

1 **Human observers differ in ability to perceive insect diversity**

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9 **Summary:**

10 Human perception of biological variation is an important and understudied issue in the
11 conservation and management of natural resources. We take a novel approach by asking
12 1152 participants, primarily college biology students, to score examples of insect
13 mimicry by the number of distinct kinds of animals they see. Latent class analysis
14 successfully separated participants based on their accuracy of perception as well as
15 demographic information and opinions about biodiversity. Contrary to expectations,
16 factors such as childhood experience (growing up in urban, suburban or rural areas) did
17 not affect the ability to see biodiversity as much as political views (location on a
18 spectrum from liberal to conservative) or the position that biodiversity is important for
19 the health of the environment. We conclude that research into effective measures of
20 biological education should consider the connection between personal views and
21 perceptions of natural variation.

22

23 **Keywords:**

24 Biodiversity, conservation, mimicry, identifying biodiversity

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26

27 **Introduction**

28 In their efforts to protect natural resources and biodiversity, conservation
29 biologists often face a gap between the need for protection as identified by scientists and
30 the perception of that same need as expressed by the general public (Nabhan 1995; Miller
31 2005). It has often been assumed that the lack of public engagement in biodiversity
32 conservation is a consequence of education or a lack thereof (Kaplan *et al.* 1998), yet
33 education programs have not always produced the desired results (Miller 2005).
34 Consequently, several studies have attempted to determine which factors influence how
35 biodiversity is perceived, from investigating what people think biodiversity is (Turner-
36 Erfort 1996), to trying to determine which factors influence how people assess photos
37 showing differing degrees of habitat degradation (Bayne *et al.* 2012).

38 Several hypotheses have emerged about factors that might influence perceptions
39 of biodiversity. Several authors, for example, have suggested that urbanization can
40 negatively impact perceptions of biodiversity as people become increasingly
41 disconnected from nature (Miller 2005; Schwartz 2006), and that perceptions will likely
42 differ between inhabitants of cities and rural areas (Heywood 1995; Maiti and Maiti
43 2011). Others have suggested that education (Lindermann-Matthies 2002; Lindermann-
44 Matthies and Bose 2008) and political views (Dunlap and McCright 2008) can influence
45 how nature is perceived.

46 Typically, these studies have focused on attitudes towards conservation of species
47 and natural areas, and not necessarily on the extent to which people might or might not
48 differ in their actual perceptions of natural variation (e.g., Dallimer *et al.* 2012). This
49 knowledge gap, with respect to individual variation in perception, is important because it

50 has been suggested that human well-being is linked to perceived species richness, but
51 researchers found that most people have poor biodiversity identification skills (McKinney
52 2002). Acknowledging the finding that most people have generally poor natural history
53 or biodiversity identification skills, we asked if differing abilities in perception can be
54 predicted based on demographic histories (e.g. education) or opinions expressed about
55 biodiversity. To test perception, we took advantage of the natural visual riddles presented
56 by mimicry among distantly related insects, from which sets of species can be examined
57 that cover a range of similarity, including sets of species that can be readily distinguished,
58 to mimicry complexes that are difficult for biologists to separate.

59

60 **Methods**

61 To quantify variation among individuals in the extent to which subtle biological
62 differences can be perceived, we designed an online survey that first presented
63 participants with a series of slides, each slide displaying six images of arthropods.
64 Students were instructed that they would be asked to decide how many kinds of animals
65 (from 1-6) were being shown. We did not ask ‘how many species are there’ because the
66 term ‘species’ can cause confusion, and lacks a universal definition among biologists.
67 After presenting a training slide that showed the correct answers (electronic
68 supplementary material), we presented seven different slides showing a variety of
69 arthropod orders, many of which are mimics of each other (Fig. 1a,b; electronic
70 supplementary material). The correct number of species on each of the seven slides
71 ranged from 2 - 6. The time participants spent on each of these slides was recorded to
72 control for search effort.

73 Next, participants were asked a series of survey questions, which included
74 questions about community structure (urban, suburban, rural), state, age, education level,
75 parent's education, knowledge of biology, political views, and three questions measuring
76 participant's feelings toward biodiversity (Table 1). Because not every state was
77 represented, we pooled states into four regions, northeast, southeast, northwest, and
78 southwest. Some participants were offered extra credit by their professors for
79 participating in the survey. To account for potential differences between those receiving
80 credit and others, we included a question asking if the participants expect to receive
81 credit.

82

83 *Participants*

84 Survey participants were recruited primarily through college biology classes (both
85 lower division and upper division courses). A link to the survey was provided to
86 instructors and they gave students the option to participate in the survey. Participation
87 was strictly voluntary and all participant data were collected and anonymized using the
88 online survey tools via Qualtrics.com. Survey methodology and recruitment procedures
89 were approved through the Utah State University's Institutional review board (Protocol
90 #4671).

91

92 *Statistical analyses*

93 To address our primary question regarding the capability of survey data to predict
94 the participant's ability to perceive biological variation, we utilized latent class analysis
95 (LCA) to look for structure among participants (i.e., groups of participants with similar

96 survey responses). Latent class analysis is analogous to multivariate factor analysis, but
97 appropriate for categorical data. As implemented in R (the poLCA package), LCA can
98 incorporate continuous covariates (in addition to the categorical data) when looking for
99 underlying, latent variables that determine membership in different clusters of (in our
100 case) individuals participating in the survey. We treated all of the answers to survey
101 questions as ordered, categorical data, and we calculated three continuous covariates.

102 Our primary covariate of interest summarized the extent to which participants
103 were able to correctly perceive the number of species on slides. For every slide, we
104 standardized answers by the correct number of species; thus if the correct answer was 4
105 species, and a participant answered 3, they receive a score of -1 (they underestimated by
106 1). As a measure of accuracy, we took the average of the absolute values of those scores
107 for each individual, which is the average extent to which participants misjudged,
108 regardless of which direction (positive or negative). Secondly, we quantified an index
109 of bias, which was the same calculation but without taking the absolute value (thus
110 allowing us to look at average over- or underestimation). Our third covariate was the
111 average number of seconds that individuals spent on each slide.

112 Using LCA, we explored the possibility that survey participants could be
113 classified into between 1 and 6 groups, and BIC values (as well as delta BIC values) were
114 used to find the optimal number of clusters. Because the model implemented by LCA is
115 relatively complex, we used simple linear models as an accessible and relatively
116 transparent complementary approach. In these models, answers to individual survey
117 questions were used as independent variables predicting performance on slides, while

118 using the average amount of time spent on slides as a covariate for effort. Survey data
119 will be made available through the authors upon request.

120

121 **Results**

122 A total of 1152 people participated in our survey. Structure in the survey answers
123 and performance on slides was readily determined by LCA, which found 2 and higher
124 numbers of groupings to be significantly better than no differentiation. Specifically, K=2
125 appeared to identify end points of a continuum that was then more finely parsed at higher
126 levels of K (electronic supplementary material, figure S1). Individuals associated with the
127 two groups (at K=2) differed in their answers to survey questions, as well as in their
128 perceptions of natural variation (Fig 1c, d, Table S1). On average, group 1 was less
129 accurate, with answers that deviated further from the correct number of species in each
130 slide (Fig. 1c). Both groups tended to underestimate the biodiversity pictured in each
131 slide (i.e. saw fewer species than were actually there), but group 1 estimated lower
132 diversity than group 2 (Fig. 1d). Results from LCA were confirmed with simple linear
133 models that found a significant relationship between most of the survey answers and
134 accuracy (Table S2). It is important to note that (in these models) the average amount of
135 time spent on slides was always a highly significant covariate: people that spent more
136 time on slides tended to get closer to the right answer (Table 1; electronic supplementary
137 material; Fig. S3). However, what is noteworthy is that while controlling for the amount
138 of time spent on slides, we were able to detect significant relationships between answers
139 to survey questions and performance. While the simple linear models provide a useful

140 confirmation, they are coarse in that they do not account for correlations among
141 variables; thus we focus most of our further discussion on the results from LCA.

142 Individuals assigned to groups 1 and 2 differed in a number of ways (Fig. 2; Table
143 1; electronic supplementary material, Figure S2A, B). Among the survey questions that
144 most strongly delineated group 1 and group 2 were: (1) how strongly individuals valued
145 biodiversity personally (Value), (2) if they thought biodiversity was important to the
146 health of the ecosystem (Health), (3) their political views on a scale from conservative to
147 liberal (Views), (4) the age and grade level of participants (Age), and (5) whether or not
148 they expected to receive extra credit for participation (Credit) (Table 1; electronic
149 supplementary material Table S1; Fig S2A, B). How knowledgeable someone considered
150 themselves to be about biology seemed to contribute to group delineation in the LCA
151 analysis, but was not significant in the linear model). Several other survey questions were
152 only weakly associated with the differences between group 1 and 2, including community
153 structure, region of the country, the education level of parents, and if they consider
154 biodiversity a political issue.

155

156 **Discussion**

157 Differences in community structure (urban, suburban, rural) have long been targeted as a
158 major factor influencing how humans relate to biodiversity (Dunlap *et al.* 2000). At least
159 among the participants of our study, results suggest that urbanization does not necessarily
160 impact perceptions of natural variation. Instead of community background or education,
161 we find that more personal or internal variables are successful predictors of biodiversity
162 perception. These included the value placed on biodiversity and political views. With

163 respect to the latter, political leanings are known to influence views on environmental
164 issues (Dunlap and McCright 2008), and we find that self-described liberal-leaning
165 individuals were more accurate in their ability to distinguish among mimetic species
166 relative to self-described conservative-leaning individuals. In sum, these results suggest
167 that liberal-minded individuals place a higher value on biodiversity and are better able to
168 perceive differences among animals that are superficially very similar in appearance.
169 While our results raise this interesting pattern, we do not at this time understand the
170 mechanism linking, for example, political views and perception of biological differences,
171 as discussed further below.

172 We find that a participant's age and grade level were somewhat related to the
173 accuracy of their biodiversity estimates, with older individuals and upperclassmen
174 (particularly graduate students) being more accurate in their estimates. Interestingly,
175 whether or not an individual expected to receive extra credit for participating in the
176 survey was related to how accurate they were in their assessment of biodiversity (Fig.
177 S2). Those participants that expected credit for participation were often much less
178 accurate in their biodiversity estimates than people that did not expect credit, presumably
179 because those people not working for credit were inherently more interested in the task.
180 This may pose a challenge to educators because it suggests that traditional approaches for
181 generating student interest might fail to truly motivate students to invest the time to arrive
182 at a carefully-considered answer, and this could be particularly true of computer based
183 tasks that can be quickly "clicked through" to get to the end. With respect to teaching
184 natural diversity and taxonomy, perhaps educators should focus on appreciation first,

185 possibly through the use of stories and examples of complex and fascinating interactions
186 among species that could facilitate later, more traditional lessons.

187 Aside from grade level, most external demographic factors (e.g., region of the
188 country, community structure (urban/suburban/rural), and parents education) were not
189 strongly associated with abilities to perceive natural variation. Instead, the factors most
190 strongly associated with accuracy in our survey were those of a more personal and
191 internal nature (e.g., the importance that people place on biodiversity). This poses a
192 challenge to conservationists and educators because it seems that rather than simply
193 educating people about biodiversity and conservation, one must affect personal feelings if
194 one is interested in affecting how biodiversity is perceived and appreciated.

195 It is important to note that the effect sizes that we have detected are not large: the
196 average difference in accuracy between groups was less than one perceived species (Fig.
197 1c). However, we believe that the contribution of our study is to point out that personal
198 attributes or background can affect not only attitudes towards biodiversity, as has been
199 documented, but can be associated with actual ability to perceive natural variation.
200 Direction of causality is not clear, as our study was not designed to answer the questions:
201 are more perceptive people more likely to judge biodiversity as important? or are people
202 that place a greater value on biodiversity more likely to take the time to perceive
203 differences? Given the general importance of time in our models (people that looked
204 longer tended to get closer to the right answer), we suspect that the latter might be true.
205 Additional studies could potentially include tasks involving non-biological diversity, as
206 the ability to perceive non-biological variation would be informative. With respect to the
207 hypothesis that people that place a higher value on biodiversity are simply more likely to

208 take the time to look closely, we might expect that those same people would not take as
209 much time for non-biological variation. However, at this time we can only pose this issue
210 as a challenge for researchers interested in the intersection between perception,
211 conservation, and education.

212

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248

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252 **Supplementary material**

253 For supplementary material accompanying this paper, visit
254 <http://www.journals.cambridge.org/ENC>

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257 profit sectors.

258 **Conflict of interest**

259 None.

260 **Ethical standards**

261 The authors assert that all procedures contributing to this work comply with applicable
262 ethical standards of the relevant national and institutional committees on human
263 experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

264

Table 1. Survey questions, and the number of participants giving different answers for each question (the order of questions here follows matches Table S2).

Abbreviation	Question	Answers
Age	What is your age?	15-19 (350); 20-24 (529); 25-29 (111); 30-39 (93); 40-49 (35); 50 and above (34)
Credit	Are you expecting to get extra credit or extra credit points in a class for taking this survey?	no (286); yes (866)
Value	How important is biodiversity to you personally?	unimportant (22); slightly important (180); important (332); very important (351); critical (267)
Health	How important is biodiversity to the health of the environment?	unimportant (0); slightly important (36); important (218); very important (350); critical (548)
Grade	What is your current grade level? or if you are not in school, what is the highest grade you completed?	freshman in college (262); sophomore in college (363); junior in college (218); senior in college (157); Master's student/degree (76); PhD student/degree (76)
Views	How would you describe your political views?	very conservative (96); somewhat conservative (273); intermediate (379); somewhat liberal (276); very liberal (128)
Region*	In what state do you currently reside?	East (54); Midwest (236); South (407); West (455)
Education	What is the highest level of education either of your parents completed?	elementary school (17); high school/GED (257); associate's degree (103); bachelor's degree (391); graduate degree (363); unknown (21)
Area	What best describes the area(s) where you were raised?	Rural (259); Suburban (642); Urban (251)
Biology	How knowledgeable do you consider yourself about biology?	I know nothing (11); limited knowledge (181); average knowledge (434); somewhat knowledgeable (377); very knowledgeable (149)
Politics	How strongly do you agree with this statement? Biodiversity is an important political issue.	strongly disagree (14); disagree (59); neither agree nor disagree (308); agree (481); strongly agree (290)

* Individuals answers by state were pooled into regions.

267 **Figure captions**

268

269 **Figure 1. (a,b).** Examples of slides used in the survey, **(a)** shows 2 species and **(b)** shows
270 4. Photos courtesy Ron Hemberger, Jean Hort, Valerie Bugh, Paul Turner of Druid
271 Environmental, Peter Bryant, Alex Wild, Flagstaffotos, and J.S. Wilson. **(c)** Graph
272 showing the accuracy (“score”), i.e. how well each group (1 and 2) estimated the number
273 of species. Smaller values indicate better observer performance (in other words, the
274 deviation from the correct answer was less). **(d).** Graph showing the biases (how much
275 each group over or under estimated the number of species) of the two groups. Both
276 groups underestimated diversity, but Group1 had a stronger bias (tended to see fewer
277 species than were actually present).

278

279 **Figure 2.** Graphs illustrating differences between Groups 1 and 2 for three survey
280 questions. Bar graphs on the left are results from latent class analysis (LCA) predicting
281 group traits (shown as relative probabilities, on the y-axes, that a member of a given
282 group would provide a particular answer, on the x-axes, to a particular question). Scatter
283 plots on the right show linear relationships based on raw data, but color coded to indicate
284 assignment to groups based on the outcome of LCA. **(a)** How strongly individuals value
285 biodiversity personally with 1 being unimportant and 5 being critical, **(b)** An individual’s
286 political views with 1 being very conservative and 5 being very liberal, **(c)** how important
287 people think biodiversity is to the health of the environment with 1 being unimportant
288 and 5 being critical.

289