Accuracy in the identification of orchids of the genus *Angraecum* by taxonomists and non-taxonomists

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Summary Misidentification of taxa is understudied but has the potential to be a highly problematic issue. If misidentification is prevalent, there could be significant ramifications for work which relies upon a reliable taxonomic base, such as the description of new species, estimating the size of populations and species prioritisation. Here we used a match-mismatch experiment from psychology to determine the accuracy of species identification in 20 pairs of orchids (*Angraecum* spp. from Madagascar). The participants were split into specialist taxonomists and non-taxonomists. There was a 57.2% accuracy across all the participants. The specialist taxonomists had a high accuracy of 80.0%, with a sensitivity analysis producing an upper accuracy estimate of 90.7%. Non-taxonomists had a much lower accuracy of 55.9%. The results provide evidence of the need for specialist taxonomists, particularly in the case of identifying Malagasy orchids. Nevertheless, since misidentification is still prevalent for specialists, this is an issue that requires further research to understand how accurate identifications are and also the implications of errors.

Key Words: Citizen Science, Classification, Expert Judgement, Madagascar, Misidentification, Orchidaceae, Plant Conservation

Introduction

Misidentification of species can have significant consequences, ranging from hospitalisation following the consumption of hemlock (*Conium maculatum*) having been wrongly identified as sweet fennel (*Foeniculum vulgare*) (Colombo *et al.* 2009) and *Helichrysum arenarium* (Erenler *et al.* 2011), to the overexploitations of white marlin (*Tetrapturus albidus*) due to misidentification with the roundscale spearfish (*Tetrapaturus georgii*) (Beerkircher *et al.* 2009). Such misidentifications have further led to flawed species management plans such as the high-profile likely misidentification of a pileated woodpecker (*Dryocopus pileatus*) sighting as the supposedly extinct ivory-billed woodpecker (*Campephilus principalis*) (Solow *et al.* 2012). Correct species identification is vital for reliable research and species management.

Fundamentally, interactions with biodiversity, whether it is through research or exploitation, requires a sound taxonomic base. Many argue there has been a decline in the number of trained taxonomic experts in the second half of the twentieth century, with some coining it a taxonomic 'crisis' (Wheeler 2004; Wheeler *et al.* 2004; Byrne & Kim 2006). A decline in taxonomic expertise is a particular problem for non-charismatic taxa (Beveridge & Spratt 2015) and those in complex groups (Ennos *et al.* 2005). Despite these claims, some have suggested (e.g. Joppa *et al.* 2011), based on a global perspective, that the number of taxonomists is actually increasing. Beveridge & Spratt (2015), however argue that while this may be the case globally for highly studied taxa, taxonomic declines have much more of an impact at a local scale where the expertise of highly trained taxonomists are most needed. If we are in a taxonomic 'crisis', it is vital to understand how misidentifications differ between trained taxonomists and non-taxonomists, especially in complex taxonomic groups where specialist taxonomists are lacking due to the shift toward generalist taxonomists (see Joppa *et al.* 2011).

Previous studies examining misidentification have often found a minimal difference between experts and non-experts. A study of bumblebees (*Bombus* spp.) found accuracy ranged from 54.0% for non-experts to 57.0% for experts (Austen *et al.* 2016). When identifying individuals within a species based on their stripe pattern, Gibbon *et al.* (2015) found experts had an accuracy of 84.0% but did not perform significantly better than non-experts who had an accuracy of 79.0%. Despite the obvious need for research to provide an understanding of the effectiveness of specialist taxonomists and experts, this is an area that has been little researched, particularly in relation to plants.

Defining who are experts is complicated (Hoffman 1996) but one definition of experts is those who's knowledge about a subject is not known universally (Martin *et al.* 2012; Austen *et al.* 2018). However, expertise is often judged by qualifications or time, and not quantifiably ratified. For example, in their study of the identification of individuals of a rare antelope, Gibbon *et al.* (2015) did not test for expertise, rather expertise was defined as those who worked with the study species. The study here follows Gibbon *et al.* (2015) as primary aim is to compare between two predefined populations: those employed as experts (hereafter referred to as specialist taxonomists) and those not employed as experts (hereafter referred to as non-taxonomists). The individual results themselves do quantify the expert's knowledge without the need for originally testing it.

The Orchidaceae is one of the largest family of flowing plants and are taxonomically challenging. With all species of orchids listed on CITES (Convention on International Trade in Endangered Species; over 70% of species listed on CITES are orchids) due to the difficulty in identification and some species being illegally traded and over-exploited for the horticultural industry, food and traditional medicines, species identification is important but challenging (Hinsley *et al.* 2018). Orchids are therefore an interesting model system to study the process of identification and the consequences of misidentification. Here we investigate the identification of the orchid genus *Angraecum* using a modified two-alternative forced-choice (2AFC) method. Under the two-alternative forced-choice (2AFC) method participants stated whether they believe photograph pairs were the same species or different. This method is frequently used in facial identification (Burton *et al.* 2010; Estudillo & Bindemann 2014), and more recently in conservation research (Gibbon *et al.* 2015; Austen *et al.* 2016).

Methods and Materials

The research was approved by the Research Ethics Committee of the School of Anthropology and Conservation at the University of Kent and follows the Economic and Social Research Council Ethics Framework guidelines (ESRC 2015).

Study subject

The genus *Angraecum* is one of the larger genera of orchids within the family Orchidaceae, comprising 221 species in 19 sections (Simo-Droissart *et al.* 2018). While they have a wide distribution from the Americas through Africa and into the Indian Ocean islands, over 55.0% are found on the island of Madagascar (Cribb & Hermans 2010). Their flowers are generally star-shaped, ranging in colour from green, through cream to white, with a spur at the base of the labellum holding the nectary (Simo-Droissart *et al.* 2018). As a result, they are commonly known as comet orchids and are sought-after by collectors.

Participants

In total, 61 participants undertook the questionnaire and all participants provided informed consent. Standard demographic information were collected and participants were also asked about their eye sight (Appendix 1). Three participants were omitted because they indicated they had poor eyesight or were colour-blind. This left 58 participants split between specialist taxonomists and non-taxonomists, three specialist taxonomists who worked on Malagasy orchids and/or the genus *Angraecum*, and 55 non-taxonomists who did not have any previous experience identifying orchids. Within this group of non-taxonomists, 28 were from the School of Anthropology and Conservation, University of Kent, that had experience in the natural sciences (hereafter referred to as naturalists), and 27 participants that had no affiliation with the School and had not hobbyist interest in natural history (hereafter referred to as non-naturalists). Non-taxonomists were asked to rate their "Species identification skill level in any taxonomic group" on a 5-point Likert scale from "very good" to "very poor".

Match – mismatch questionnaire

Following the demographic and identification skills questions, a match-mismatch questionnaire was completed using species in the *Angraecum* sections *Angraecum, Gomphocentrum* and *Perrierangraecum*. The match-mismatch questionnaire required a minimum of two images for each species. To begin with, the images for every species within each section was sourced from the only field guide for Malagasy Orchids (Cribbs & Herman 2010). Every species was then searched in two extensive and reputable online databases, Madaorchidee and Orchid Species (Madaorchidee 2017; Orchid Species 2017). When an image for a species was found in these databases, it was examined with the image and description from the field guide. If it appeared to match, the species pair was formed. One species image was found from the Kew Science database (Kew Science 2015) and was subjected to the same comparison. This left 20 species pairs, seven species from the section *Angraecum*, four species from the section *Gomphocentrum* and nine species from the section *Perrierangraecum* (Appendix 2). Only images that were forward facing close-up of the flower were selected. To create the questionnaire, 10 species were randomly chosen to be matching species pairs from the pool of species in the three sections. The remaining 10 species formed the mismatching species pairs and were created by randomly assigning another species from the same section to be in a pair with it. For the 20 pairs, participants were asked to decide whether they thought that the species pairs were the ‘same’, ‘different’ or that they ‘didn’t know’ (Appendix 1).

Data analysis

All data were analysed using SPSS Statistics Version 22 (IBM 2017). Accuracy was calculated by taking the total incorrect scores over the total number of pairs (n = 20). A sensitivity analysis was undertaken for every analysis by discounting ‘don’t know’ scores from the total. Accuracies were calculated for all participants, for the two expertise groups (specialist taxonomists and non-taxonomists) and the identification skill level in the non-taxonomists.

Results

Within the non-taxonomist group, one participant (1.8%) stated they had ‘very good’ species identification skill, 12 (21.8%) had ‘good’ species identification skill, 14 (25.5%) reported ‘average’, 6 (10.9%) ‘poor’ and 22 (40.0%) had ‘very poor’.

Accuracy for all the participants

The mean accuracy for all participants was 57.2% (± 1.5 SE), ranging from 30.0% to 90.0%, and resulted in a 42.8% identification error. When orchid identification accuracy was corrected by removing ‘don’t knows’ it increased to 62.8% (± 1.6 SE). The corresponding identification error was 34.7% (± 1.7 SE), ranging from 5.0% to 60.0%, and the mean ‘don’t know’ percentage was 8.2% (± 1.6 SE), ranging from 0% to 40.0%.

Accuracy within specialist taxonomists and non-taxonomists

Specialist taxonomists had a mean accuracy of 80.0% (± 5.0 SE; 75.0% to 90.0% range), and the non-taxonomists' mean accuracy score was 55.9% (± 1.4 SE; 30.0% to 80.0% range). When corrected for 'don't knows', specialist taxonomists' accuracy was 90.7% (± 1.6 SE), while the non-taxonomists' was 61.3% (± 1.5 SE). Following a Mann-Whitney U test, both the accuracy scores with and without 'don't knows' were found to be significantly different ($U = 3.0$, $p < 0.001$; $U = 0$, $p < 0.001$). The mean response of 'don't knows' was not significantly different when compared between specialist taxonomists and non-taxonomists 11.7% (± 6.0 SE) and 8.0% (± 1.7 SE) respectively ($U = 62.5$, $p > 0.05$).

Accuracy of identification skill levels within the non-taxonomist group

Only one participant said they had a 'very good' identification skill level in the non-expert group and they achieved an accuracy of 60.0%. Beyond this sole participant who considered their identification skill as 'very good', there was an increase in accuracy seen from 'good' to 'very poor' participants. The group 'good' scored 49.6% (± 3.0 SE; n = 12), 'average' scored 54.6% (± 2.9 SE; n = 14), 'poor' scored 57.5% (± 2.1% SE; n = 6) and 'very poor' scored 59.6 (± 2.1 SE; n = 22). Excluding the sole 'very good' individual there was a statistically significant negative correlation between the self-assessed identification abilities and accuracy ($R^2 = 0.13$, $p < 0.05$). However, this relationship was not apparent when 'don't knows' were excluded ($R^2 = 0.0005$, $p > 0.05$): 'good' – 58.9% (± 3.8 SE), 'average' – 63.5% (± 3.2 SE), 'poor' – 62.1 (± 3.2 SE), 'very poor' – 60.9% (± 2.2 SE). The percentage of 'don't knows' for the 'good' group was 14.6% (± 4.5 SE), 'average' was 15.0% (± 4.2 SE), 'poor' was 6.7% (± 4.0 SE) and 'very poor' was 1.9% (± 0.9 SE).

Discussion

The overall identification error was high (42.8%), however, when separated into specialist taxonomists and non-taxonomists, specialist taxonomists were substantially and significantly better at identifying Malagasy orchids than non-taxonomists. Specialist taxonomists had an identification error of 20.0% dropping to 9.3% when 'don't knows' where excluded. Within the non-taxonomists, a surprising increase in accuracy was seen with a decrease in self-reported identification skill. When looking at the specific participant scores in the non-taxonomist group, the highest accuracy participant was a naturalist, but the next 13 (23.6%) highest participants were non-naturalists. Furthermore, when looking at the lowest accuracy scoring 18 (32.7%) participants, 14 (77.8%) of these were naturalists, including the three (5.5%) lowest scorers. However, this may be explained by the fact that those with a higher self-reported identification skill in the non-taxonomist group were more cautious to commit to an answer.

In the only species-level study using a match-mismatch experimental design, Austen *et al.* (2016), in their study of bumblebees, found accuracy ranged from 57.0% for experts to 54.0% for non-experts. While non-taxonomists in our study achieved a comparable accuracy of 55.9%, specialist taxonomists were much higher (80.0%). This study's difference between specialist taxonomists and non-taxonomists indicates the important role of specialist taxonomists in the identification of *Angraecum* orchids. The difference between specialist taxonomist and non-taxonomist identifications in this study and that of Austen *et al.* (2016) suggests one cannot generalise identification errors across all taxa or participant groups.

In a previous study, Joppa *et al.* (2011) showed that the number of specialist taxonomists in developed countries was reducing and that there was a shift toward generalist taxonomists. This is a worrying trend for taxa such as *Angraecum* as all the specialist taxonomists in this study were based in developed countries. This decline, along with the suggestion that we are in a taxonomic 'crisis' (Byrne & Kim 2006) is particularly pressing. In the case of

Angraecum, the gulf between non-taxonomist and trained taxonomists is clearly apparent. This is therefore potentially a worrying trend that has implications for the reliability of future plant identifications. Moreover, the fact that only three specialist orchid taxonomists with expertise in the genus could be recruited to this study illustrates the need for increased training.

This study did not test for a difference between groups of generalist taxonomists and specialists for different taxon. Neither did we investigate how different types of information impact identification (e.g. descriptions, herbarium specimens, other vegetative and flora features and angle), due to the need for consistence and reduce confounding factors in identification. Both aspects present significant scope for valuable future research to provide an understanding of the overall prevalence of misidentification, determining those characters that aid identification and identify taxa for which loss of specialist taxonomists is likely to have a significant impact.

While, orchid taxonomists had a low mean identification error (9.3%) once ‘don’t knows’ were taken into account, this is still a potential concern. For the majority of species, orchids included, much of our knowledge is based on museum specimens which are often used to calculate the extent of occurrence and area of occupancy for preliminary IUCN Red List assessment. Rivers *et al*. (2011) suggested that it was possible to undertake a preliminary IUCN Red List assessment based on only 15 specimens to ensure a 95.0% area accuracy. This of course assumes that the species were correctly identified, therefore even a low error rate in identification could have a significant impact on our understanding of the threat status of species.

We should, however, be cautious in our interpretation of the study presented here as it is a simplified version of the process of species identification based solely on the comparison of images. Even if this is the main process when using a field guide, field guides may contain multiple images of the species, as well as additional information such as a full description, distribution and phenological timings such as flowering. This information is not available purely from a single image. Additional information may help in the process of identification, however it can also hinder by drawing attention away from more taxonomically informative characteristics (see Gibbon *et al.* 2015) and information. In order to draw generalisations about the identification of orchid genera, or plants in general, further studies are required using a wider species pool.

The process of species identification is often taken for granted, as is the impact of misidentifications. While others have shown little difference in the accuracy of identification between experts and non-experts (e.g. Austen *et al.* 2016), our study illustrates that this cannot be generalised and could be highly prevalent. Understanding when and how errors in identification occur will help focus and improve training, and identify where specialist knowledge is needed, but also allow greater confidence in engagement with citizen scientists and the valuable data they collect.

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Appendix 1. Match-mismatch questionnaire

The implication of identification error on IUCN Red List assessments

I am a taught MSc. Conservation Biology student at the Durrell Institute of Conservation and Ecology (DICE) at the University of Kent. I am undertaking a project to understand if identification error affects the endangered level of Malagasy Orchids. Identification error is common in plants because of their huge variety. If a species is documented from 10 specimens and one of these is incorrectly identified, it may have large implications on its resulting endangered level. For the project, I need a true identification error percentage from students with varying levels of species identification skill. This questionnaire has 20 orchid pairs and you will be asked if you think they are the same, different or you do not know. The two best photos for each species have been chosen (one from the only field guide and the other from a referenced source). However, the quality on some of the photos is still poor. This highlights the problem of plant identification. You will also be asked some questions about yourself. Your answers are anonymous. Your name and address will not be asked for, along with any other personal information.

Do you agree to complete this questionnaire? (Please circle one) Yes / No

1. Are you a conservation student/affiliated with the School of Anthropology and Conservation at the University of Kent? Yes No

(Please tick one box)

2. What is your sex? Female Male Other

(Please tick one box)

3. What year were you born?

(Please enter write in the box in the format YYYY)

4. Do you consider yourself to have good eye sight? (Including with the use of glasses) Yes No

(Please tick one box)

5. Are you colour blind? Yes No

(Please tick one box)

If you answered “No” in question 4, please move on to question 6. If you answered “Yes”, please answer question 5.

6. Please explain what form of colour blindness you have.

(Please write in the box)

7. How would you rate your species identification skill level in any taxonomic group? If you have no previous background in identifying species please tick the “very poor” box.

(Each box corresponds to the answer above)

Very Poor	Poor	Average	Good	Very Good

Now please look through the insert with the 20 species pairs. Do you think they are the same species, different or you do not know?

8. List of Pairs (Please tick one box in each row)	Same	Different	Don’t know
Pair 1			
Pair 2			
Pair 3			
Pair 4			
Pair 5			
Pair 6			
Pair 7			
Pair 8			
Pair 9			
Pair 10			
Pair 11			
Pair 12			
Pair 13			
Pair 14			
Pair 15			
Pair 16			
Pair 17			
Pair 18			
Pair 19			
Pair 20			

Thank you for your time, it is greatly appreciated. If you feel like giving any comments about this survey, please use the box below.

Appendix 2. Questionnaire species pairs (*Angraecum* spp.) with image sources

Pair No.	Left Species[1]	Image Source[2]	Right Species[1]	Image Source[2]
1	*A. longicalcar* (G)	(1)	*A. eburneum* (A)	(1)
2	*A. sesquipedale* (A)	(2)	*A. sesquiped*ale (A)	(1)
3	*A. obesum* (P)	(3)	*A. obesum* (P)	(1)
4	*A. dollii* (P)	(1)	*A. dryadum* (P)	(1)
5	*A. caulescens* (G)	(3)	*A. caulescens* (G)	(1)
6	*A. dryadum* (P)	(3)	*A. curnowianum* (P)	(1)
7	*A. didieri* (P)	(3)	*A. didieri* (P)	(1)
8	*A. dollii* (P)	(3)	*A. rutenberg*ianum (P)	(1)
9	*A. mahavavense* (A)	(3)	*A. mahavavense* (A)	(1)
10	*A. calceolus* (G)	(3)	*A. calceolus* (G)	(1)
11	*A. praestans* (A)	(3)	*A. praestans* (A)	(1)
12	*A. clareae* (P)	(1)	*A. clareae* (P)	(4)
13	*A. breve* (P)	(3)	*A. breve* (P)	(1)
14	*A. multiflorum* (G)	(1)	*A. acutipetalum* (G)	(3)
15	*A. longicalcar* (A)	(3)	*A. eburneum* (A)	(3)
16	*A. multiflorum* (G)	(3)	*A. acutipetalum* (G)	(1)
17	*A. rutenbergianum* (P)	(3)	*A. curnowianum* (P)	(3)
18	*A. urschianum* (P)	(3)	*A. urschianum* (P)	(1)
19	*A. protensum* (A)	(3)	*A. sororium* (A)	(1)
20	*A. sororium* (A)	(3)	*A. protensum* (A)	(1)

[1] A = *Angraecum*; G = *Gomphocentrum*; P = *Perrierangraecum*

[2] (1) Cribb & Hermans (2010); (2) Kew Science (2015); (3) Orchid Species (2017); (4) Madaorchidee (2017)