Scientific Note: Capturing a green *Morpho*: In polarized low light in the tropical rainforest, *Morpho* wing iridescence may contribute to camouflage

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Abstract: *Morpho* Fabricius, 1807 species have served as models for producing bioinspired materials with variable structural colors, which have wide applications. Our recent field observation in French Guiana, suported by a lab experiment, demonstrates that the dorsal surface of *Morpho menelaus* can produce cryptic green coloration in low-light reflected from green vegetation. These observations are consistent with recently published evidence from experiments on jewel beetles that iridescent color is an effective form of camouflage.

"*The trees grew close together and were so leafy that he could get no glimpse of the sky. All the light was green light that came through the leaves: but there must have been a very strong sun overhead, for this green daylight was bright and warm*."
From *The Magician's Nephew*, by C. S. Lewis.

In the dark understory of the primary rainforest, a *Morpho menelaus* (Linnaeus, 1758) (Nymphalidae) resting on vegetation at 1.5 m above the ground was lightly contacted by our guide's machete to initiate a flight response (see Sourakov & Houlihan (2017) for details about the study site). We fired two Canon DSLR cameras simultaneously at the immediate moment when the individual lifted off from the vegetation. One camera (an older Ti) had an on-camera flash, while the other (a more recent 5Ds) had enough light sensitivity to freeze the specimen in flight using ambient light only. Both cameras were operated in manual mode. The colors in the two images contrasted greatly (Fig. 1A,B): under natural light, the insect's wings appeared green, blending with the surrounding vegetation, the color of which is accurately represented in the image (Fig. 1B). The effect observed in the natural-light photo may have been due to the prevalence of polarized green light in the environment, since light coming from above was obscured by the dense canopy. Using a museum specimen of *M. menelaus*, we took photographs in the lab in varying light conditions (Fig. 1C,E).

An indirect white LED light shone through a green filter and reflected from a green surface replicated almost exactly the wing color of *M. menelaus* captured *in situ* in the forest (Fig. 1D,E). One iconic aspect of *Morpho* Fabricius, 1807 butterflies is the presence in a number of species of colorless scales covering large sections of their dorsal wing surfaces (Ghiradella, 1991), which reflect visible light from different angles and intensities in various shades color spectrum (Vukusic *et al.*, 1999; Vukusic & Sambles, 2003). The mechanism behind this optical illusion is well-studied (Kinoshita *et al.*, 2002), but for detailed analysis of similarities and differences in optical coloration of *Morpho* butterflies, one is referred to Berthier *et al.* (2006), who clearly demonstrate (p. 150) the reflectivity of *M. menelaus* scales and how it changes with light angle and light mode. This latter study provides ample theoretical explanations for our natural history observation presented here. Another species with documented green reflectance in a natural setting while flying in the canopy, *Morpho rhetenor* (Cramer, 1775), was studied in detail by Plattner (2004), who demonstrated that this species' scales are adapted to reflect most of the light below 550 nm at all angles with near-complete transmission at wavelengths above the threshold of 550 nm. As a result, this species' wings could potentially serve as a near-perfect mirror reflecting light coming from surrounding vegetation. Interspecific differences in structural colors have been linked not only to *Morpho* evolutionary history, but also to the strata within the forest where species fly (Cassildé *et al.*, 2010). There has been an increasing number of applications of these structural colors for engineering (e.g., Chung *et al.*, 2002), nanotechnology (e.g., Fu *et al.*, 2016), and biomimicry (e.g., Das *et al.*, 2017). A new biosensor was developed by culturing cardiomyocytes on *M. menelaus*'s wing surface, and the contractions of these mammalian cells was detected through optical color shifts from blue to green on the butterfly's wings (Chen *et al.*, 2018). Beyond *Morpho*, two recent studies by Kjernsmo *et al.* (2018, 2020) examined iridescence as a form of camouflage, demonstrating that this optical phenomenon may serve as a defensive trait through interference with object recognition by predators. The role of iridescent coloration as a predator-avoidance mechanism in *Morpho* butterflies remains to be demonstrated experimentally.

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Fig. 1. (A,B) *Morpho m. menelaus*, French Guiana, taking off. Two Canon DSLR cameras photos: **(A)** with built in flash (© Andrei Sourakov); **(B)** with natural light (© Peter Houlihan). **(C-E)** Forewing of *Morpho menelaus*: **(C)** museum specimen illuminated by incandescent light; **(D)** *in situ*, under low natural light of the forest understory, French Guiana (fragment of Fig. B); **(E)** museum specimen illuminated by green light reflected from a green surface.

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