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## Partial wing transparency works better when disrupting wing edges: evidence from a field experiment

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**Title:** Partial wing transparency works better when disrupting wing edges: evidence from a field experiment

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1 **Abstract**

2 Lepidoptera – a group of insects in which wing transparency has arisen multiple  
3 times - exhibit much variation in the size and position of transparent wing zones.  
4 However, little is known as to how this variability affects detectability. Here, we test  
5 how the size and position of transparent elements affect predation of artificial moths  
6 by wild birds in the field. Morphs with transparent elements touching wing borders  
7 showed a reduced predation risk, with the effect being the same regardless of the  
8 number of wing borders being touched. By contrast, transparent element size had  
9 little to no effect on predation risk. Overall, this experiment shows for the first time  
10 that transparency offers higher protection when it disrupts prey contour in terrestrial  
11 habitats.

12 **Keywords**

13 background matching, disruptive coloration, transparency, wild bird predators,  
14 artificial prey

15

## 16 **Introduction**

17 Predator evasion has promoted some of the most striking adaptations in the living  
18 world, including lures, mimicry and camouflage in prey (Ruxton *et al.*, 2004). High  
19 transparency (with minimal reflection and absorption at any angle or wavelength)  
20 constitutes, by definition, the most effective mechanism of background matching  
21 against all types of backgrounds. Transparency is more common in pelagic  
22 environments, where there is no place to hide, than in terrestrial environments  
23 (Johnsen, 2001), because: 1) small differences in refractive index between water and  
24 biological tissues limit reflections that would betray the presence of a prey, 2) UV  
25 absorbing pigments are not necessary in the depths of oceans because UV radiation  
26 is filtered out by water and 3) often tissues on land need to be thick and/or dense to  
27 keep an animal's physical structure in place despite gravity, counteracted by buoyant  
28 forces in water but not on land. Contrary to aquatic species, in which animals' entire  
29 bodies are often transparent, transparency on land has only evolved as "elements"  
30 (i.e. parts of the body). It is currently unknown which visual configurations of  
31 transparent and opaque elements are more efficient at reducing prey detectability on  
32 land.

33 On land, a handful of terrestrial groups have evolved transparency, a trait  
34 largely represented in insect wings. In Lepidoptera, most species display wings  
35 covered by opaque scales. However, transparency has evolved independently  
36 several times in butterflies and moths (Gomez *et al.*, 2021). According to recent  
37 experimental evidence, translucency (low level of transparency with high amount of  
38 light diffusion) can smoothen and blur the animal-environment transition, and reduce  
39 body outline detectability in glass frogs (Barnett *et al.*, 2020). The presence of well-  
40 defined transparent windows, often found in Lepidoptera exhibiting transparency,  
41 reduces detectability in both conspicuous (Arias *et al.*, 2019) and cryptic (Arias *et al.*,  
42 2020) butterflies and moths. However, wing transparency can occur in different forms  
43 (Figure 1): as small windows (e.g., as in the moths *Attacus atlas*, or *Carriola*



44 *ecnomoda*) or as large windows (e.g., as in the sphinx *Hemaris fuciformis*) delimited  
45 by brownish elements or conspicuous wing borders (e.g., as in the Ithomiini tribe).  
46 Wing transparency can also be associated with discontinuous borders, touching prey  
47 edges (e.g., as in moths of the genus *Bertholdia*). Whether the size of transparent  
48 windows or their disruption of contour have any effect on prey detectability remains  
49 to be studied.

50 This diversity of forms suggests that including transparent elements can  
51 reduce detectability by different mechanisms. For example, a transparent window  
52 surrounded by an opaque border could reduce detectability by increasing  
53 background resemblance. The larger the transparent area, the larger the proportion  
54 of the prey's surface area that matches its background ("background matching  
55 hypothesis"). On the other hand, transparent elements in contact with the prey  
56 outline can hamper detection as a form of disruptive coloration. In disruptively  
57 coloured prey, colours that imitate the background are combined with contrasting  
58 elements that are located on the prey border, breaking its visual edges and making it  
59 difficult to detect ("disruptive coloration hypothesis") (Cuthill *et al.*, 2005; Stevens &  
60 Cuthill, 2006). Broken edges have been shown to work better than background  
61 matching (Cuthill *et al.*, 2005), especially when low and intermediate colour contrast  
62 elements are included (Stobbe & Schaefer, 2008). Additionally, transparent elements  
63 touching prey edges can make the prey appear to be of smaller size than it actually  
64 is, reducing its perceived profitability and its risk of being attacked, as predation rate  
65 is directly correlated with prey size (Berger *et al.*, 2006). To understand the relative  
66 importance of these different mechanisms in partially transparent terrestrial prey, we  
67 need to investigate the effects of the size and position of transparent elements.

68 Here, we explored the perceptual mechanisms by which transparent wing  
69 windows decrease predation, using wild avian predators of artificial moths, naïve to  
70 transparent butterflies and moths. Field experiments with artificial prey models are a  
71 common way to explore the behaviour of natural predators in response to the visual

72 characteristics of prey and thus to infer the perceptual mechanisms of predation  
73 avoidance (Cuthill *et al.*, 2005, 2006; Stevens *et al.*, 2013). We carried out field  
74 experiments to analyse the effect of different sizes and positions of transparent  
75 “windows” on the attack of prey by avian predators. We predicted that larger  
76 transparent windows would decrease prey detectability by background matching, and  
77 that transparent windows touching prey outlines would make prey more difficult to  
78 detect, presumably *via* disruptive coloration. Hence, large transparent windows  
79 touching wing edges should produce the maximal protection against visual predators.

80

## 81 **Material and methods**

### 82 Field experiments

83 We followed an experimental design similar to that described in Arias *et al* (2020).  
84 Briefly, we performed predation experiments in April and May 2019 in two forests in  
85 southern France with evergreen and white oaks as predominant tree vegetation: La  
86 Rouvière forest (43.65°N, 3.64°E) and a large natural wooded area of the Montpellier  
87 Zoological Park (43.64°N, 3.87°E), for three 1-week sessions at each place. We  
88 monitored artificial prey survival from predation by bird local communities once per  
89 day for four consecutive days after placing them on trunks, and removed them  
90 afterwards. Common birds at each site included great tits (*Parus major*), blue tits  
91 (*Cyanistes caeruleus*), Eurasian jays (*Garrulus glandarius*), common chaffinches  
92 (*Fringilla coelebs*), golden orioles (*Oriolus oriolus*) and European robins (*Erithacus*  
93 *rubecula*). Artificial prey (body and wings) were pinned on evergreen oak (*Quercus*  
94 *illex*) tree trunks (>10cm in diameter, with little or no moss cover) every 10m. To deter  
95 ant attacks, we applied Vaseline and double-sided transparent tape between the  
96 wings and the trunk. Prey were placed perpendicularly to the ground and mostly on  
97 the north-facing side of tree trunks to reduce direct sunlight reflection that could

98 facilitate their detection. We monitored prey survival once per day for the following  
99 four consecutive days after placing them on trunks, and removed them afterwards.

#### 100 Artificial moths

101 Artificial moths consisted of paper wings and an edible body, as described by Arias  
102 *et al* (2020), and similar to other experiments (Cuthill *et al.*, 2005; Stevens & Cuthill,  
103 2006). Wings consisted of paper right triangles resembling resting generic moths  
104 (i.e., not representing any one particular species). Each triangle was 25mm high by  
105 36mm wide, giving a surface area of 450mm<sup>2</sup>. In choosing a printed-colour and paper  
106 combination for the wings, we sought paper that would bear low chromatic and  
107 achromatic contrasts with the oak trunk for birds regardless of whether they had the  
108 UVS or VS visual system. To choose it, we performed reflectance measurements of  
109 evergreen oak trunk colouration (120 measurements on 6 trunks) and we also  
110 measured reflectance from laminated grey paper of a range of grey levels. For that  
111 purpose, we used a deuterium halogen lamp (Avalight DHS) emitting over the 300-  
112 700 nm range, including UV to which birds are sensitive (Chen & Goldsmith, 1986), a  
113 spectrophotometer (Starline Avaspec-2048 L), an optical probe (including both  
114 illumination and measurement fiber optics) with its tip cut at 45° (FC-UV200-2-1.5 x  
115 100, Avantes), and a white diffuse reference (spectralon, WS2). We then calculated  
116 colour and brightness contrasts between paper and trunk as potentially seen by birds  
117 by applying the Vorobyev and Osorio discriminability model (Vorobyev & Osorio,  
118 1998) using the *pavo* package of R software (Maia *et al.*, 2013). We calculated  
119 discriminability for both UVS vision (blue tit, (Hart *et al.*, 2000)) and VS vision  
120 (shearwater, (Hart, 2001)). We used a forest shade light environment (Gomez &  
121 Théry, 2007). Single photoreceptor noise was 0.1 and cone numbers corresponded  
122 to 1:1.7:2.5:3 (U/V:S:M:L) (Hart, 2001; Kram *et al.*, 2010; Rahman *et al.*, 2010;  
123 Baumhardt *et al.*, 2014; Ensminger & Fernández-Juricic, 2014). A Weber fraction of  
124 0.2 was used for the brightness response (as the average reported values for known  
125 bird species (Lind *et al.*, 2013)). Within the range of printed grey papers, we found

126 that colour Grey155 (R=G=B=155), printed on Canson® sketch paper with a HP  
127 officejet pro 6230 printer, was chromatically indistinguishable from trunk coloration  
128 (chromatic contrast of  $0.47 \pm 0.16$  JND for UVS vision and of  $0.41 \pm 0.14$  JND for VS  
129 vision), and marginally lighter than oak trunks (achromatic contrast of  $1.65 \pm 0.69$   
130 JND for UVS vision and of  $1.65 \pm 0.68$  JND for VS vision). The brightness mismatch  
131 ensured that opaque uniformly coloured prey were detectable enough to be predated  
132 upon at high enough rates to be able to test for differences among treatments. Since  
133 achromatic vision is involved in object detection while in motion (Schaerer &  
134 Neumeyer, 1996), it was important that the mismatch occurred on brightness (see  
135 Figure 1 for pictures of the different morphs against their natural background during  
136 the experiment). This design thus enabled us to explore the effect of transparent  
137 windows and their spatial configuration on reducing detectability of imperfectly cryptic  
138 prey.

139 We tested five types of artificial grey moth morphs with different wing  
140 characteristics (Figure 1): an opaque morph (O), a morph with small transparent  
141 windows (SW), a morph with large transparent windows (LW), a morph with large  
142 transparent windows touching the bottom edge of the wing (BE), and a morph with  
143 large transparent windows touching all three wing edges (B3E). Morphs that included  
144 transparent elements were built by cutting two right triangular windows out of the  
145 laminated grey triangle. Dimensions for each triangular window were 10 mm high by  
146 7 mm wide (transparency occupying 70 mm<sup>2</sup>; thus 15% of the original grey surface)  
147 for the SW morph, and 18 mm high by 14 mm wide for the LW, BE and B3E morphs  
148 (transparency occupying 252 mm<sup>2</sup>; thus 56% of the original grey surface). To

149 simulate transparent wing surfaces, we then added a transparent film (3M for inkjet,  
150 chosen for its high transparency even in the UV range; see ESM, Figure S1)  
151 underneath the remaining parts. On top of the moth wings, we added an artificial  
152 body made from pastry dough (428g flour, 250g lard, and 36g water, following  
153 (Carroll & Sherratt, 2013)), dyed grey by mixing yellow, red and blue food dyes  
154 (spectrum in Figure S1). This malleable mixture allowed us to make small bodies on  
155 which we could record marks made by bird beaks and distinguish them from those  
156 made by insects. Morphs were randomised in blocks of 25 artificial moths.

### 157 Data collection and analysis

158 During monitoring, we considered artificial moths as attacked by birds when their  
159 body showed V-shaped or U-shaped marks, or when the body was missing without  
160 signs of invertebrate attacks (i.e. no body scraps left on the wings or around the moth  
161 on the trunk). We removed all remains of artificial moths attacked by birds, and  
162 replaced them when attacked by invertebrates or when the entire artificial prey  
163 (wings, body, and pin) was missing, as we could not exclude that the prey item fell  
164 down or was blown away by the wind. Non-attacked prey items were treated as  
165 censored data in the analyses (i.e. prey that survived at least until the end of the  
166 experiment). We analysed prey survival, applying mixed effects and hierarchical (with  
167 block nested within location) Cox Proportional Hazards models (Cox, 1972) using the  
168 *coxme* package (Therneau, 2020) in R (R Foundation for Statistical Computing,  
169 2014). We tested four models, each of which included different ways of describing  
170 morph visual characteristics as explanatory variables: 1) the morph (O, SW, LW, BE,  
171 B3E, Model 1), 2) the number of borders touched by transparent windows  
172 (continuous variable with 0 in O, SW, and LW, 1 border in BE, and 3 borders in B3E,  
173 Model 2), and 3) the transparent window size (continuous variable describing the  
174 relative surface area of the transparent windows altogether (0 for O, 0.14 for SW and  
175 0.57 for LW, BE and B3E), Model 3), and 4) a model including both transparent  
176 window size and the number of borders touched by transparent windows (Model 4).

177 We used the AICc criterion to compare them. We fitted two additional models to two  
178 subsets of our data. The first included only morphs that had the same transparent  
179 surface area (LW, BE and B3E) in order to evaluate the effect of the number of  
180 borders touched while holding transparent window size constant (Model 5). The  
181 second included only complete border morphs (O, SW and LW) in order to evaluate  
182 the effect of transparent window size while holding the continuity of the border  
183 constant (Model 6). Continuous explanatory variables were scaled for all models.

## 184 **Results**

185 A total of 618 artificial moths were attacked out of the 1733 used in the field  
186 experiment (35.7% attack rate). The model with border characteristics as the  
187 explanatory variable (Model 2) had the lowest AICc value, followed by the model  
188 including both border and surface area characteristics (Model 4), followed by the  
189 model with only surface area characteristics (Model 3, Table S1). The model using  
190 morphs as the explanatory variable was not among the best models according to the  
191 AICc criterion (Model 1, Table S1).

192 Prey with transparent windows touching the borders (morphs BE and B3E)  
193 survived slightly better than morphs with unbroken borders (survival: 68% for morphs  
194 touching the borders versus 62% for morphs with unbroken borders; Model 2: Cox  
195 mixed-effects model coefficient =  $-0.09 \pm 0.04$ ,  $z = -2.2$ ,  $p = 0.03$ , Table S2 and  
196 Figure 2), suggesting that this characteristic rendered morphs less detectable.  
197 However, this difference did not hold when restricting the dataset to morphs with  
198 large transparent windows (Model 5, Cox mixed-effects model coefficient = -  
199  $0.08 \pm 0.05$ ,  $z = -1.49$ ,  $p = 0.14$  for a restricted dataset with 1039 prey and 355  
200 attacks).

201 In model 3, morphs sporting large transparent windows had a marginally  
202 higher survival compared to the other morphs (morphs LW, BE, B3E (66% of  
203 survival) as compared to the morph SW (63% of survival) and the morph and C  
204 (61.4% of survival); Model 3: Cox mixed-effects model coefficient =  $0.07 \pm 0.04$ ,  $z =$

205 1.84,  $p = 0.07$ ). However, the survival of morphs with different transparent surface  
206 areas was not significantly different when restricting the dataset to the morphs with  
207 unbroken borders (Model 6: Cox mixed-effects model coefficient =  $-0.03 \pm 0.05$ ,  $z = -$   
208  $0.54$ ,  $p = 0.59$ , Table S2 for a restricted dataset with 1040 prey and 393 attacks).

209

## 210 **Discussion**

211 The position of transparent elements was the key visual characteristic that  
212 affected moth survival in our experiment. However, the role of transparent window  
213 size was less clear. Model 2, which included only border characteristics, had the  
214 lowest AICc and also the only significant effect out of all of the statistical models.  
215 Adding an effect of transparent window size (Model 4) did not improve model fit.  
216 Including only an effect of window size (Model 3) yielded a marginally significant  
217 effect. This marginally significant effect was likely a spurious effect driven by border  
218 characteristics, however, as two of the three morphs with large windows also had  
219 broken borders, whereas the morphs with small (SW) and non-existent (O)  
220 transparent windows had complete borders. The fact that SW morphs had slightly  
221 higher survival than LW morphs (Fig. 2) further supports the conclusion that the  
222 marginally significant effect of window size in model 3 was spurious. It is puzzling  
223 that subsetting the dataset to include only morphs with the same transparent window  
224 size (LW, BE, B3E) yielded no significant effect of border (Model 5). Our best  
225 explanation is that this reduced dataset lacked statistical power due to the lower  
226 sample size. However, the lack of significance in this reduced dataset prevents us  
227 from completely excluding the possibility that transparent window size had an effect  
228 on the results of model 2. Further experiments producing larger datasets are needed  
229 to clarify the importance of transparent window size on prey survival.

230 In aquatic organisms, increased camouflage effect for transparency touching  
231 animal edges has been suggested, but never tested experimentally. Bagge *et al*  
232 (2016) have found in several hyperiid species (Amphipods, Crustacea) that their

233 transparent appendages – which facilitate prey detection when visible - have more  
234 efficient antireflective nanostructures than the rest of the body, probably due to a  
235 stronger selective pressure for camouflage on body contour elements. In terrestrial  
236 organisms, Barnett et al (2020) have explored the effect of translucent elements (low  
237 transparency and high reflection levels) in glass frogs, which smoothen the animal-  
238 environment transition by increasing environmental reflections around the animal  
239 contour. In our experiment, morphs with broken contours had higher survival than  
240 morphs with complete contours. We thus provide the first experimental evidence that  
241 transparency (high transmission and reduced reflection) can function better when  
242 disrupting animal edges. As found in opaque species (Cuthill *et al.*, 2005; Schaefer &  
243 Stobbe, 2006; Fraser *et al.*, 2007), our results suggest that breaking the body outline  
244 is more efficient at reducing prey detectability than matching the background while  
245 keeping all borders intact. It would be interesting to test whether the advantage of  
246 transparent windows disrupting wing edges would remain if the opaque portions of  
247 the wings more closely matched bark brightness or had patterns mimicking the  
248 heterogeneous visual texture of real tree bark.

249         Despite the fact that several Lepidoptera species show transparent elements  
250 breaking prey edges, including the cossid *Zeuzera pyrina*, the noctuid *Gaujonia*  
251 *arbosi* and the erebids *Hypercompe robusta*, *Perina nuda* and *Senecauxia coraliae*,  
252 the disruption of wing outline is actually rather uncommon in butterflies and moths  
253 exhibiting transparent wing elements. Transparency in wings is sometimes combined  
254 with highly visible wing edges as in several bee/wasp mimics, such as the hawk-  
255 moth *Hemaris fuciformis* as well as in the unpalatable Ithomiini tribe. Transparent  
256 elements in these latter species may reduce prey detectability as they are large  
257 transparent zones that one would expect to enhance background matching (Arias *et*  
258 *al.*, 2019; McClure *et al.*, 2019). However, transparency in these species could also  
259 potentially function as a means of visual communication such as mimicry (Pinna *et*  
260 *al.*, 2021). It is also possible that in the relatively large-winged Lepidoptera, evolving



261 transparent areas touching wing edges is constrained by factors linked to wing  
262 strength or flight dynamics. Whether transparent zones not surrounded by opaque  
263 borders are indeed more fragile or more sensitive to wind and/or water than opaque  
264 patches remains an open question.

265         However, in contrast to the recent findings reported by Arias *et al* (2020), we  
266 did not find that the mere presence of transparent elements decreases detectability  
267 in imperfectly uniformly coloured cryptic prey (no significant survival difference  
268 between morphs “O”, “SW” and “LW” in Model 3 and Figure 2). Perhaps the overall  
269 attack rate in our field experiment was too high to see differences in predation rates  
270 among morphs. The attack rate in this experiment was over double that of the study  
271 by Arias *et al* (2020) study carried out under similar conditions (35.1% in the current  
272 study vs. 14.08% in (Arias *et al.*, 2020)). Under strong predation pressure, once the  
273 most detectable prey morphs in a given area have already been attacked, less  
274 detectable prey are more likely to be attacked. This could potentially have led to a  
275 homogenization of attack rates among morphs. Another difference between our  
276 study and that of Arias *et al.* (2020) was the number of morphs simultaneously  
277 available to predators. Instead of three prey types, including two moth-like types as in  
278 Arias *et al.* (2020), the present study included five moth-like forms with fewer  
279 phenotypic differences among them, which may have elicited less divergent predator  
280 reactions to each of them. Certain levels of phenotypic similarity, such as that  
281 exhibited by imperfect mimics, is often enough to trigger predator generalization and  
282 a similar response to distinct phenotypes (Ruxton *et al.*, 2008; Kikuchi & Pfennig,  
283 2010; Arias *et al.*, 2016). Additionally, feeding on many instead of a small number of  
284 prey types affects detection of changes in predator foraging behavior. For instance,  
285 theoretical approaches suggest that prey switching (i.e. when a given prey becomes  
286 relatively more abundant in predators’ diet (Murdoch, 1969)) is less marked and  
287 more difficult to detect when predators feed on a greater diversity of prey items (van  
288 Leeuwen *et al.*, 2013).

289 Overall, according to the results of our fieldwork experiment, having transparent  
 290 elements breaking at least one prey border seems to be the most effective  
 291 mechanism for reducing detectability of prey and subsequent predation.

## 292 **Data Availability Statement**

293 Field experiment data is available in Dryad (doi:10.5061/dryad.3n5tb2rjb)

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407

408

409 **Figure Legends**

410

411 Figure 1. Examples of the diversity of position and size of transparent elements in  
412 butterflies and moths. a. The thyridid *Siculodes aurorula* shows small windows  
413 (indicated by the yellow arrow, photo: © Adrian Hoskins), b. The erebid *Carriola*  
414 *ecnomoda* shows large windows (wingspan ~ 40mm, photo: © Ann van Wijgerden  
415 via projectnoah.org), c. The erebid *Hypercompe scribonia* shows windows breaking  
416 the bottom edge (wingspan 76 mm, photo: © Green Futures). d. the 5 artificial moths  
417 used in this study (25mm high by 36mm wide) against a white background and  
418 against the natural background used during the experiment.

419

420 Figure 2. Survival of artificial prey without transparent elements (O-opaque), with  
421 small (SW) and large (LW) transparent elements touching none, one (B1E) or three  
422 prey edges (B3E). Artificial butterflies were placed on tree trunks and monitored for  
423 their 'survival' every day for 4 days. Data from the six weeks during which the  
424 experiment was conducted are pooled together.

425

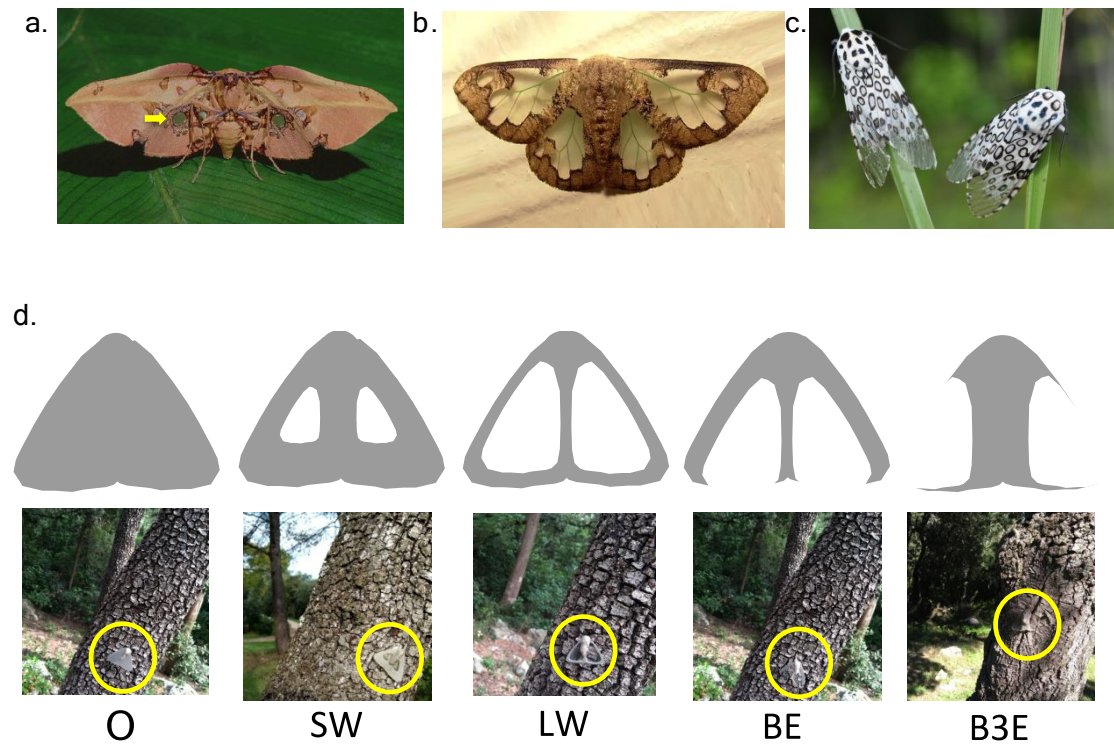


Figure 1

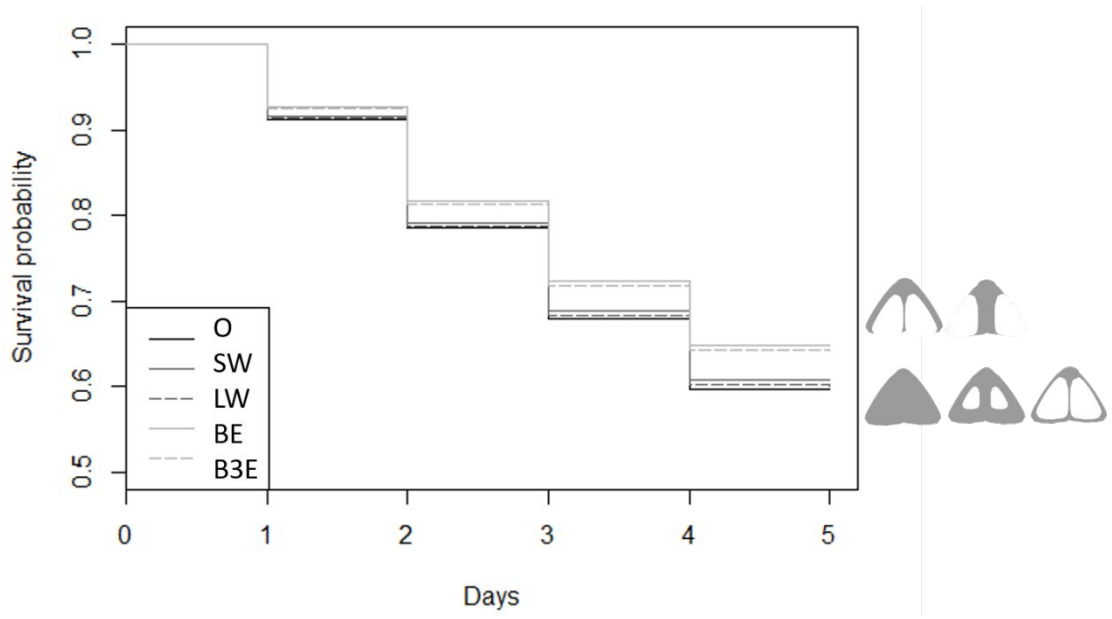


Figure 2



## Electronic supplementary material

### Partial wing transparency works better when disrupting wing edges: evidence from a field experiment

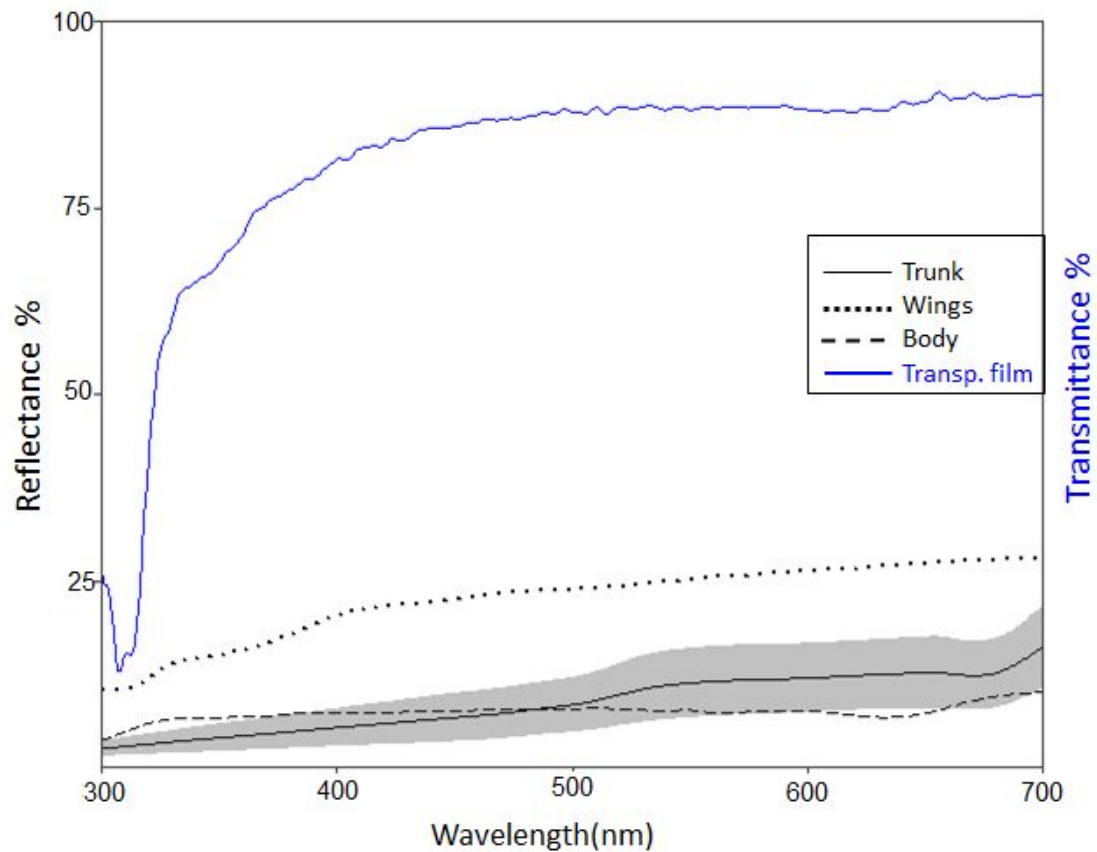


Figure S1. Reflectance spectra of the background (oak tree trunks in solid black line with a confidence interval of  $\pm 1$  standard deviation) and opaque areas: body (dashed line) and opaque wings (dotted line), and transmittance of the transparent film (solid blue line).

Table S1. AICc of mixed effect and hierarchical (with block nested within location) Cox Proportional Hazards models on morph attack. Models are ranked according to their AICc values, from lowest (best fit) to highest. K stands for the number of parameters and delta AICc for the difference in AICc with the best model.

Model	Number of prey	Number of attacks	Exp. variables	K	AICc	Delta AICc
2	1733	618	Border	3	8571.15	0
4	1733	618	Border+Surface	4	8572.66	1.50
3	1733	618	Surface	3	8572.85	1.69
1	1733	618	Morph	6	8576.59	5.44

Table S2. Results from different mixed effect and hierarchical (always with block nested within location) Cox Proportional Hazards model on morph attack

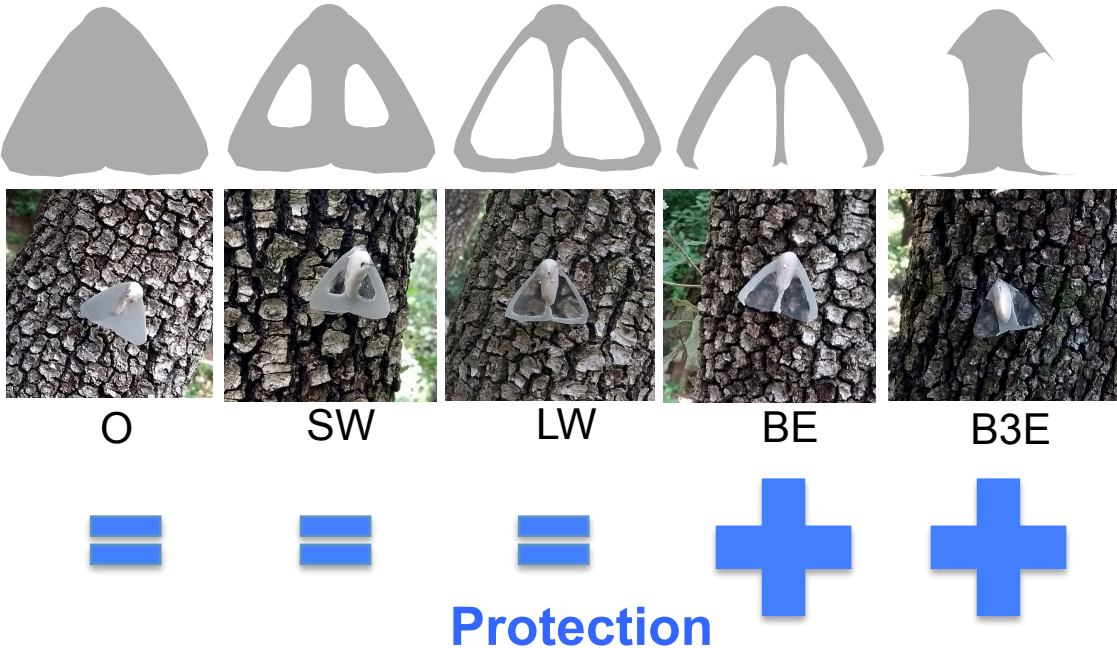
	Number of prey	Number of attacks	Morphs included	Variable	Coef. $\pm$ SE	z	<i>p</i> -value
Model 2	1733	618	All	Border	-0.09 $\pm$ 0.04	-2.2	0.03
Model 4	1733	618	All	Border	-0.07 $\pm$ 0.05	-1.47	0.14
				Surface	0.03 $\pm$ 0.05	0.71	0.48
Model 3	1733	618	All	Surface	0.07 $\pm$ 0.04	1.84	0.07
Model 5	1039	355	Large windows	Border	-0.08 $\pm$ 0.05	-1.49	0.14
Model 6	1040	393	Unbroken edges	Surface	-0.03 $\pm$ 0.05	-0.54	0.59

Each row shows the explanatory variable used in each model and the results obtained. Models 2-4 were fitted using the entire dataset and are the best models according to the AIC criteria (Table S1). Model 5 explored the survival variation explained by border characteristics between LW (0 broken edges), BE (1 broken edge) and B3E (3 broken edges) in morphs with a constant transparent surface area. Model 6 explored survival variation explained by transparent surface area between O (0 transparent surface), SW (15% of the original opaque surface) and LW (56% of the original opaque surface) thus, only including morphs with unbroken edges.

Transparent elements of different sizes and positions can be found on insect prey. Do these elements confer similar protection against visual predators?



We performed field experiments with 5 artificial forms varying in surface area and position of their transparent elements.



We found that transparent elements are most effective when disrupting wing edges