

Rapid Shifts in Visible Carolina Grasshopper (*Dissosteira carolina*) Coloration During Flights

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FEAR, CONFUSION, AND VISION

- *D. carolina* is brown and **camouflaged** at rest (**Fig. 1A**), but **contrasting** black & cream hindwings **appear rapidly** during takeoff (**Fig. 1B**), then **oscillate unpredictably** during flight before **disappearing** upon landing
- Rapid appearance may be startle defense against passerine bird predators (e.g. moth wing eyespots), oscillation may be protean defense (e.g. zig-zagging during flight to confuse predators)
- However, the **temporal dynamics** have not been studied, especially when considering different temporal vision.



Figure 1. *D. carolina* at rest (**A**) and during flight (**B**). Photos courtesy of Brae Salazar.

SEEING THROUGH NEW EYES

1. Filmed 300+ grasshoppers flying at 480 fps, then picked 8 best landings & 8 best takeoffs
2. Graphed amount of each color (**brown**, **black**, and **cream/yellow**) visible over 1st 120 frames (0.25 secs) of each takeoff (**Fig. 2**) & last 120 frames of each landing (**Fig. 3**)
3. Used sampling to **simulate color changes** through lower "framerate" (CFF) vision; blended every 8 frames into 1 for 60 Hz human/grasshopper vision, 4 into 1 for 120 Hz passerine bird vision (**Fig. 4**)

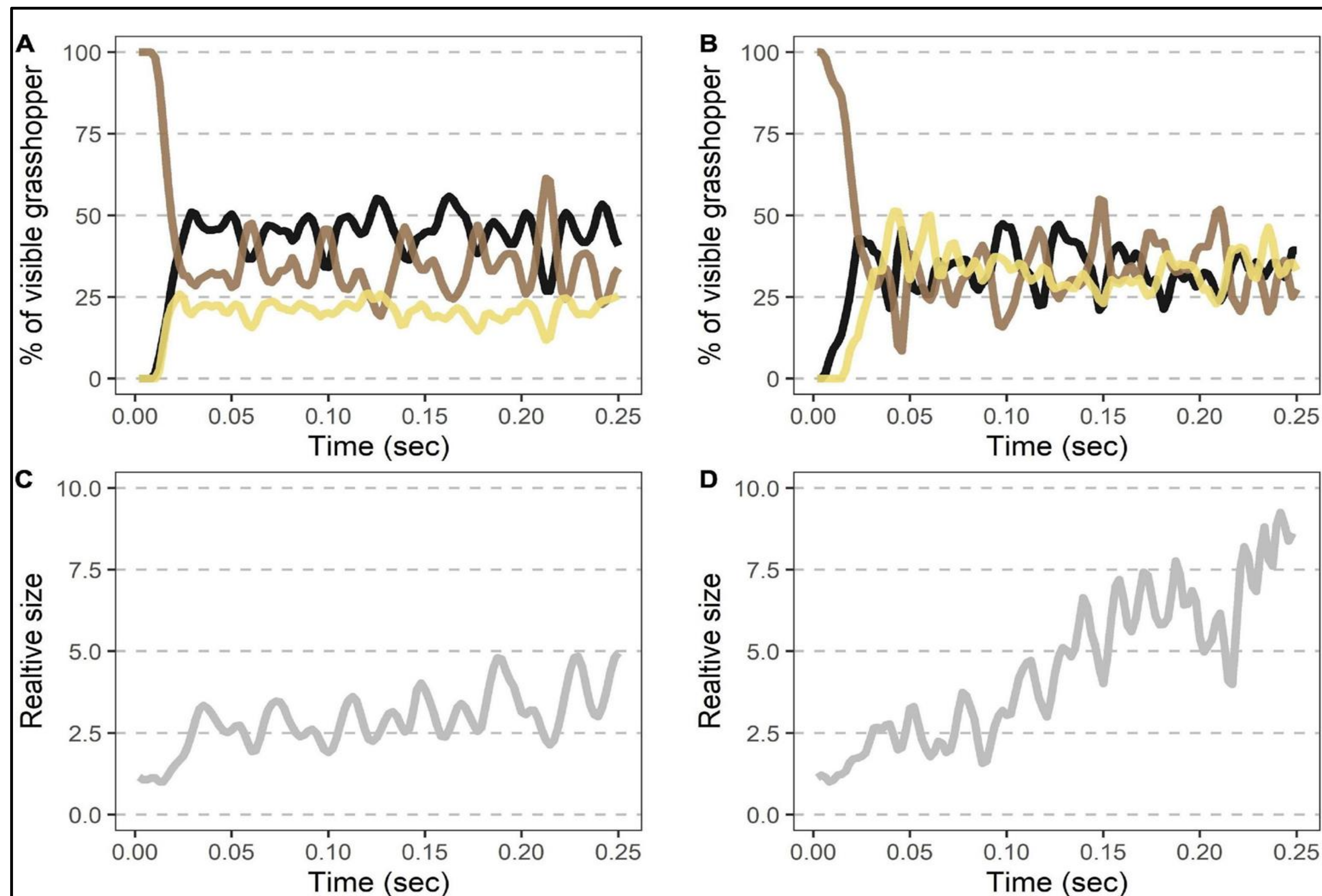


Figure 2 Rapid shifts in visible color regions and size during **takeoffs**. (**A**) and (**B**) show visible coloration during example flights, while (**C**) and (**D**) show changes in relative size during the same flights. In each takeoff, there is (1) a quick transition from a brown, resting grasshopper to a hindwing display (average time to 50% of the viewable grasshopper being hindwings = $7.6 \text{ ms} \pm 1.5 \text{ SEM}$), followed by (2) oscillation of visible coloration.

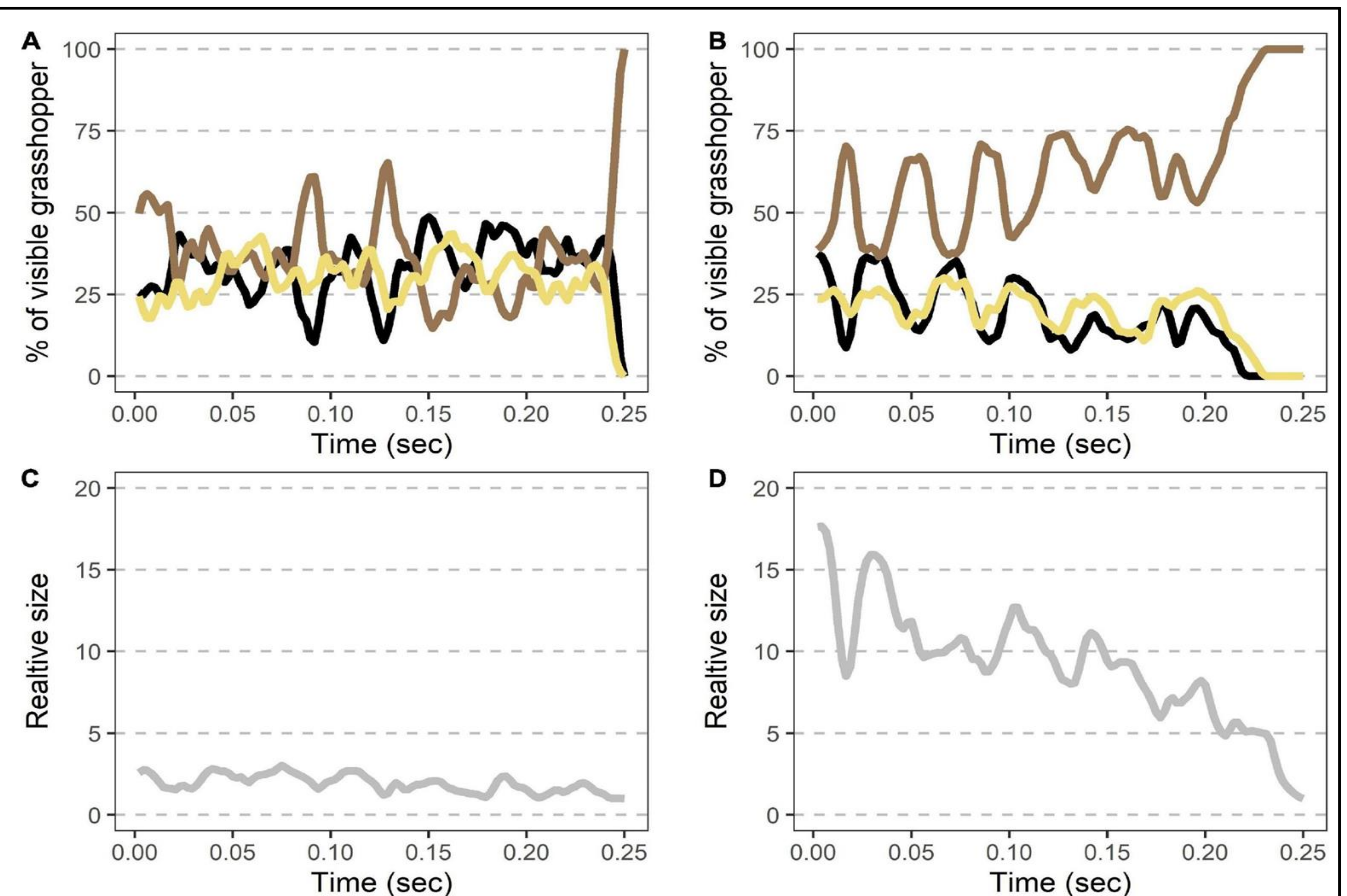


Figure 3. Rapid shifts in visible color regions and size during **landings**. (**A**) and (**B**) show visible coloration during example flights, while (**C**) and (**D**) show changes in relative size during the same flights. In each landing, there is (1) a period of color oscillation followed by (2) a rapid return to the brown camouflaged coloration (time from 50% brown to fully brown = $11.3 \text{ ms} \pm 3.0$). In general, the return to camouflage was slower and more variable in speed than during takeoffs.

FASTER THAN THE EYE CAN SEE

- Takeoff: **camouflage** → **contrast** in $11.46 \pm 4.02 \text{ ms}$
- Main flight: wings **oscillated wildly** during (**Fig. 4**)
- Landing: **contrast** → **camouflage** in $20.57 \pm 12.72 \text{ ms}$
- Further observation of wild passerine bird behavior is necessary to test these hypotheses

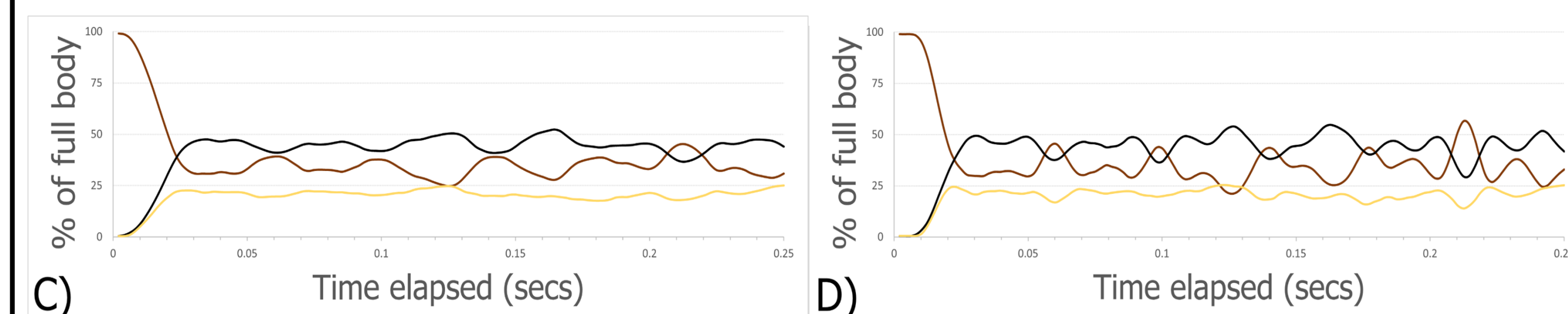


Figure 4. A typical takeoff modeled in 60 Hz vision (resolvability threshold = 16.67 ms) (**C**) and 120 Hz (resolvability threshold = 18.33 ms) (**D**). Oscillations during main flight were more intense in 120 Hz models than in 60 Hz models.

LITERATURE CITED Belovsky, G. E., and J. B. Slade. 1993. The Role of Vertebrate and Invertebrate Predators in a Grasshopper Community. *Oikos* 68:193. Boström, J. E., M. Dimitrova, C. Canton, O. Håstad, A. Qvarnström, and A. Ödeen. 2016. Ultra-Rapid Vision in Birds. *PLOS ONE* 11. Cooper, W. E. 2006. Risk factors and escape strategy in the grasshopper *Dissosteira carolina*. *Behaviour* 143:1201–1218. Healy, K., L. McNally, G. D. Ruxton, N. Cooper, and A. L. Jackson. 2013. Metabolic rate and body size are linked with perception of temporal information. *Animal Behaviour* 86:685–696. Miall, R. C. 1978. The flicker fusion frequencies of six laboratory insects, and the response of the compound eye to mains fluorescent "ripple." *Physiological Entomology* 3:99–106.