

Lichter-Marck, I. H., Wylde, M., Aaron, E., Oliver, J. C. and Singer, M. S. 2014. The struggle for safety: effectiveness of caterpillar defenses against bird predation. – *Oikos* doi: 10.1111/oik.01515

Appendix 1

Bird exclusion experiment

Bird exclosures consisted of bags (2.13×2.13 m) constructed from nylon netting (13 or 20 mm mesh size) sealed around branches with a strip of Velcro. We paired each bird-excluded branch or sapling with a control branch or sapling (lacking bird exclosure) of the same tree species matched for spatial proximity, height, and size. Field sites were divided into four to six spatially independent blocks in which we applied the bird-exclusion treatment to branches and saplings in the late spring (May) for four successive years (2008–2011). Experimental treatments were removed before the end of each growing season (October). To scale caterpillar abundance to leaf area (no. m^{-2} foliage), in 2008 and 2009, we counted the number of leaves on each sampling branch, collected 10 intact leaves from each branch, and measured them with a leaf areameter. We used 2008-2009 mean leaf areas for each host-plant species at each site to calculate total leaf areas in 2010 and 2011.

To verify that the response variable of LRR was truly a measure of the magnitude of bird exclusion effects and hence bird predation effects, we compared caterpillar densities on experimental and control branches before and after applying bird exclosures during the 2010 and 2011 field seasons. As we identified each experimental and paired control branch during the set-up period in May, we sampled caterpillars as described in the Methods. For each caterpillar species with 10 or more records accumulated across the set-up periods in 2010 and 2011 ($n = 7$ species), we calculated its density on branches destined for experimental as well as on branches destined for control treatments. We calculated LRR based on these data (pre-treatment LRR) as described in the

Methods. We then calculated the mean and 95% confidence intervals of the pre-treatment LRR. We determined that the mean pre-treatment LRR was not significantly different from zero because its upper 95% confidence interval overlapped with zero (Supplementary material Appendix 1 Fig. A5). The same procedure was used to determine post-treatment LRR values for the set of caterpillar species present during the set-up periods in 2010 or 2011 with 10 or more records accumulated across the experimental sampling periods in 2010 and 2011 ($n = 6$ species). We determined that the mean post-treatment LRR most comparable to the mean pre-treatment LRR was significantly different from zero because its 95% confidence interval did not overlap with zero (Supplementary material Appendix 1 Fig. A5).

Apparency

We categorized any caterpillar with hairlike setae that were visible without a hand lens as 'hairy,' and any caterpillar lacking conspicuous setae as 'smooth'. We called any caterpillar that was predominantly green or brown 'camouflaged', and any species with an appearance dominated by white, red or yellow 'warningly colored'. We also scored caterpillars for possession of an osmeterium. None of the caterpillars in our sample had spine-like setae. We sent our assessment to David L. Wagner (Univ. of Connecticut), who was blind to our data on magnitude of bird predation, and he revised it and gave feedback. Our final scoring of caterpillar color and morphology was based on this revised assessment.

Camouflage

The computer program we used to record latency randomized the order that images were presented as follows: 1) by randomly selecting a subset of 40 images without duplication from a library of 99 and 2) by presenting those images in random order. To partially control for caterpillar size, we chose a library of 99 images in which the caterpillar length was restricted to a range of 3 to 7 cm when displayed on the test screen (15 inch Emachines HD monitor). To reduce location bias, we

made images in which the caterpillar was somewhere other than in the center of the image; the location of the caterpillar varied among images. The number of image replicates per caterpillar species – number of images (number of caterpillar species) – were distributed as follows: 1(5), 2(13), 3(10), 4(5), 5(1), 6(1), 7(1). To test for the undesired effect of caterpillar image size on latency, we performed a linear regression with image size as a predictor of mean latency ($R^2 < 0.002$, $n = 99$, $p = 0.82$). To test for the undesired effect of image replication on latency, we performed a general linear model with the number of image replicates as a predictor of mean latency ($R^2 = 0.03$, $n = 36$, $p = 0.28$). The non-significance of these analyses is evidence that these possible spurious effects did not strongly determine latency values.

Table A1. Taxonomic checklist, putative defenses, and bird predation risk of the caterpillar species in this study. Species possessing warning signals (WS) include some combination of the following: bright coloration (color), conspicuous setae (hairy), colorful eversible organ emitting odor (osmeterium). Bird predation risk of each species is estimated as a log response ratio (LRR).

Species	Family	Putative defense	LRR
<i>Machimia tentoriferella</i>	Amphisbatidae	camouflage	1.143
<i>Malacosoma disstria</i>	Lasiocampidae	WS (color, hairy)	0.878
<i>Papilio glaucus</i>	Papilionidae	WS (color, osmeterium)	-2.331
<i>Satyrium calanus</i>	Lycaenidae	camouflage	0.0672
<i>Satyrium liparops</i>	Lycaenidae	camouflage	-0.603
<i>Alsophila pometaria</i>	Geometridae	camouflage	1.002
<i>Itame pustularia</i>	Geometridae	camouflage	0.208
<i>Iridopsis ephyraria</i>	Geometridae	camouflage	0.486
<i>Melanolophia canadaria</i>	Geometridae	camouflage	0.781
<i>Hypagyrtis unipunctata</i>	Geometridae	camouflage	0.822
<i>Lomographa glomeraria</i>	Geometridae	camouflage	0.442
<i>Lomographa vestaliata</i>	Geometridae	camouflage	0.965
<i>Ennomos subsignaria</i>	Geometridae	camouflage	0.0576
<i>Besma quercivoraria</i>	Geometridae	camouflage	1.302
<i>Eutrapela clemataria</i>	Geometridae	camouflage	1.202
<i>Prochoerodes lineola</i>	Geometridae	camouflage	0.560
<i>Nematocampa resistaria</i>	Geometridae	camouflage	0.560
<i>Nadata gibbosa</i>	Notodontidae	camouflage	0.185
<i>Heterocampa guttivitta</i>	Notodontidae	camouflage	-0.539
<i>Parallelia bistriarius</i>	Erebidae	camouflage	0.454
<i>Zale lunata</i>	Erebidae	camouflage	0.965
<i>Zale lunifera</i>	Erebidae	camouflage	0.965
<i>Orgyia leucostigma</i>	Erebidae	WS (color, hairy)	1.072
<i>Lymantria dispar</i>	Erebidae	WS (hairy)	0.724
<i>Nola triquetrana</i>	Nolidae	WS (color, hairy)	0.172
<i>Acronicta hasta</i>	Noctuidae	WS (color, hairy)	-1.455
<i>Amphipyra pyramidoides</i>	Noctuidae	camouflage	1.166
<i>Lithophane antennata</i>	Noctuidae	camouflage	0.998
<i>Lithophane hemina</i>	Noctuidae	camouflage	1.371
<i>Lithophane patefacta</i>	Noctuidae	camouflage	2.169
<i>Pyreferra hesperidago</i>	Noctuidae	WS (color)	-0.316
<i>Orthosia hibisci</i>	Noctuidae	camouflage	1.860
<i>Orthosia rubescens</i>	Noctuidae	camouflage	1.071
<i>Crocigrapha normani</i>	Noctuidae	camouflage	0.965
<i>Himella intractata</i>	Noctuidae	camouflage	0.477
<i>Achatia distincta</i>	Noctuidae	camouflage	0.799
<i>Morrisonia confusa</i>	Noctuidae	camouflage	0.975
<i>Morrisonia latex</i>	Noctuidae	camouflage	1.067

Table A2. Bird species, number of times counted, and relative abundance (no. counted / total no. of birds counted) in thirty 5-min point counts from a 2010 and 2011 bird survey at our field sites.

Foliage-gleaning insectivores are shown in bold.

Common name	Scientific name	No. counts	Relative abundance
American crow	<i>Corvus brachyrhynchos</i>	3	0.6
American redstart	<i>Setophaga ruticilla</i>	2	0.4
American robin	<i>Turdus migratorius</i>	20	4.4
Baltimore oriole	<i>Icterus galbula</i>	1	0.2
Barred owl	<i>Strix varia</i>	1	0.2
Black and white warbler	<i>Mniotilta varia</i>	8	1.7
Black capped chickadee	<i>Poecile atricapilla</i>	31	6.9
Blue jay	<i>Cyanocitta cristata</i>	14	3.1
Blue-gray gnatcatcher	<i>Poliophtila caerulea</i>	18	4
Brown headed cowbird	<i>Molothrus ater</i>	1	0.2
Chipping sparrow	<i>Spizella passerina</i>	8	1.7
Downy woodpecker	<i>Picoides pubescens</i>	6	1.3
Eastern wood pee-wee	<i>Cantopus virens</i>	29	6.4
Gray catbird	<i>Dumetella carolinensis</i>	7	1.5
Hairy woodpecker	<i>Picoides villosus</i>	2	0.4
Hermit thrush	<i>Catharus guttatus</i>	1	0.2
Mourning dove	<i>Zenaida macroura</i>	1	0.2
Northern cardinal	<i>Cardinalis cardinalis</i>	20	4.4
Oven bird	<i>Seiurus aurocapillus</i>	82	18.3
Philadelphia vireo	<i>Vireo philadelphicus</i>	2	0.4
Pileated woodpecker	<i>Dryocopus pileatus</i>	1	0.2
Raven	<i>Corvis corax</i>	5	1.1
Red bellied woodpecker	<i>Melanerpes carolinus</i>	1	0.22
Red eyed vireo	<i>Vireo olivaceus</i>	50	11.1
Red winged blackbird	<i>Agelaius phoeniceus</i>	1	0.2
Ruby throated hummingbird	<i>Archilochus colubris</i>	1	0.2
Scarlet tanager	<i>Piranga olivacea</i>	17	3.7
Tufted titmouse	<i>Baeolophus bicolor</i>	50	11.1
Veery	<i>Catharus fuscescens</i>	21	4.6
White-breasted nuthatch	<i>Sitta carolinensis</i>	3	0.6
Wood thrush	<i>Hylochicla mustelina</i>	17	3.7
Worm eating warbler	<i>Helmitheros vermivora</i>	12	2.6

Table A3. Operational descriptions of behavioral categories. These categories were used in an assay of caterpillar responses to simulated attack by a bird with blunt forceps.

Behavior	Description
Thrash	rapidly jerked body
Bite	closed mandibles upon forceps
Regurgitate	regurgitated liquid substance
Hold on	gripped substrate with legs and/or prolegs
Drop	dropped from substrate
Evade	locomoted away
Still	no observable behavior

Figure A1. Color photographs of forest caterpillars from this study. A) *Heterocampa guttivitta* B) *Amphipyra pyramidoides* C) *Morrisonia confusa* D) *Besma quercivoraria* E) *Nadata gibbosa* F) *Parrallelia bistriarius* G) *Satyrium liparops* H) *Orgyia leucostigma* I) *Pyreferra hesperidago* J) *Lymantria dispar* and K) *Papilio glaucus*. Photographs by ILM.

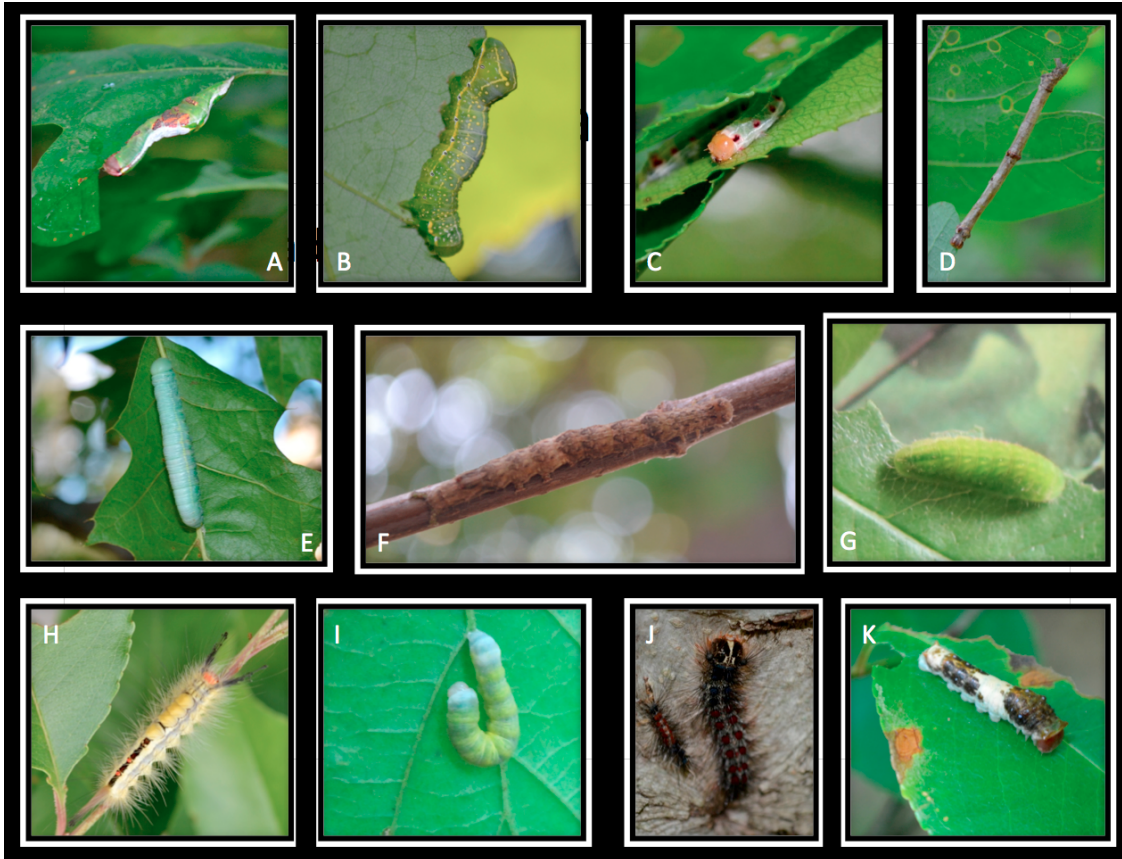


Figure A2. Example image from an experimental bioassay measuring the camouflage of forest caterpillars. The species depicted here is *Amphipyra pyramidoides*.



Figure A3. Example image from an experimental bioassay measuring the camouflage of forest caterpillars. The species depicted here is *Nadata gibbosa*.



Figure A4. Composite phylogeny of the caterpillar species included in this study.

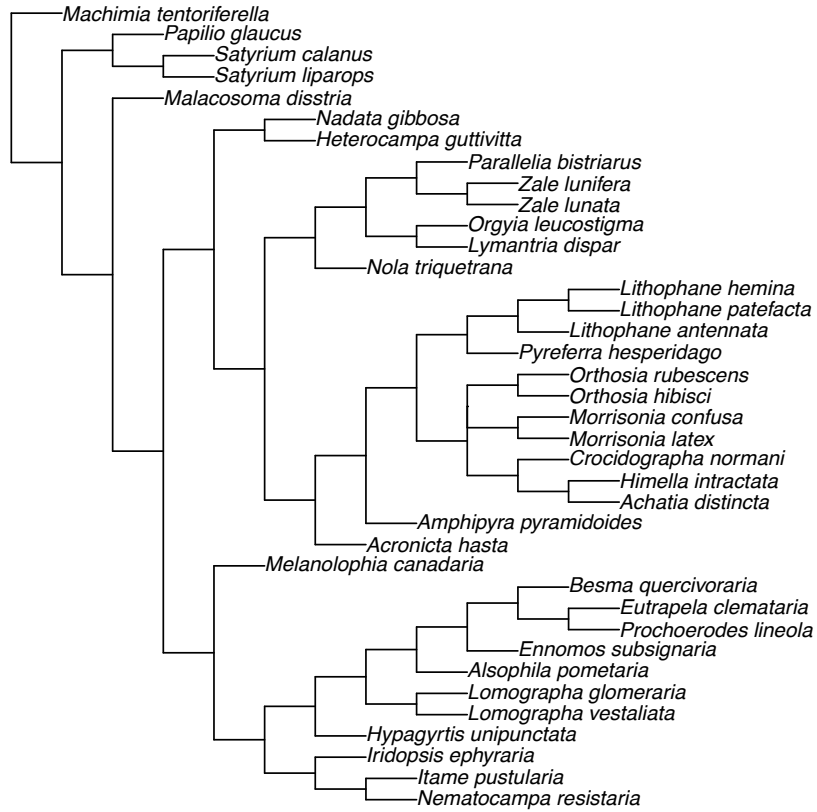


Figure A5. Mean and 95% confidence intervals of LRR of caterpillar species before (pre-treatment) and after (post-treatment) implementation of the bird-exclusion treatment based on the 2010 and 2011 field seasons. The horizontal line intercepting the y-axis at zero is included to illustrate any overlap between the 95% confidence interval and zero.

