (n=78, 60.9%), while others were from the UK (n=34, 26.6%) and Ukraine (n=2, 1.6%). A total of 13 *Calumma* species were found for sale, *C. parsonii* being the most common (n=68, 53.1%), followed by *C. oshaughnessyi* (n=18, 14.1%), *C. globifer* (n=11, 8.6%), *C. brevicorne* (n=8, 6.2%), *C. malthe* (n=6, 4.7%), *C. nasutum* (n=4, 3.1%), *C. gastrotaenia* (n=3, 2.3%), *C. boettgeri* (n=2, 1.6%) and *C. crypticum*, *C. glawi*, *C. guillaumeti*, *C. hilleniusi* and *C. marojezense* (each n=1, 0.8%). Wild caught specimens (39.1%, n=50) were more common than captive bred (18.7%, n=24) and long-term captive (5.5%, n=7) specimens. A substantial number of advertisements (36.7%, n=47) did not report the source of the specimens. Only 6 advertisements (4.7%) mentioned CITES permits. According to information on quotas (speciesplus.net), *C. globifer* and *C. parsonii* were traded during years of trade suspension. We therefore identified 16 potentially questionable advertisements (12.5% of all advertisements), in which the source of the specimen for sale was not reported. In a further 16 advertisements, captive bred was reported as the source, although this cannot be confirmed. A Mann-Whitney *U* test showed sale prices for *C. globifer* (median = \$1,401.05, n=9), under zero quotas since 1996, were not significantly different from prices for *C. parsonii* (median=\$1,324.50, n=56, *U*=250.5, p=0.977), but significantly different from those for *C. oshaughnessyi* (median = \$600, n=16, *U*=29, p=0.140), *C. brevicorne* (median=\$400, n=7, *U*=6, p=0.005) and *C. nasutum* (median=\$175, n=4, *U*=0, p=0.003).

3.2 Species identification error rate

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

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

4. Discussion

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

The question remains as to why zero-quota species are appearing in trade. Misidentification among *Calumma* species appears to be heterogeneous, with particularly high error rates among certain species, here identified as ‘look-alike’ species. Variation in species misidentification using the same methodology has previously been shown to occur for bumblebees, with potential implications for selecting target species in pollinator surveys

(Austen 2018). In the case of *Calumma*, we suggest that zero quota species recorded in the online trade could be attributed to two, potentially co-occurring, factors. One is accidental collection of non-target species due to errors in identification. The other is deliberate laundering (Xiong et al. 2016). In the case of *C. globifer*, which was found in the trade but with zero quota, it had high levels of misidentification with two species that have quotas, *C. oshaughnessyi* and *C. parsonii* (76.2% and 61.9% misidentification respective). However, *C. globifer* is only sympatric with *C. parsonii*, therefore misidentification could occur during collection of *C. parsonii*. The high market demand for the larger species of chameleons, such as *C. parsonii*, may incentivize traders to illegally export specimens of morphologically similar species, such as *C. globifer*. This is particularly of concern when two species with a high rate of misidentification (e.g. 76.2% for *C. globifer* vs *C. oshaughnessyi*) also have significant disparity in price (e.g. *C. globifer* median price = $1,401.05 vs *C. oshaughnessyi* median price = $600). Future research could take advantage of market research methods (e.g. Hinsley et al. 2015) to further analyse the consumption behaviour of importing countries, such as the demand for either morphologically similar or dissimilar species, thus evaluating desirable traits (e.g. body size, colour patterns, ornamentation, skin softness, behaviour, rarity, Angulo et al. 2009).

Capacity building through targeted training may help reduce incidences of misidentification, particularly among customs officers, as well as other stakeholders. Match-mismatch experiments as well as other methods from psychology have the potential to provide a more rigorous test base for training, beyond mere gestalt of those providing the training. Training will, however, only be successful if good governance is in place (Ewers and Smith 2007, Gehring and Ruffing 2008). Beyond training, the application of such methodologies can also help provide a stronger evidence base for listing species on CITES appendices under the look-alike principle, as well as managing the quota system.

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

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8. Tables and Figures with Captions

Table 1. Identification error rates among 19 species of *Calumma*, calculated as the percentage of the number of wrong answers given per stimulus, divided by the number of participants[1, 2]

Species[3]	*C. amb*	*C. ambr*	*C. and*	*C. boe*	*C. bre*	*C. cry*	*C. cuc*	*C. fal*	*C. fur*	*C. gal*	*C. gas*	*C. gla*	*C. glo*	*C. hil*	*C. mal*	*C. mar*	*C. nas*	*C. osh*	*C. par*
C. amb	23.8%																		
C. ambr	23.8%	4.8%																	
C. and	14.3%	19.1%	14.3%																
C. boe	0.0%	0.0%	0.0%	0.0%															
C. bre	90.5%	19.1%	0.0%	23.8%	4.8%														
C. cry	90.5%	52.4%	0.0%	4.8%	90.5%	14.2%													
C. cuc	9.5%	4.8%	28.6%	0.0%	19.1%	4.8%	0.0%												
C. fal	14.3%	28.6%	9.5%	52.4%	9.5%	38.1%	14.3%	52.4%											
C. fur	0.0%	19.1%	9.5%	40.8%	9.5%	4.8%	4.8%	19.1%	0.0%										
C. gal	4.8%	0.0%	4.8%	19.1%	14.3%	0.0%	0.0%	14.3%	4.8%	4.8%									
C. gas	23.8%	23.8%	80.9%	0.0%	9.5%	9.5%	28.6%	19.1%	33.3%	4.8%	0.0%								
C. gla	0.0%	28.6%	71.4%	0.0%	4.8%	4.8%	33.3%	23.8%	14.3%	4.8%	57.1%	9.5%							
C. glo	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%						
C. hil	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%					
C. mal	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%				
C. mar	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%			
C. nas	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%		
C. osh	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%	
C. par	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%

[1] Identification error rates have been classified as low if below 25% (white), medium-low if comprised between 25 and 50% (light grey), medium-high if comprised between 50 and 75% (dark grey) and high if above 75% (black).

[2] Species for which trade is allowed under a quota system are highlighted

[3] Species abbreviations: *C. amb = C. amber*; *C. ambr = C. ambreense*; *C. and = C. andringitraense*; *C. boe = C. boettgeri*; *C. bre = C. brevicorne*; *C. cry = C. crypticum*; *C. cuc = C. cucullatum*; *C. fal = C. fallax*; *C. fur = C. furcifer*; *C. gal = C. gallus*; *C. gas = C. gastrotaenia*; *C. gla = C. glawi*; *C. glo = C. globifer*; *C. hil = C. hilleniusi*; *C. mal = C. malthe*; *C. mar = C. marojezense*; *C. nas = C. nasutum*; *C. osh = C. oshaughnessyi*; *C. par = C. parsonii*

9. Supplementary Materials

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

Calumma Chameleons Photographic Matching Task

Welcome to the survey!

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

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

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

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

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

- You have read and understood why this survey is being conducted
- You understand that data from it may be published
- You understand that you may withdraw from survey completion at any time
- You are aged 18 years or over

- You consent to complete this survey

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

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

- Female
- Male
- Other
- Decline to specify

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

- 18 to 24
- 25 to 34
- 35 to 44
- 45 to 54
- 55 to 64
- 65 to 74
- 75 or older
- Decline to specify

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

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

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

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

- No experience
- Little experience
- Some experience
- Experienced
- Competent

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

Photographic Matching Task

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

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

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

Example match (*C. oshaughnessyi*)

Image of *C. oshaughnessyi*	Image of *C. oshaughnessyi*

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

- Yes
- No

- I do not know

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

Image of *C. nasutum*	Image of *C. brevicorne*

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

- Yes
- No
- I do not know