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The Role of Male Flight Performance in the Evolution of Extreme Sexual Dimorphism in Leaf Insects

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THE ROLE OF MALE FLIGHT PERFORMANCE IN THE EVOLUTION OF EXTREME SEXUAL DIMORPHISM IN LEAF INSECTS

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SUMMARY

In many insect groups, males are much smaller than females. While selection for large females through fecundity benefits is well understood, selection for small males through increased mobility is often assumed but rarely tested empirically. Small males are thought to benefit from increased mobility, enabling them to seek out mates more readily. We studied the relationship between male body size and flight performance in males of the leaf insect *Phyllium philippinicum* to determine if smaller males indeed display enhanced mobility. Females of this species do not fly, so they were excluded. We found that flight performance was negatively associated with male body size, as predicted. Maximum vertical velocity and mean stable velocity were lower in larger individuals. Larger males were also less maneuverable. Finally, males did not appear to compensate for large size through development of disproportionately larger wings. Consequently, our results provide empirical evidence that smaller males are more mobile, contributing to our understanding of the evolution of sexual dimorphism in these insects.

METHODS

Phyllium live in canopies of trees and are susceptible to being knocked off and falling. We simulated this by dropping the males to initiate flight. We recorded videos (500 frames per second) of 17 individuals flying and used Matlab to mark the head and the tail tip in each frame. Velocity and body angle were measured using customized coding in R. Mounted insect wings were analyzed using ImageJ to calculate area and wing loading. Insect size was determined by mass. Wing loading was calculated as wing area divided by mass.

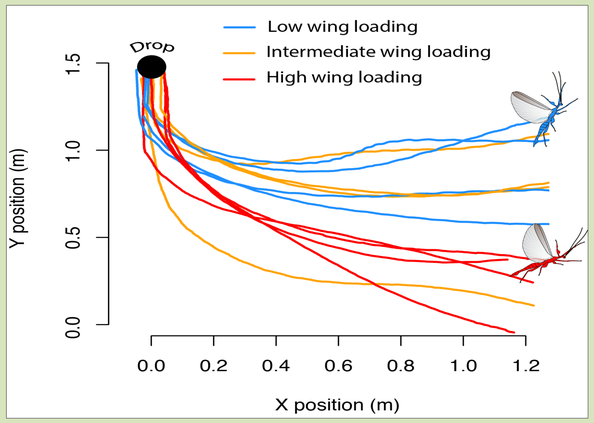

FIGURE 1 – Larger males lose more potential energy

FIGURE 2 – *Phyllium philippinicum* Male and Female

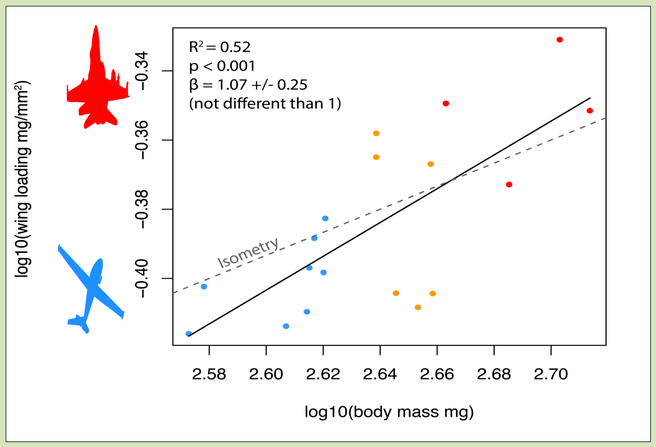

FIGURE 3 – Larger males have higher wing loading

Because wing loading is related to the amount of power required for flight, larger males are likely to fly more efficiently than smaller males.

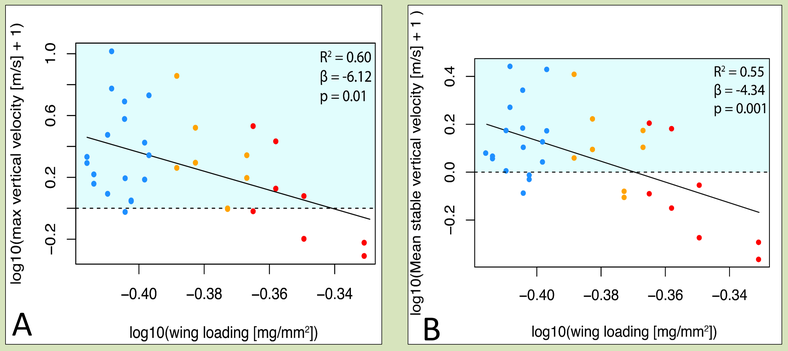

FIGURE 4 – Wing loading affects vertical flight performance

- Above the y = 0 line (blue area) is ascension and below is descension
- Fig. 4A: Maximum vertical velocity is representative of an individual's peak performance in a given trial.
- Fig. 4B: Mean stable vertical velocity was determined after stability was reached.

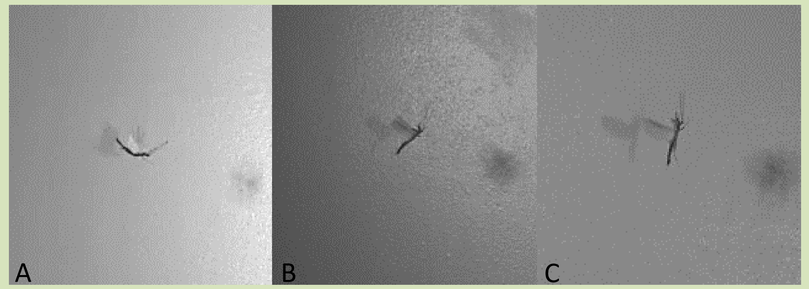

FIGURE 5 – Change in body angle in degrees/second is a measure of maneuverability

- Fig. 5A: falling after being dropped
- Fig. 5B: stabilized from falling
- Fig. 5C: ascending

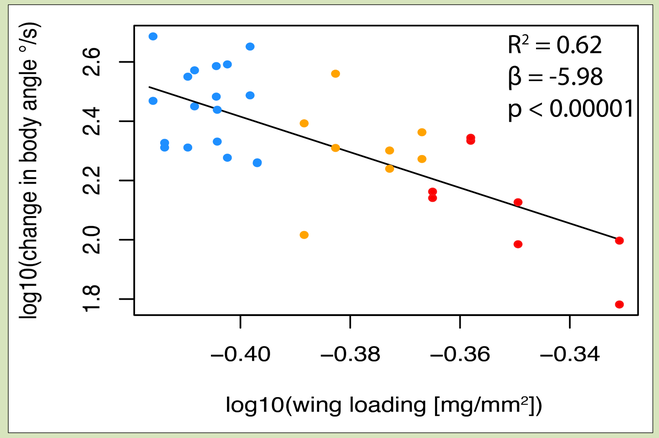

FIGURE 6 – Wing loading affects maneuverability

Maneuverability is measured by the rate of change of body angle. Smaller insects corrected their body angle faster as they transitioned from free falling to stable flight, thus signifying them as more maneuverable.

DISCUSSION

Our results provide evidence that small males are better fliers than larger males; they have lower wing loading that translates into better ascension and maneuverability in flight. The better flight performance may impact mating opportunities for smaller males, thus selecting for such individuals and contributing to the overt sexual dimorphism observed in *Phyllium philippinicum.* Beyond mating-based selection, large males may be disadvantaged by a higher energetic cost of moving, whether to recover from falling off a tree or to escape a predator. However, larger males may benefit from larger energy reserves or morphological compensations that decrease their mobility costs. Further research into these complexities of male size selection is required to better understand this relationship.