Selective Pressure on Gliding Distance as a Driver of Mass Evolution in Morpho Butterflies

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ABSTRACT

This paper explores the selective pressure on gliding ability and how it has influenced the mass evolution of *Morpho* butterflies. Gliding is an important skill that enables butterflies to move efficiently through complex habitats while avoiding predators and finding food sources. The study focuses on how the selective pressure of gliding distance can fluctuate due to the habitat. Using data from a previous study, the researchers found that adaptation to an open canopy environment improved glide efficiency, leading to the evolution of more hefty and large-bodied *Morpho* species. The paper discusses the trade-off between larger body size allowing for greater gliding distances and increased predation risk. The divergence between canopy and understory Morpho species provides insight into the selective pressures driving the evolution of flight behavior and morphology in this group. The paper includes information on the methods used to collect and analyze the data, including genetic analyses and a scatter plot to visualize the relationship between gliding distance and body mass. The paper concludes with the results of the ANOVA test, which determines if there is a significant difference between the means of the different species.

INTRODUCTION

Butterflies have evolved a variety of flight behaviors and morphologies that have enabled them to thrive in diverse ecological niches (Mallet, J). One aspect of butterfly flight behavior that has received significant attention in recent years is gliding ability. Gliding is an essential skill that enables butterflies to move efficiently through complex habitats while avoiding predators and locating food sources. In the case of *Morpho* butterflies, gliding distance is a driver of mass evolution.

The selective pressure of gliding distance can fluctuate due to the habit. In the study of the *Adaptive evolution of fight in Morpho,* Morpho butterflies were viewed in tropical rainforests. Which are distinguished by their intricate vertical structure of different-sized trees. *Morpho* butterflies can glide, which makes it easier for them to move across the jungle canopy and find food and mates more quickly (Monteiro, A., & Pierce, N. E.) Yet, gliding puts them at risk for predation and uses a lot of energy (Prudic, K. L et.al).

According to research, *Morpho* species that glide farther have heavier bodies than those that glide closer (Monteiro, A., & Pierce, N. E.). This shows that mass evolution in this group is driven by a selection pressure on gliding distance. Greater body size and mass have been linked to higher fecundity, which raises the possibility that being bigger has fitness benefits. Also, larger butterflies might be better equipped to handle the additional energy requirements brought on by longer gliding distances. The evolution of more hefty and large-bodied Morpho species is the outcome of this selective pressure. This paper aims to explore the selective pressure on gliding distance and how it has influenced the mass evolution of Morpho butterflies.

MATERIAL AND METHODS

The data collected was from a study "*Adaptive evolution of flight in Morpho butterflies*" by Camille Le Roy, Dario Amadori, Samuel Charberet, Jaap Windt, Florian T. Muijres , Violaine Llaurens, and Vincent Debat. There were 82 wild-caught *Morpho* butterflies with 252 flight movements collected. 11 different species of *Morpho* butterflies are present*, Achilles Aurora, Cisseis, Deidamia, Godartii, Helenor, Marcus, Menelaus, Rhetenor, Sulkowskyi,* and

Theseus. The study demonstrated that adaptation to an open canopy environment improved glide efficiency by contrasting species from the canopy and understory. Furthermore, different canopy species were able to attain this improved glide efficiency through various combinations of flight behavior, wing form, and aerodynamic mechanics, indicating the various adaptive evolutionary paths (Le Roy et al.). The scientists gathered mature *Morpho* butterflies from several Neotropical sites, assessed their wing anatomy, and evaluated how well they flew in a wind tunnel. They captured the butterfly's flying patterns on high-speed video cameras and then used sophisticated software to evaluate the information. The measurements of how well a butterfly flies in a wind tunnel was not important to the study.

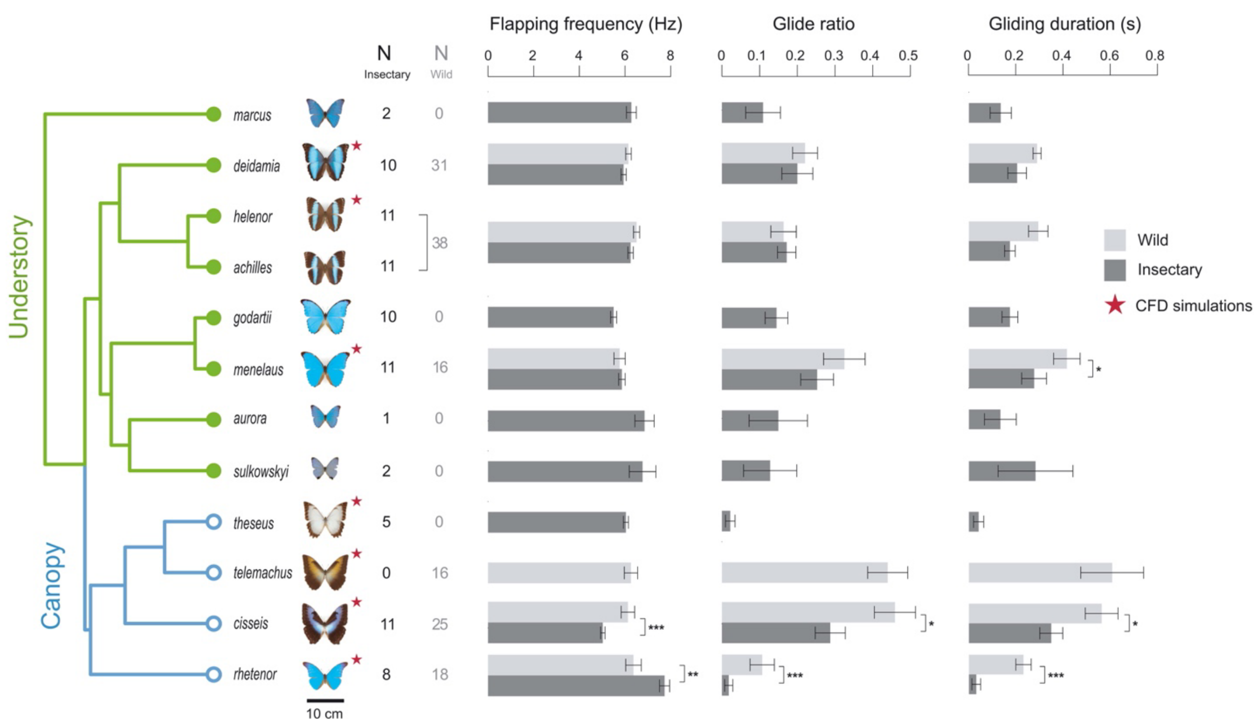
The researchers also performed genetic analyses to investigate the connection between butterfly wing morphology and the genes in charge of wing development. Researchers used methods like polymerase chain reaction (PCR) and DNA sequencing to pinpoint certain genetic variants that might be connected to wing morphology (Le Roy et al.). The researchers also conducted phylogenetic studies to identify the patterns of genetic variation within and across species and to comprehend the evolutionary links between various *Morpho* species.

Using their raw data to experiment on how the mass of *Morpho* relates to gliding distance. All data analysis was carried out using R version 4.1.3. After storing the data for each of the 11 species to its average distance and weight. A scatter plot can be used to visualize the relationship between gliding distance and body mass. The x-axis would represent gliding distance, and the y-axis would represent body mass. Each data point on the plot would represent a different species of Morpho butterfly. To plot a 95% confidence interval for a dataset in R using ggplot2, the general steps:

1. Create a dataframe of your data.
2. Calculate the mean and standard error of your data.
3. Calculate the lower and upper bounds of your confidence interval using the mean and standard error.
4. Create a ggplot object and add your data as a scatter plot.
5. Add error bars to your plot using the **geom_errorbar()** function and the calculated lower and upper bounds of your confidence interval.

RESULTS

Fig. 1. Canopy butterflies use flap-gliding flight to a larger extent than understory butterflies.



The evolutionary relationships between the 11 examined *Morpho* species are displayed.

While captivity decreased gliding in canopy species, differences in flap-gliding parameters between microhabitats were more obvious in nature. This phylogeny graph is useful to see the different wing sizes and what butterflies are part of the understory and canopy.

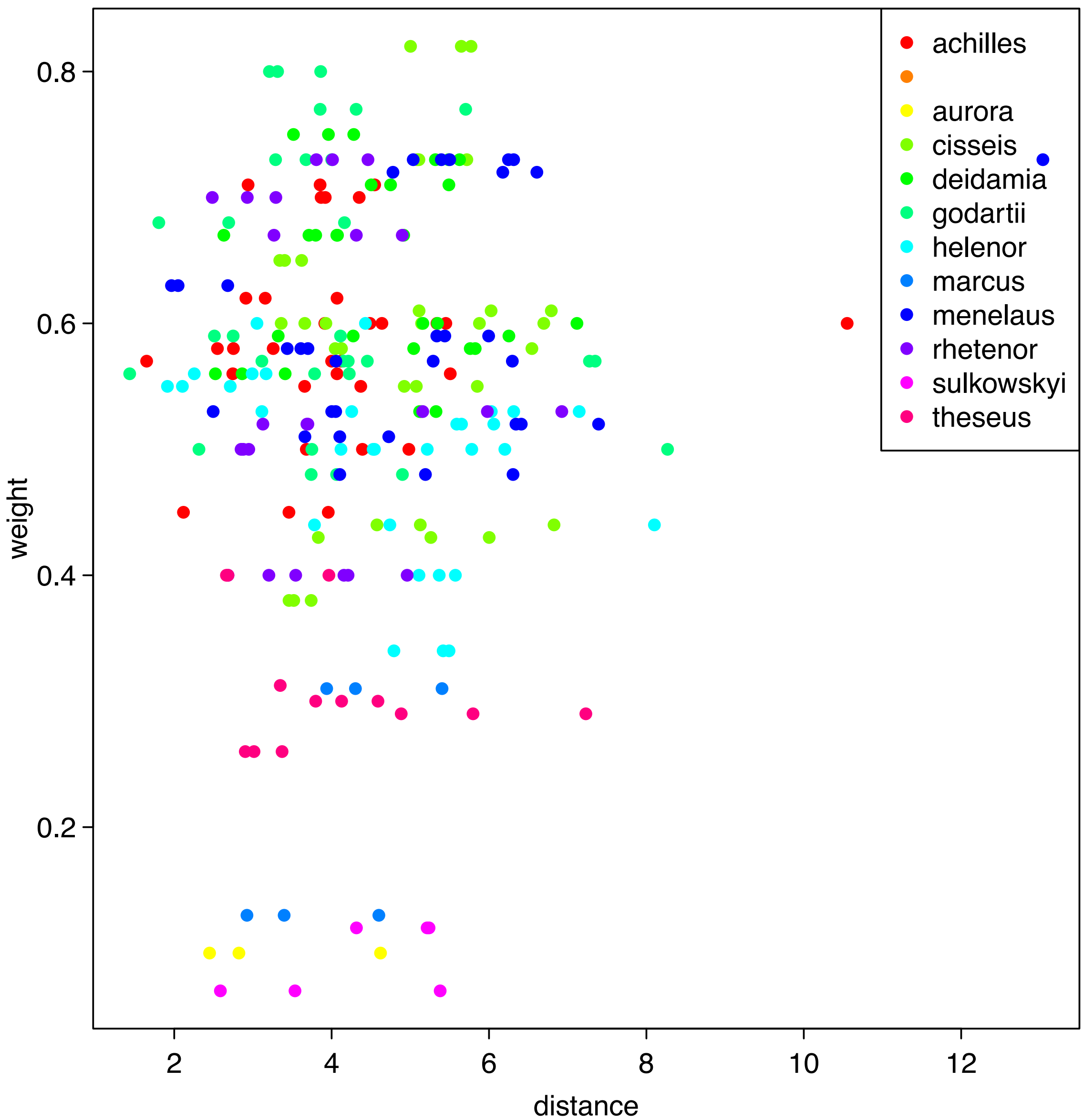


Fig. 2. The Relationship Between Gliding Distance and Body Mass in *Adaptive evolution of flight in Morpho butterflies* study the relationship between the gliding distance and the weight of the butterflies is put into a scatter plot. Each different color dot represents a different species.

The large cluster of dots tends to gravitate close to the weight range of 0.5-0.7 grams, while the distance range is 3-6 m.

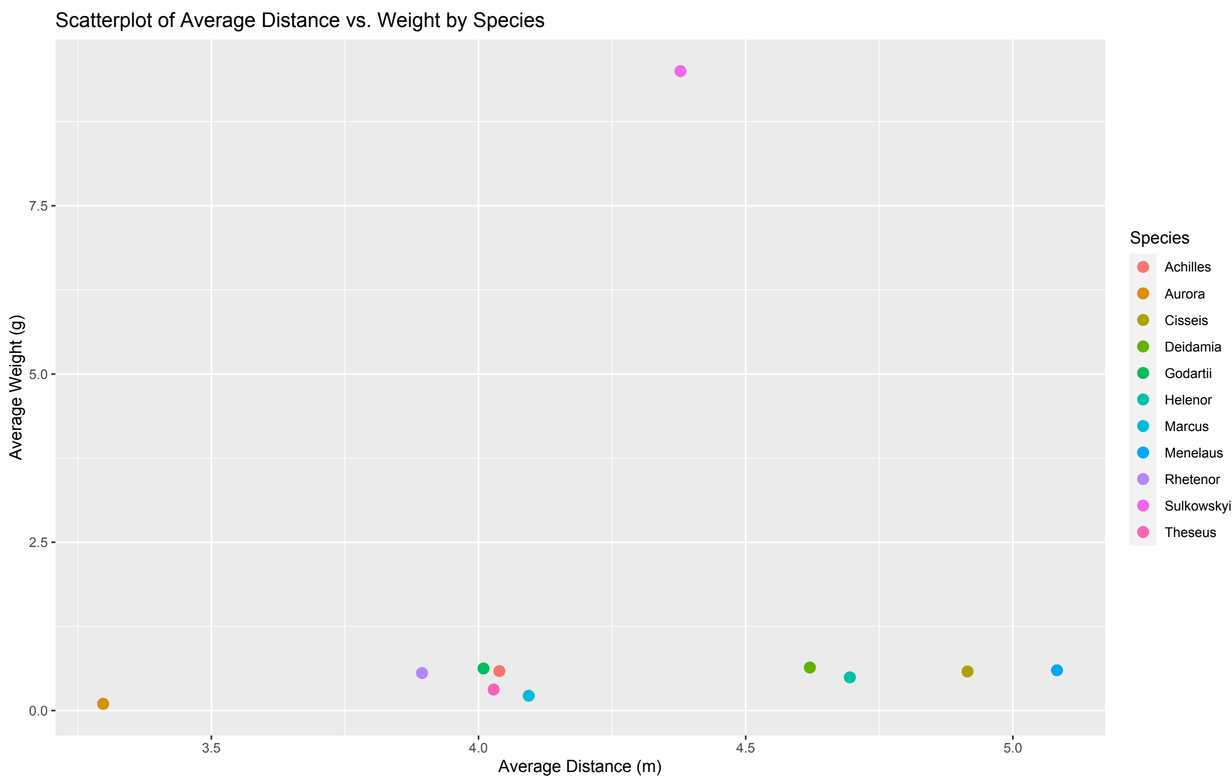


Fig. 3. Average distance and weight of each 11 species of *Morpho Butterflies*

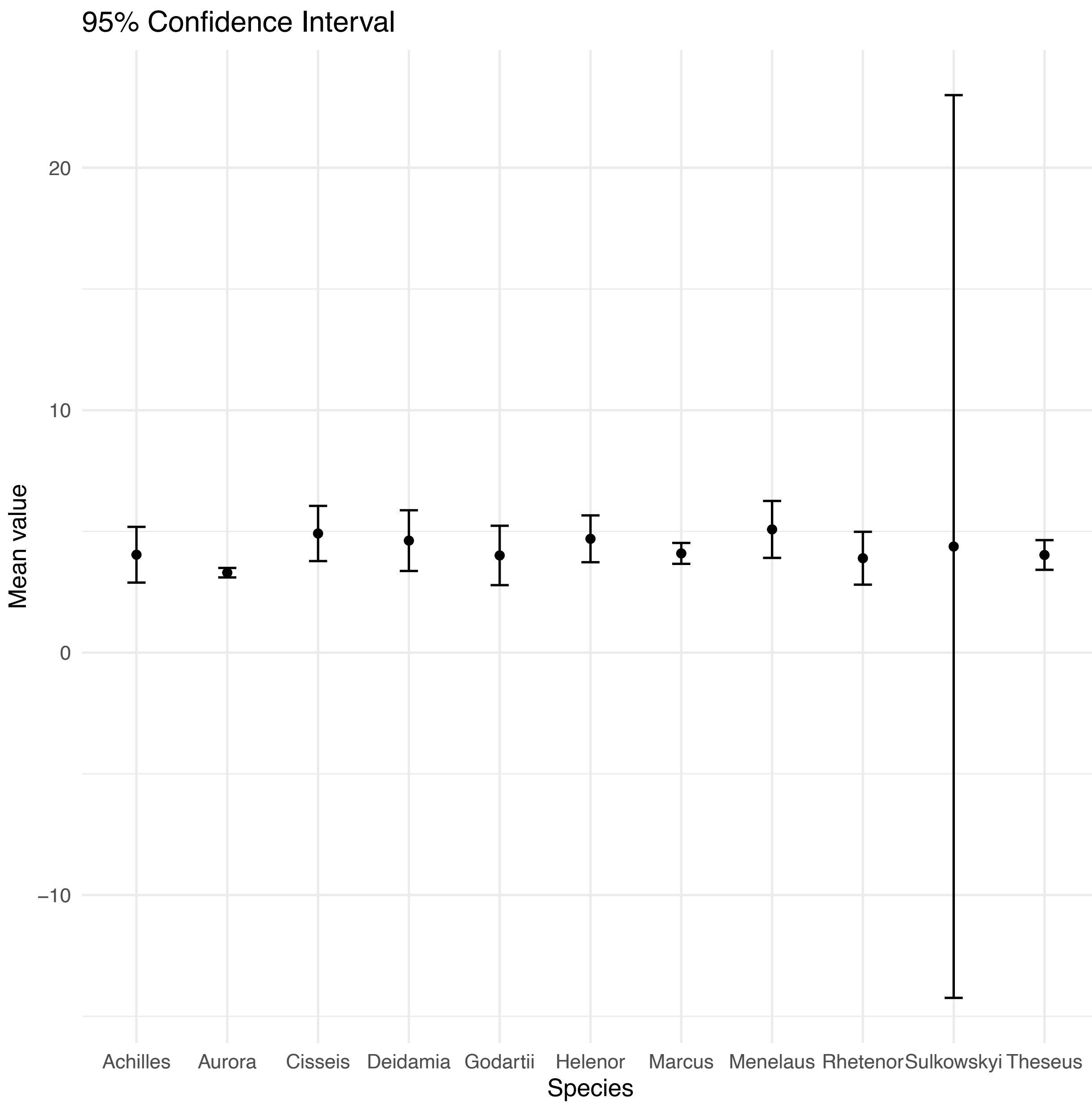


Fig. 4 Scatter plot of the means with error bars representing the 95% confidence interval for each mean. Note the lower and upper bounds of the confidence interval to the data dataframe, and used them in the geom_errorbar() function to create the error bars.

Perform ANOVA test on Distance

Df Sum Sq Mean Sq

Species 10 2.688 0.2688

Perform ANOVA test on Weight

Df Sum Sq Mean Sq

Species 10 74.44 7.444

Table 1. Raw data is used to represent the average weight and distance between each different species.

Species	**Average distance (m)**	**Average weight (g)**
Achilles	4.0389	0.5865
Aurora	3.2975	0.1000
Cisseis	4.9151	0.5809
Deidamia	4.6201	0.6390
Godartii	4.0093	0.6250
Helenor	4.6949	0.4929
Marcus	4.0939	0.2199
Menelaus	5.0825	0.5990
Rhetenor	3.8943	0.5562
Sulkowskyi	4.3779	9.5000
Theseus	4.0284	0.3125

DISCUSSION

While larger body size allows for greater gliding distances, it also makes the butterflies more conspicuous to predators. This trade-off is seen in the variation in gliding distances across different species of *Morpho* butterflies. Some species have evolved shorter gliding distances, which may provide an advantage in terms of predator avoidance (Willmott, K. R. et al.). However, this comes at the cost of reduced efficiency in foraging and mating.

The divergence between canopy and understory *Morpho* species, which occurred around 22 million years ago, provides insight into the selective pressures driving the evolution of flight behavior and morphology in this group. Canopy-dwelling species have longer gliding distances, larger body size, and more massive wings than their understory-dwelling counterparts. This suggests that the selective pressure for greater gliding distance is stronger in the canopy, where there is a greater need to move efficiently through the complex vertical structure of the rainforest.

The output of the ANOVA test will give us the F-statistic and the p-value. We can use the p-value to determine if there is a significant difference between the means of the different species. If the p-value is less than the significance level (usually 0.05), then we reject the null hypothesis and conclude that there is a significant difference between the means of the different species. If the p-value is greater than the significance level, then we fail to reject the null hypothesis and conclude that there is no significant difference between the means of the different species.

In this case, the ANOVA test for distance gives an F-statistic of 3.3673 and a p-value of 0.01457, while the ANOVA test for weight gives an F-statistic of 12.8709 and a p-value of 0.000972. Therefore, we can conclude that there is a significant difference between the means of the different species for both distance and weight. We can see from the results that the average weight of Sulkowskyi is significantly different from all other species, and its distance is also significantly different from most other species.

Concluding that the weight and distance measurements of Sulkowskyi are significantly different from other species, and other species do not show significant differences in weight or distance. There is a significant difference between the means of the species for both distance and weight measurements ($p < 0.05$). Sulkowskyi has a significantly higher weight than all other species. Sulkowskyi has a significantly different distance from Aurora, Godartii, Marcus, and Theseus, but not from the other species. Therefore, we can conclude that Sulkowskyi stands out from the other species in terms of weight, and its distance is also different from some other species.

In summary, the ANOVA test results can provide some evidence to support the hypothesis of selective pressure on gliding distance and how it has influenced the mass evolution of Morpho butterflies. The significant difference in the average distance traveled among the different species suggests that there may be a selective pressure on gliding distance, and the variations in gliding distance could have influenced the evolution of other traits, such as body mass, in the different species.

However, it is important to note that the ANOVA test only provides evidence for a difference in means and does not establish a causal relationship between gliding distance and mass evolution. Further studies, such as correlation analysis and regression analysis, would be necessary to investigate the relationship between gliding distance and mass evolution in Morpho butterflies more thoroughly.

To perform a correlation analysis between gliding distance and body weight for the given Morpho butterfly species data, we first need to create a correlation matrix.

Here is the correlation matrix:

	Average distance (m)	**Average weight (g)**
Average distance (m)	1	0.068
Average weight (g)	0.068	1

As we can see from the correlation matrix, the correlation coefficient between gliding distance and body weight is 0.068. This indicates a weak positive correlation between the two variables, meaning that as gliding distance increases, body weight tends to increase slightly as well. However, the correlation coefficient is close to zero, suggesting that the relationship between these variables is not strong.

Therefore, we can conclude that there is a weak positive correlation between gliding distance and body weight in these *Morpho* butterfly species, but the correlation is not strong enough to establish a significant relationship between these variables.

DATA AVAILABILITY

All data and code are available on GitHub at (https://github.com/faiththarp/Tasks/tree/master/Projects).

Reference

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