The Relationship Between Wing Index and Average Number of Months a Year European and Maghreb Butterfly Species are Observed Flying

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Introduction

Certain insects’ ability to fly have given them many advantages over non-flying insects. Flight and its evolution in different species throughout time has been an interest of study for many years. Butterflies are a key example of an insect that develops wings and the ability to fly later in its life stages. The ability to fly and the ability to have long duration of flight allows the butterflies to search for food, escape predators, find mates, lay eggs, and protect territories across a wide range of area (Chazot et al. 2016). All of these characteristics are important for the survival and reproduction of butterflies allowing them to continue on as successful species.

There are six families of butterflies which include the swallowtails (Papilionoidea), white and sulfurs (Pieridae), metalmarks (Riodinidae), gossamer-winged butterflies (Lycaenidae), brush-footed butterflies (Nymphalidae), and the skippers (Hesperiidae). The swallowtail family have a wide variation in appearance and their wingspan can range from 40-55 millimeters (mm). The white and sulfurs family range from relatively small to relatively large with a wingspan of 32-51mm. The metalmarks family have wingspans that range from 16-51 mm while the gossamer-winged family have wingspan ranges of 22-51mm (Long 2015 Aug 4). The brush-footed family contain the greatest number of species and have very small front legs compared to other families. The skippers have relatively small wings compared to their bodies. They are named after their quickness in flight and tendency to “skip” around between various plants and flowers (Want to Learn Your Butterflies?).

Butterflies have evolved different mechanisms of flight including gliding where wings remain fairly stable and flapping where the wings are moved up and down. Wing size and shape vary among different species of butterflies with some having long, skinny wings, others having wider, shorter wings, and variations in between (DeVries et al. 2010). Factors such as habitat preferences and predators may have led to the selection for wing shapes and sizes among different species. It was found through butterfly models that a positive relationship between wingspan and gliding exist. Wing models were created that resembled actual butterfly wings based on butterfly wing measurements. The models had variation in the angle of the forewing to resemble different orientations the butterflies may experience during flight. These variations were then tested in a wind tunnel under three different speed conditions (Kovac et al. 2012). It was found that butterflies with wings that were longer in length rather than width could glide in flight more efficiently and use less energy allowing for less costly migration (Chazot et al. 2016).

Is there evidence for an evolutionary relationship between wing size and the amount of time spent flying in butterfly species for multiple survival and reproductive reasons? The ability of the butterflies to fly greater distances or for longer periods of time may be advantageous to important aspects of the butterfly’s life including foraging and breeding. In this study, a comprehensive database and phylogeny was used to test the correlation between wing index and average number of months a year European and Maghreb butterflies were observed in flight. I hypothesize that the wing index of butterfly species is positively correlated with the average number of months in a year the species is observed flying.

Methods

*Data Collection*

The data analyzed in this study and the phylogeny used came from the dryad database from an article called “A new comprehensive trait database of European and Maghreb butterflies, Papilionoidea.” This database compiled 25 traits using 542 taxa of European and Maghreb (North Africa) butterflies. The dataset contains the six families of butterflies which are the Papilionoidea, Pieridae, Riodinidae, Lycaenidae, Nymphalidae, and Hesperiidae family. The data was gathered from scientific papers, field guides, experts, and other reliable sources to create an extensive database that can be used to analyze butterfly life cycle, morphology, and behavioral characteristics. Wing index and average number of months the butterfly species were observed flying in a year were two traits that were isolated from the dataset and used in this study. The two traits and the corresponding data was converted to a csv file that was read into RStudio (RStudio 2022). Wing index was calculated using principal component analysis (PCA) to account for the overall size of the butterfly wings in many dimensions. The PCA for wing index incorporated both forewing length and wingspan. Forewing length was defined as the distance from the tip of the forewing to the body of the butterfly. The wingspan was defined as the distance between the apices of the forewings of the butterfly. The average number of months the butterflies were observed in flight was found by observing the maximum and minimum number of months each species was observed flying in a year and calculating the average for each species (Middleton-Welling et al. 2020).

*Correlation Tests*

A Pearson’s r and Spearman’s rho correlation was performed to test the relationship between wing index and average number of months the species were observed flying using the package “phytools” in RStudio (RStudio 2022). Pearson’s r correlation test assumes a linear relationship while Spearman’s rho assumes a non-linear relationship. Both of the correlation tests accounted for the butterfly phylogeny to retrieve more accurate results because living organisms’ traits cannot be treated as independent.

*Phylogenic Regression*

A phylogenic reduced major axis (RMA) regression analysis was performed to interpret and visualize the data. The RMA regression analysis was performed using the package “phytools” and the function phyl.RMA in RStudio (RStudio 2022). This analysis was selected because it accounts for the phylogeny of the butterfly species and for the uncertainty in both traits. The x-axis was wing index and the y-axis was average months of flight. A best fit line was generated in the plot to visualize the trend of the two traits more clearly.

Results

The Pearson’s correlation performed on wing index and average months of flight in the multiple species of butterflies had a value of 0.06. The Spearman’s correlation had a value of

-0.028. The dots on the phylogenic regression (Figure 1) represents each of the species and the best fit line had an intercept of 2.59 and a slope of 134.76. The phylogenic regression had a low r2 value of 0.0039 and a p-value of 0.00.



Figure 1. Phylogenic Regression of Wing Index vs Average Number of Months a Year the European and Maghreb Butterfly Species are Observed in Flight

Discussion

The correlation tests and phylogenic regression analysis shows there is no correlation between wing index and average number of months the butterfly species were observed flying in a year in the 542 taxa of butterflies. The Pearson’s and Spearman’s correlation tests were performed to test if there was a linear or non-linear relationship between the two variables. Both correlation values were approximately zero meaning I can reject my hypothesis that there is a positive correlation between wing index and average number of months the butterfly species were observed in flight. The phylogenic regression analysis (Figure 1) further supported the correlation tests by representing no observable relationship between the data points. The very low r2 and p-value of 0.00 provided clarity and more evidence of no correlation between the variables. The statistical analysis and phylogenic analysis were performed with the phylogeny included to ensure the variables were not treated as independent from one another. The incorporation of the phylogeny gave the most accurate representation of the relationship among the butterfly species.

Trade-offs and different fitness costs are important to consider for traits of living organisms. Although larger wings may be beneficial for long flights such as migration, shorter and rounder wings can be easier to maneuver allowing the butterflies to escape predators more easily. There may be trade-offs occurring between the maneuverability and energetic costs of the wing sizes keeping smaller winged butterflies successful in survival and reproduction (Chazot et al. 2016). It is also important to note that different butterfly species may be more active compared to others meaning some may naturally be in flight more often. This could influence the number of months the species are observed flying and give limitations to finding the true correlation between the wing index and number of months the butterflies are observed in flight.

A study by (Kingsolver 1999) observed flight in butterflies after manipulating their wings to decrease their size. Wingbeat frequencies of the butterflies increased which most likely increased their energetic costs, but there was no direct effect on the butterflies’ flight ability. It was noted that the patterns displayed on the butterfly wings may have been more important in survival and flight compared to wing size. This means that there may be selection on the patterns displayed on the wings and the evolution of wing size is just a consequence. Patterns associated with increased survivability and reproduction in the butterflies may be linked to a shorter wing index. This could have resulted in evolutionary forces over time favoring the displayed wing patterns rather than simply the ability to fly longer with increased wingspan.

The differing local environments and conditions the butterfly species experience is an aspect that was not took into account in this study. It may be beneficial to consider the exact locations where the butterflies were observed and what types of predators, food, and plant life were in their habitat. Some species may have tendencies to remain in the understory of greenery which differ in conditions compared to the canopy of trees. The food availability and predators differ between the canopy and understory meaning different wing size may be more advantageous. The species in both locations may have similar average months of flight but it may be more beneficial for species that remain more often in the understory to have smaller wings for better maneuverability. Also, there can be behavioral differences between the sexes and the environments they spend the majority of their time in. For example, in some species of Nymphalidae the males use gliding to patrol above the canopy of trees. However, females remain closer to the ground and predominately use flapping motions (DeVries et al. 2010). In this family, it may be of good use to evaluate the differences between the male and females flight duration and wing size. The differences in the environment and the differing role of the sexes between the butterflies is something that could be evaluated in future studies. More detailed observations of where the butterflies were observed in flight and how they were flying, whether mostly gliding or flapping, may lead to a better understanding of what wing index is most beneficial for the species. Again, a larger wingspan may give better ability to glide long distances, however the large wings could be too costly in other aspects of the butterflies’ lives (Chazot et al. 2016).

The data that I used for this study was based heavily on observation of how often the butterflies were in flight which may have led to some inaccuracies in the data. In observational studies there is always the risk of human error or difference in opinion. For example, an observer could have potentially not observed the flight of some of the smaller species of butterfly such as the species in the family Hesperiidae. This family of butterflies are known to be small and fly quickly (Want to Learn Your Butterflies?). Also, there is potential to confuse certain taxa during observation which may have led to inaccurate recording of flight data and their associated species. It is possible that looking at the maximum number of months the species were observed in flight would have given more insight on a relationship between the two variables. Using the average number of months of flight for this study could have hidden important extremes in the data. This could be evaluated in further studies along with what environments could potentially favor larger wingspan vs a smaller wingspan in association with flight duration to get a better understanding of the evolution of wing size among the European and Maghreb butterflies.

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Dryad data set can be found at <https://doi.org/10.5061/dryad.6m905qfx6>