Ways to wing it: correlation of wing shape with habitat preferences, toxicity and migration in butterflies

Introduction
Wing shape influences the airflow over the wings surface, which governs the aerodynamics forces acting on the wing. Wing shape in bats and birds is generally correlated with their flight speed [1]. Typically, most birds and bats that have longer, more slender wings (higher aspect ratio) fly faster, whereas animals with shorter, wider wings (lower aspect ratio) are slower fliers but better at maneuvering. A bird or bat’s wing shape is usually subject to the selective pressures of the habitat they live in, foraging strategy, and flight behavior. In this study, we investigated the relationship of aspect ratio and wing shape of butterfly forewings, relative to habitat preferences, toxicity, and migration using geometric morphometrics [2].

Hypotheses
• Higher aspect ratio wings in butterflies living in open habitats, non-toxic and migratory species (compare to Fig. 1b)
• Lower aspect ratio wings in butterflies living in forests, toxic and non-migratory species (compare to Fig. 1a)

Materials and Methods
• 424 specimens of 21 species were supplied by Reiman Gardens Ames, Iowa.
• Pictures were taken with Cannon EOS Rebel T3i connected to a PC, allowing remote operation via EOS Utility software (Canon USA, Inc. Melville, NY).
• Biological landmarks on the forewings were digitized using custom written software tpsUtil and tpsDig by F. James Rohlf (Stony Brook University).
• Data were analyzed using RStudio (RStudio, Inc. Boston, MA) using the custom package "geomorph" by Dean C. Adams (Iowa State University).

Results

Figure 1: Low aspect ratio wing of Hypna eustrommatis (a), high aspect ratio wing of Phalaenissa (b)  

Figure 2: Forewing of Atenea clarinode. Wing veins are labeled and red dots show the digitized landmarks. The five digitized landmarks are the wing base, and the end of the veins 1, 2, 4, 5, and 6. The aspect ratio was calculated by dividing the wing length (distance between wing base and 4) by the wing width (distance between 1 and 6).

Figure 3: The five digitized landmarks (wing base, 5, 2, 5, 2, and 4) were translated, scaled and rotated following Procrustes superimposition [2] to calculate an average shape of the butterfly forewings. The landmark positions of all individuals after superimposition are shown in grey; the average landmark positions are shown in black. The background wing shows an example of a species close to the average wing (Euryale septentrionalis).

Figure 4: Butterflies from different habitats (forest dwelling species, generalists and species from open habitats, such as fields or grasslands) have a significant difference in their forewing aspect ratio (ANOVA, F=112, p<0.0001), indicated by an asterisk.

Figure 5: There is a significant difference in aspect ratio between toxic and non-toxic species (ANOVA, F=56, p<0.0001), indicated by an asterisk.

Figure 6: There is no significant difference in forewing aspect ratio between migratory and non-migratory species (ANOVA, F=1, p=N.S.).

Discussion
Our hypothesis that species that 1) live in open habitat or are 2) non-toxic or 3) migratory would potentially fly faster and therefore have higher aspect ratio wings than forest dwelling and toxic species was not supported. On the contrary, our results show that forest and toxic butterflies have higher aspect ratios and therefore more slender and elongated wings than open habitat and non-toxic species. This indicates that the relationship between wing shape and flight performance in larger fliers like bats and birds may not scale down to butterflies. Butterflies utilize different techniques to produce lift than larger fliers. These unsteady effects, such as the clap-and-fling mechanism are unique to insects, which operate in a different aerodynamic regime than birds and bats [3]. The changed physical properties of the air surrounding the wings may explain this discrepancy.

Conclusion
• Butterflies do not appear to show the same correlation of wing shape to habitat that birds and bats do.
• Forest dwelling butterflies and toxic species have more slender and elongated wings; butterflies living in open habitats and non-toxic species have broader and shorter wings.

References