



Kent Academic Repository

MacKay-Smith, Thomas H. and Roberts, David L. (2019) *Accuracy in the identification of orchids of the genus Angraecum by taxonomists and non-taxonomists* Kew Bulletin, 74 . ISSN 0075-5974.

Downloaded from

<https://kar.kent.ac.uk/75168/> The University of Kent's Academic Repository KAR

The version of record is available from

<https://doi.org/10.1007/S12225-019-9813-6>

This document version

Author's Accepted Manuscript

DOI for this version

Licence for this version

UNSPECIFIED

Additional information

Versions of research works

Versions of Record

If this version is the version of record, it is the same as the published version available on the publisher's web site. Cite as the published version.

Author Accepted Manuscripts

If this document is identified as the Author Accepted Manuscript it is the version after peer review but before type setting, copy editing or publisher branding. Cite as Surname, Initial. (Year) 'Title of article'. To be published in *Title of Journal* , Volume and issue numbers [peer-reviewed accepted version]. Available at: DOI or URL (Accessed: date).

Enquiries

If you have questions about this document contact ResearchSupport@kent.ac.uk. Please include the URL of the record in KAR. If you believe that your, or a third party's rights have been compromised through this document please see our [Take Down policy](https://www.kent.ac.uk/guides/kar-the-kent-academic-repository#policies) (available from <https://www.kent.ac.uk/guides/kar-the-kent-academic-repository#policies>).

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

Thomas H. Mackay-Smith^{1*} and David L. Roberts¹

*Corresponding Author: thomassmith1307@gmail.com

¹ Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Marlowe Building, Canterbury, Kent, CT2 7NR, UK

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

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

16 **Introduction**

17 Misidentification of species can have significant consequences, ranging from hospitalisation
18 following the consumption of hemlock (*Conium maculatum*) having been wrongly identified
19 as sweet fennel (*Foeniculum vulgare*) (Colombo *et al.* 2009) and *Helichrysum arenarium*
20 (Erenler *et al.* 2011), to the overexploitations of white marlin (*Tetrapturus albidus*) due to
21 misidentification with the roundscale spearfish (*Tetrapturus georgii*) (Beerkircher *et al.*
22 2009). Such misidentifications have further led to flawed species management plans such as
23 the high-profile likely misidentification of a pileated woodpecker (*Dryocopus pileatus*)
24 sighting as the supposedly extinct ivory-billed woodpecker (*Campephilus principalis*)
25 (Solow *et al.* 2012). Correct species identification is vital for reliable research and species
26 management.

27 Fundamentally, interactions with biodiversity, whether it is through research or exploitation,
28 requires a sound taxonomic base. Many argue there has been a decline in the number of
29 trained taxonomic experts in the second half of the twentieth century, with some coining it a
30 taxonomic ‘crisis’ (Wheeler 2004; Wheeler *et al.* 2004; Byrne & Kim 2006). A decline in
31 taxonomic expertise is a particular problem for non-charismatic taxa (Beveridge & Spratt
32 2015) and those in complex groups (Ennos *et al.* 2005). Despite these claims, some have
33 suggested (e.g. Joppa *et al.* 2011), based on a global perspective, that the number of
34 taxonomists is actually increasing. Beveridge & Spratt (2015), however argue that while this
35 may be the case globally for highly studied taxa, taxonomic declines have much more of an
36 impact at a local scale where the expertise of highly trained taxonomists are most needed. If
37 we are in a taxonomic ‘crisis’, it is vital to understand how misidentifications differ between
38 trained taxonomists and non-taxonomists, especially in complex taxonomic groups where
39 specialist taxonomists are lacking due to the shift toward generalist taxonomists (see Joppa
40 *et al.* 2011).

41 Previous studies examining misidentification have often found a minimal difference between
42 experts and non-experts. A study of bumblebees (*Bombus* spp.) found accuracy ranged from
43 54.0% for non-experts to 57.0% for experts (Austen *et al.* 2016). When identifying
44 individuals within a species based on their stripe pattern, Gibbon *et al.* (2015) found experts
45 had an accuracy of 84.0% but did not perform significantly better than non-experts who had
46 an accuracy of 79.0%. Despite the obvious need for research to provide an understanding of
47 the effectiveness of specialist taxonomists and experts, this is an area that has been little
48 researched, particularly in relation to plants.

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

59 The Orchidaceae is one of the largest family of flowering plants and are taxonomically
60 challenging. With all species of orchids listed on CITES (Convention on International Trade
61 in Endangered Species; over 70% of species listed on CITES are orchids) due to the
62 difficulty in identification and some species being illegally traded and over-exploited for the
63 horticultural industry, food and traditional medicines, species identification is important but
64 challenging (Hinsley *et al.* 2018). Orchids are therefore an interesting model system to study
65 the process of identification and the consequences of misidentification. Here we investigate

66 the identification of the orchid genus *Angraecum* using a modified two-alternative forced-
67 choice (2AFC) method. Under the two-alternative forced-choice (2AFC) method participants
68 stated whether they believe photograph pairs were the same species or different. This method
69 is frequently used in facial identification (Burton *et al.* 2010; Estudillo & Bindemann 2014),
70 and more recently in conservation research (Gibbon *et al.* 2015; Austen *et al.* 2016).

71

72 **Methods and Materials**

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

76 *Study subject*

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

84 *Participants*

85 In total, 61 participants undertook the questionnaire and all participants provided informed
86 consent. Standard demographic information were collected and participants were also asked
87 about their eye sight (Appendix 1). Three participants were omitted because they indicated
88 they had poor eyesight or were colour-blind. This left 58 participants split between specialist

89 taxonomists and non-taxonomists, three specialist taxonomists who worked on Malagasy
90 orchids and/or the genus *Angraecum*, and 55 non-taxonomists who did not have any
91 previous experience identifying orchids. Within this group of non-taxonomists, 28 were from
92 the School of Anthropology and Conservation, University of Kent, that had experience in the
93 natural sciences (hereafter referred to as naturalists), and 27 participants that had no
94 affiliation with the School and had not hobbyist interest in natural history (hereafter referred
95 to as non-naturalists). Non-taxonomists were asked to rate their “Species identification skill
96 level in any taxonomic group” on a 5-point Likert scale from “very good” to “very poor”.

97 *Match – mismatch questionnaire*

98 Following the demographic and identification skills questions, a match-mismatch
99 questionnaire was completed using species in the *Angraecum* sections *Angraecum*,
100 *Gomphocentrum* and *Perrierangraecum*. The match-mismatch questionnaire required a
101 minimum of two images for each species. To begin with, the images for every species within
102 each section was sourced from the only field guide for Malagasy Orchids (Cribbs & Herman
103 2010). Every species was then searched in two extensive and reputable online databases,
104 Madaorchidee and Orchid Species (Madaorchidee 2017; Orchid Species 2017). When an
105 image for a species was found in these databases, it was examined with the image and
106 description from the field guide. If it appeared to match, the species pair was formed. One
107 species image was found from the Kew Science database (Kew Science 2015) and was
108 subjected to the same comparison. This left 20 species pairs, seven species from the section
109 *Angraecum*, four species from the section *Gomphocentrum* and nine species from the section
110 *Perrierangraecum* (Appendix 2). Only images that were forward facing close-up of the
111 flower were selected. To create the questionnaire, 10 species were randomly chosen to be
112 matching species pairs from the pool of species in the three sections. The remaining 10
113 species formed the mismatching species pairs and were created by randomly assigning

114 another species from the same section to be in a pair with it. For the 20 pairs, participants
115 were asked to decide whether they thought that the species pairs were the ‘same’, ‘different’
116 or that they ‘didn’t know’ (Appendix 1).

117 *Data analysis*

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

124

125 **Results**

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

129 *Accuracy for all the participants*

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

135 *Accuracy within specialist taxonomists and non-taxonomists*

136 Specialist taxonomists had a mean accuracy of 80.0% (± 5.0 SE; 75.0% to 90.0% range), and
137 the non-taxonomists' mean accuracy score was 55.9% (± 1.4 SE; 30.0% to 80.0% range).
138 When corrected for 'don't knows', specialist taxonomists' accuracy was 90.7% (± 1.6 SE),
139 while the non-taxonomists' was 61.3% (± 1.5 SE). Following a Mann-Whitney U test, both
140 the accuracy scores with and without 'don't knows' were found to be significantly different
141 ($U = 3.0$, $p < 0.001$; $U = 0$, $p < 0.001$). The mean response of 'don't knows' was not
142 significantly different when compared between specialist taxonomists and non-taxonomists
143 11.7% (± 6.0 SE) and 8.0% (± 1.7 SE) respectively ($U = 62.5$, $p > 0.05$).

144 *Accuracy of identification skill levels within the non-taxonomist group*

145 Only one participant said they had a 'very good' identification skill level in the non-expert
146 group and they achieved an accuracy of 60.0%. Beyond this sole participant who considered
147 their identification skill as 'very good', there was an increase in accuracy seen from 'good'
148 to 'very poor' participants. The group 'good' scored 49.6% (± 3.0 SE; $n = 12$), 'average'
149 scored 54.6% (± 2.9 SE; $n = 14$), 'poor' scored 57.5% ($\pm 2.1\%$ SE; $n = 6$) and 'very poor'
150 scored 59.6 (± 2.1 SE; $n = 22$). Excluding the sole 'very good' individual there was a
151 statistically significant negative correlation between the self-assessed identification abilities
152 and accuracy ($R^2 = 0.13$, $p < 0.05$). However, this relationship was not apparent when 'don't
153 knows' were excluded ($R^2 = 0.0005$, $p > 0.05$): 'good' – 58.9% (± 3.8 SE), 'average' –
154 63.5% (± 3.2 SE), 'poor' – 62.1 (± 3.2 SE), 'very poor' – 60.9% (± 2.2 SE). The percentage
155 of 'don't knows' for the 'good' group was 14.6% (± 4.5 SE), 'average' was 15.0% (± 4.2
156 SE), 'poor' was 6.7% (± 4.0 SE) and 'very poor' was 1.9% (± 0.9 SE).

157

158 **Discussion**

159 The overall identification error was high (42.8%), however, when separated into specialist
160 taxonomists and non-taxonomists, specialist taxonomists were substantially and significantly
161 better at identifying Malagasy orchids than non-taxonomists. Specialist taxonomists had an
162 identification error of 20.0% dropping to 9.3% when ‘don’t knows’ were excluded. Within
163 the non-taxonomists, a surprising increase in accuracy was seen with a decrease in self-
164 reported identification skill. When looking at the specific participant scores in the non-
165 taxonomist group, the highest accuracy participant was a naturalist, but the next 13 (23.6%)
166 highest participants were non-naturalists. Furthermore, when looking at the lowest accuracy
167 scoring 18 (32.7%) participants, 14 (77.8%) of these were naturalists, including the three
168 (5.5%) lowest scorers. However, this may be explained by the fact that those with a higher
169 self-reported identification skill in the non-taxonomist group were more cautious to commit
170 to an answer.

171 In the only species-level study using a match-mismatch experimental design, Austen *et al.*
172 (2016), in their study of bumblebees, found accuracy ranged from 57.0% for experts to
173 54.0% for non-experts. While non-taxonomists in our study achieved a comparable accuracy
174 of 55.9%, specialist taxonomists were much higher (80.0%). This study’s difference between
175 specialist taxonomists and non-taxonomists indicates the important role of specialist
176 taxonomists in the identification of *Angraecum* orchids. The difference between specialist
177 taxonomist and non-taxonomist identifications in this study and that of Austen *et al.* (2016)
178 suggests one cannot generalise identification errors across all taxa or participant groups.

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

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

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

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

206 We should, however, be cautious in our interpretation of the study presented here as it is a
207 simplified version of the process of species identification based solely on the comparison of
208 images. Even if this is the main process when using a field guide, field guides may contain

209 multiple images of the species, as well as additional information such as a full description,
210 distribution and phenological timings such as flowering. This information is not available
211 purely from a single image. Additional information may help in the process of identification,
212 however it can also hinder by drawing attention away from more taxonomically informative
213 characteristics (see Gibbon *et al.* 2015) and information. In order to draw generalisations
214 about the identification of orchid genera, or plants in general, further studies are required
215 using a wider species pool.

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

223 **References**

- 224 Austen, G. E., Bindemann, M., Griffiths, R. A. & Roberts, D. L. (2016). Species
225 identification by experts and non-experts: comparing images from field guides.
226 *Scientific Reports*. 6: 33634.
- 227 Austen, G.E., Bindemann, M., Griffiths, R. A. & Roberts, D. L. (2018). Species
228 identification by conservation practitioners using online images: accuracy and
229 agreement between experts. *PeerJ*. 6:e4157.
- 230 Beerkircher, L., Arocha, F., Barse, A., Prince, E., Restrepo, V., Serafy, J. & Shivji, M.
231 (2009). Effects of species misidentification on population assessment of overfished
232 white marlin (*Tetrapturus albidus*) and roundscale spearfish (*T. georgii*). *Endangered*
233 *Species Research*. 9: 81 – 90.

- 234 Beveridge, I. & Spratt, D. M. (2015). Biodiversity and parasites of wildlife: Helminths of
235 Australian Marsupials. *Trends in Parasitology*. 31: 142 - 148.
- 236 Burton, M. A., White, D. & McNeill, A. (2010). The glasgow face matching test. *Behavior*
237 *Research Methods*. 42: 286 – 291.
- 238 Byrne, L.B. & Kim, K.C. (2006). Biodiversity loss and the taxonomic bottleneck: Emerging
239 biodiversity science. *Ecological Research*. 21: 794 – 810.
- 240 Colombo, M. L., Marangon, K., Locatelli, C., Giacchè, M., Zulli, R. & Restani, P. (2009).
241 Hemlock poisoning due to plant misidentification. *Journal of Pharmaceutical Sciences*
242 *and Research*. 1: 43 – 47.
- 243 Cribb, P. & Hermans, J. (2010). *Field Guide to the Orchids of Madagascar*. Royal Botanic
244 Gardens, Kew. London, UK.
- 245 Culverhouse, P. F., Williams, R., Reguera, B., Herry, V. & Gonzalez, G. S. (2003). Do
246 experts make mistakes? A comparison of human and machine labelling of
247 dinoflagellates. *Marine Ecology Progress Series*. 247: 17 – 25.
- 248 Delta, D. & Reserve, B. (2012). Doubtful records of reptile species in some areas of the
249 Danube Delta Biosphere Reserve (Romania). *ZooKeys*. 18: 223 – 232.
- 250 Di Lorenzo, C., Ceschi, A., Kupferschmidt, H., Lüde, S., De Souza Nascimento, E., Dos
251 Santos, A., Colombo, F., Frigerio, G., Nørby, K., Plumb, J. & Finglas, P. (2015).
252 Adverse effects of plant food supplements and botanical preparations: A systematic
253 review with critical evaluation of causality. *British Journal of Clinical Pharmacology*.
254 79: 578 – 592.
- 255 Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., Phillips, T. &
256 Purcell, K. (2012). The current state of citizen science as a tool for ecological research
257 and public engagement. *Frontiers in Ecology and the Environment*. 10: 291 – 297.
- 258 Dopson, S. R., Lange, P. J., de Ogle, C. C., Rance, B. D., Courtney, S. P. & Molloy, J.

259 (1999). *The Conservation Requirements of New Zealand's Nationally Threatened*
260 *Vascular Plants*. Biodiversity Recovery Unit, Department of Conservation. Wellington,
261 New Zealand.

262 Ennos, R. A., French, G. C. & Hollingsworth, P. M. (2005). Conserving taxonomic
263 complexity. *Trends in Ecology & Evolution*. 20: 164 – 168.

264 Erenler, A. K., Baydin, A., Duran, L., Yordan, T. & Turkoz, B. (2011). A case of respiratory
265 failure due to poison hemlock poisoning presented to an emergency department. *Hong*
266 *Kong Journal of Emergency Medicine*. 18: 235 – 238.

267 ESRC. (2015). *Economic and Social Research Council (ESRC) Framework for Research*
268 *Ethics*. Economic and Social Research Council. Swindon, UK.

269 Estudillo, A. J. & Bindemann, M. (2014). Generalization across view in face memory and
270 face matching. *i-Perception*. 5: 589 – 601.

271 Gibbon, G. E. M., Bindemann, M. & Roberts, D. L. (2015). Factors affecting the
272 identification of individual mountain bongo antelope. *PeerJ*. 3: 1303.

273 Hinsley, A., de Boer, H.J., Fay, M. F., Gale, S.W., Gardiner, L. M., Gunasekara, R. S.,
274 Kumar, P., Masters, S., Metusala, D., Roberts, D. L., Veldman, S., Wong, S. & Phelps,
275 J. (2018). A review of the trade in orchids and its implications for conservation.
276 *Botanical Journal of the Linnean Society*. 186: 435 – 455.

277 Hoffmann, R.R. (1996). How can expertise be defined? Implications of research from
278 cognitive psychology. In: *Exploring expertise*. London. Palgrave Macmillan. 81-100.

279 IBM Corp. (2012). IBM SPSS statistics for windows. Armonk, IBM Corp.

280 Joppa, L. N., Roberts, D. L. & Pimm, S. L. (2011). The population ecology and social
281 behaviour of taxonomists. *Trends in Ecology and Evolution*. 26: 551 –553

282 Kew Science. (2015). Plants of the World Online. <http://www.plantsoftheworldonline.org/>.
283 Access on: 04 Febuary 2017.

284 Madaorchidee. (2017). Les Orchidées de Madagascar.
285 [http://madaorchidee.free.fr/les%20orchidees%20de%20madagascar/les%20orchidees](http://madaorchidee.free.fr/les%20orchidees%20de%20madagascar/les%20orchidees%20de%20madagascar.htm)
286 [%20de%20madagascar.htm](http://madaorchidee.free.fr/les%20orchidees%20de%20madagascar/les%20orchidees%20de%20madagascar.htm). Access on: 04 February 2017.

287 Martin, T., Burgman, M., Fidler, F. (2012). Eliciting expert knowledge in conservation
288 science. *Conservation Biology*. 26: 29-38

289 Orchid Species. (2017). Orchid Species Photo Encyclopedia.
290 <http://www.orchidspecies.com/>. Access on: 10 January 2017.

291 Rivers, M.C., Taylor, L., Brummitt, N.A., Meagher, T.R., Roberts, D.L. & Lughadha, E.N.
292 (2011). How many herbarium specimens are needed to detect threatened species?
293 *Biological Conservation*. 144: 2541 – 2547.

294 Simo-Droissart, M., Sonké, B., Droissart, V. & Stévant, T. (2018). Afropectinariella
295 (Vandaeae, Orchidaceae), a new genus of the Angraecum alliance. *PhytoKeys*. 96: 79 –
296 86.

297 Solow, A., Smith, W., Burgman, M., Rout, T., Wintle, B. & Roberts, D. L. (2012). Uncertain
298 sightings and the extinction of the ivory-billed woodpecker. *Conservation Biology*. 26:
299 180 – 184.

300 Wheeler, Q.D. (2004). Taxonomic triage and the poverty of phylogeny. *Philosophical*
301 *Transactions of the Royal Society B*. 359: 571 – 583.

302 Wheeler, Q.D., Raven, P.H. & Wilson, E.O. (2004). Taxonomy: impediment or expedient?
303 *Science*. 303: 285 – 285.

304 **Appendix 1. Match-mismatch questionnaire**

305

306 **The implication of identification error on IUCN Red List assessments**

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

320

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

322

323

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)

<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------

324

2. What is your sex?

Female Male Other

(Please tick one box)

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------

3. What year were you born?

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

<input type="text"/>

325

326

327

328

4. Do you consider yourself to have good eye sight? (Including
with the use of glasses)

Yes No

(Please tick one box)

<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------

5. Are you colour blind?

Yes No

(Please tick one box)

<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------

329

330

331 If you answered “No” in question 4, please move on to question 6. If you answered “Yes”,
 332 please answer question 5.
 333

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

(Please write in the box)

334

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.

335

336

(Each box corresponds to the answer above)

337

Very Poor

Poor

Average

Good

Very Good

338

339

340

341 Now please look through the insert with the 20 species pairs. Do you think they are the same
 342 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			

343

344
345
346
347
348
349
350

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



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

352

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

353

354 ¹ A = *Angraecum*; G = *Gomphocentrum*; P = *Perrierangraecum*

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

356 Madaorchidee (2017)