Investigating the impact of environmental factors and species traits on bird-building collision rates

Introduction

Collision with buildings is a major threat to bird species and disrupts migration in urban areas [3, 5a]. This is particularly well-documented in North American studies, a region where bird-building collisions are the primary source of bird mortality [3]. Although this phenomenon has been widely studied, further knowledge of contributing factors to bird-building collision rates are needed to inform bird conservation initiatives. For instance, although attraction to lighted buildings is thought to present a danger to nocturnally migrating bird populations [5a], the mechanisms by which artificial light increases bird-building collisions have not been sufficiently documented [3]. Further assessments are also needed to investigate taxonomic differences in bird-building collision rates, as well as seasonal patterns [3].

To investigate the role of these factors on collision frequency, two hypotheses were tested (alpha = 0.05) using data from Winger and colleagues [5b] and Avibase [1]. (1) To test for an effect of artificial light intensity collision frequency, a linear regression was performed using both a generalized linear model (GLM) and a generalised linear mixed model (GLMM). (2) To explore differences among species in collision frequency, the effects of two species-specific traits were investigated. (a) A linear mixed model was used to test for an effect of wing maneuverability on the number of collisions, using wind load as a proxy for wing maneuverability (see Methods). (b) A permutation test was used to test for an effect of trophic level (omnivorous vs. not omnivorous) on number of collisions.

First, given that attraction to artificial lighting has been linked to increased risk of collision [3, 5a], it was predicted that a higher frequency of bird-building collisions would be observed at more intense light levels. Second, given that wing maneuverability is associated with higher resistance to windy conditions during flight [2], it was predicted that more bird-building collisions would be observed in species with lower wing maneuverability. Finally, based on indications that trophic level may influence collision risk in some bird communities [6], it was predicted a higher frequency of bird-building collisions in non-omnivorous species as compared to omnivorous species.

Methods

Data Description

Winger and colleagues monitored lethal bird-building collisions at a building in Chicago, U.S.A., recording Genus, Species and the date of each observation seasonally from 1978 to 2016 [5b]. The researchers also quantified the intensity of artificial lighting at the study site at night seasonally from 2000 to 2018 [5b]. To obtain the total number of collisions and light intensity level on each date, collision observations were matched with light levels on dates when light intensity data was available, and observations not at the Chicago study site were excluded.

Additional raw data on bird species-specific body mass, wingspan and trophic level were gathered from Avibase. Wind load was calculated by dividing species average body mass by species average wingspan. High wind load is associated with low wing maneuverability and was thus used as a proxy for maneuverability [2]. Collisions were tallied by species, and a second set of processed data was obtained containing the number of collisions and the calculated average wind load for each species. Finally, species were classified as either omnivorous or non-omnivorous based on information from Avibase, and a third set of processed data was obtained containing the number of collisions and the trophic classification for each species.

Data Analysis

To test for an effect of artificial light collision frequency given that collisions represented non-normal count data, a GLM using a Poisson distribution was run using the first processed data set to regress the number of collisions on light intensity [Figure S3]. However, considering the potential non-independence of bird collisions observed on the same dates, a second regression was performed using a GLMM with date as a random effect [Figure S4]. This model was found to be a better explanation of the data based on its AIC value (8924.414 for GLMM as compared to 16601.326 for GLM).

To investigate the relationship between instances of high wind load (low wing maneuverability) and high collision frequency, variables which were both highly right-skewed [Figure S5], collision frequency was first log-transformed [Figure S6]. The right-skewed pattern can be attributed to evolutionary adaptations that favor lower wind loading through an optimal balance of body mass and wing size, enhancing flight efficiency and obstacle avoidance [4]. An initial correlation analysis was performed (using the second processed data set) to explore the relationship between wind load and collisions [Figure S7]. A regression of wind load on log number of collisions was then carried out using a LMM with date as a random effect [Figure S8].

Finally, to test for an effect of trophic level on collision rates, a permutation test was used to assess the difference in mean collision frequencies between omnivore and non-omnivore groups [Figure S10]. A t-test was not appropriate given the non-normal distribution of collision frequency in both omnivorous and non-omnivorous species [Figure S9].

Results

Regression of artificial light intensity on number of collisions using the selected GLMM rejected a null hypothesis of no effect, finding that a unit increase in light level was associated with a 0.050097 increase in the number of bird-building collisions (p-value $< 2\times10^{-16}$).

The correlation analysis did not reveal a strong positive relationship between wind load and collisions, perhaps due to an insufficient sample size or the presence of outliers. Regression of wind load on log number of collisions, however, found that a unit increase in wind load was associated with a 1.308 increase in the log number of bird-building collisions (p-value $< 2\times10^{-16}$).

The permutation test failed to reject a null hypothesis of no difference in collision frequency between omnivorous and non-omnivorous species, giving a large p-value of 0.782 [Figure S10]. This may be attributed to small sample size leading to a potential type-II error (e.g. only 27 omnivorous species were observed).

Discussion

The analyses detected moderate effects of both artificial light intensity and wing maneuverability (wind load) on the number of bird-building collisions but did not detect a significant effect of trophic level on collision frequency. There are several limitations of this analysis with implications for future study. For instance, further investigation of multicollinearity between species traits should be undertaken, and the local abundance of species should be accounted for in discussing collision frequency [6]. More variables could be considered in the construction of models to predict collision rates (such as flight behaviors [e.g. 5a]). Furthermore, the integration of data from other locations and a wider range of bird species would improve the generalisability of findings in future studies. Improved knowledge of the factors affecting bird-building collision are essential in understanding species-specific vulnerability and informing bird conservation strategies in urban areas.

References

1. Avibase - the world bird database. Bsc-eoc.org. [accessed 2023 Nov. 10]. https://avibase.bsc-eoc.org/avibase.jsp

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4. Spear LB, Ainley DG. Flight behaviour of seabirds in relation to wind direction and wing morphology. The Ibis. 1997;139(2):221–233. http://dx.doi.org/10.1111/j.1474-919x.1997.tb04620.x. doi:10.1111/j.1474-919x.1997.tb04620.

5a. Winger BM, Weeks BC, Farnsworth A, Jones AW, Hennen M, Willard DE (2019) Nocturnal flight-calling behaviour predicts vulnerability to artificial light in migratory birds. Proceedings of the Royal Society B 286(1900): 20190364. https://doi.org/10.1098/rspb.2019.0364

5b. Winger BM, Weeks BC, Farnsworth A, Jones AW, Hennen M, Willard DE (2019) Data from: Nocturnal flight-calling behaviour predicts vulnerability to artificial light in migratory birds. Dryad Digital Repository. https://doi.org/10.5061/dryad.8rr0498

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Supplementary Material

All processed data and code used to produce this report are available at https://github.com/EEB313/2023-GroupD. Author contributions and contents of the repository are summarized in the README.md file.

Raw bird-building collision data and artificial light intensity data are available at https://doi.org/10.5061/dryad.8rr0498. Raw species traits data (average body mass and wingspan, trophic level) are available at https://avibase.bsc-eoc.org/avibase.jsp.

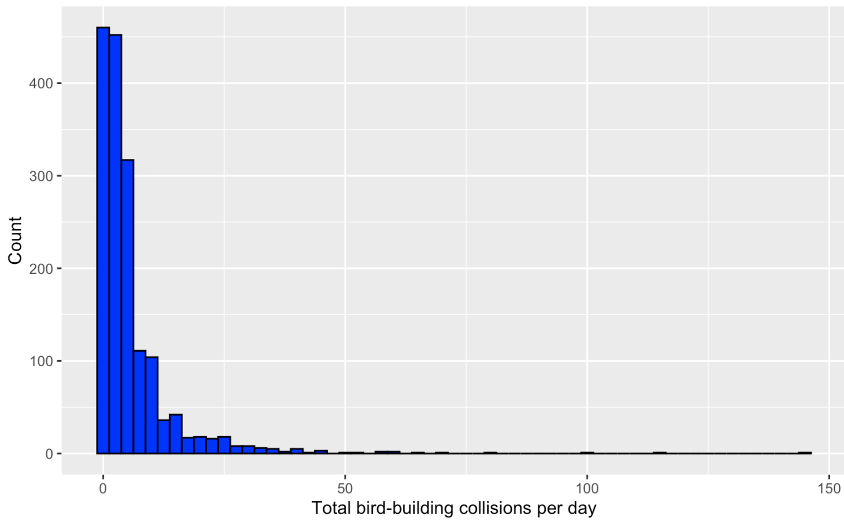


Figure S1. Distribution of collision frequency in the first processed data set which includes number of collisions and light intensity by date. Collisions are not normally distributed and were modeled under a Poisson distribution.

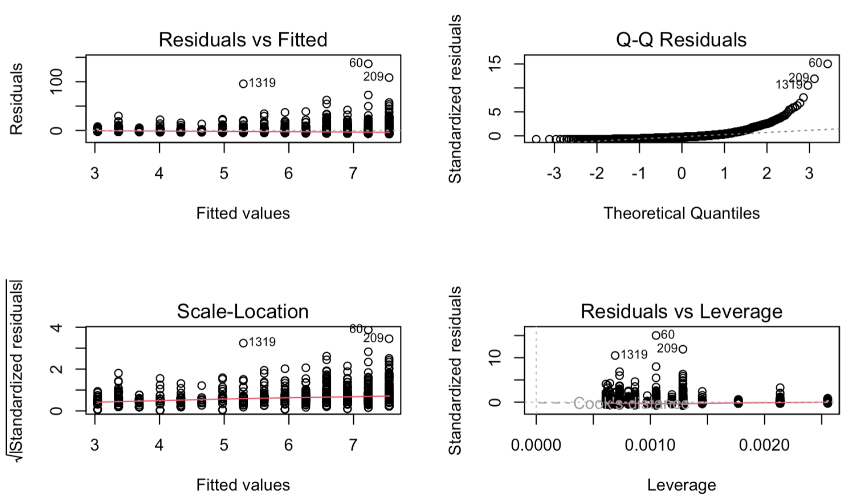


Figure S2. Residuals plots showing that error variance is not homogenous in the first processed data set (greater variance of residuals and standardised residuals at higher fitted values, non-linear standardised residuals, and standardised residuals outside Cook's distance).

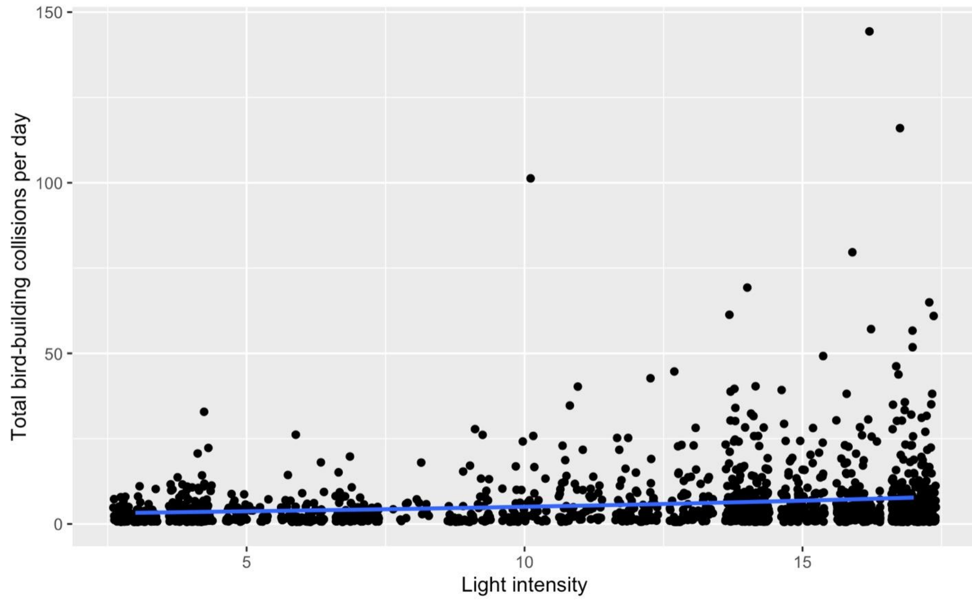


Figure S3. GLM regressing total bird-building collisions per day on intensity of artificial lighting using a Poisson distribution. Each point represents a date, and the blue line shows the positive relationship between light intensity and bird-building collisions.

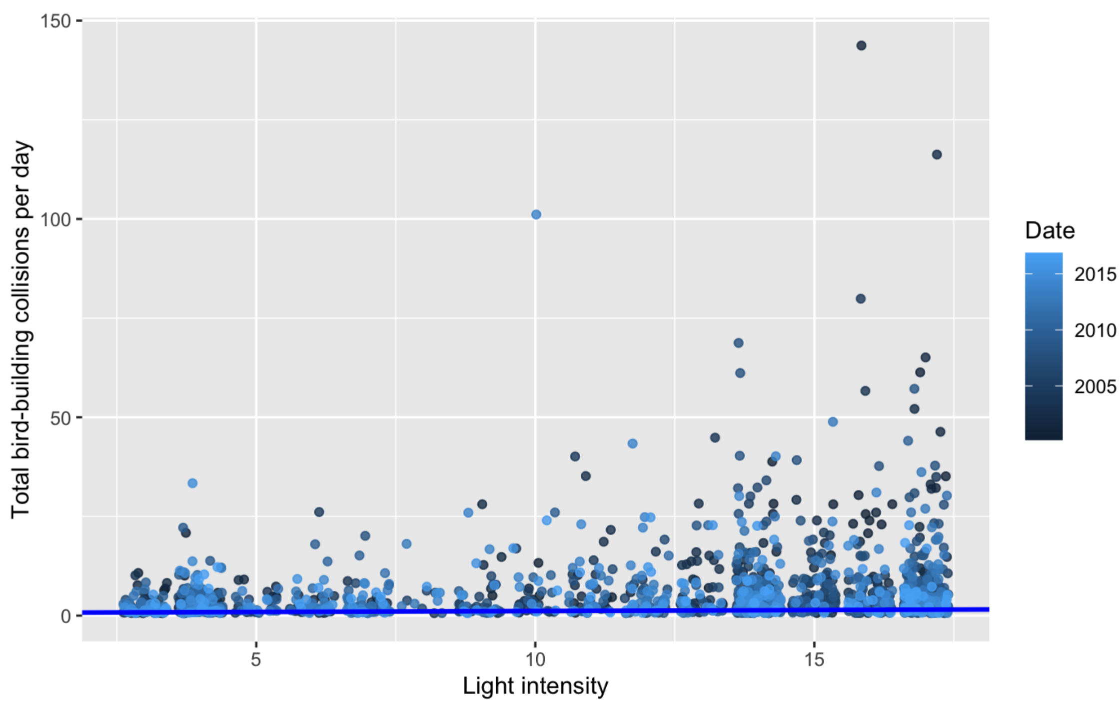


Figure S4. GLMM regressing total bird-building collisions per day on intensity of artificial lighting with date as a random effect. Points are coloured by date to attempt to visualise random effects, which is challenging given the data comprise more than 1600 distinct dates, so date has been represented here as a discrete continuous variable. The blue line shows a weak positive relationship between light intensity and bird-building collisions.

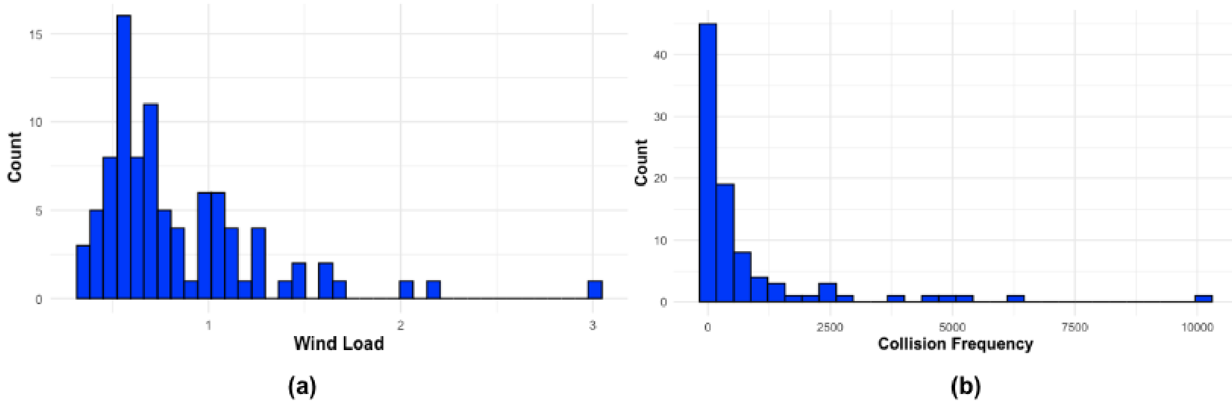


Figure S5. (a) Frequency distribution of wind load across different bird species. The distribution appears right-skewed, most bird species experience lower wind loads, with fewer species encountering higher wind loads. (b) Distribution of collision frequencies of birds with buildings. Right-skewed distribution, with a high frequency of species experiencing fewer collisions and very few species having high collision counts.

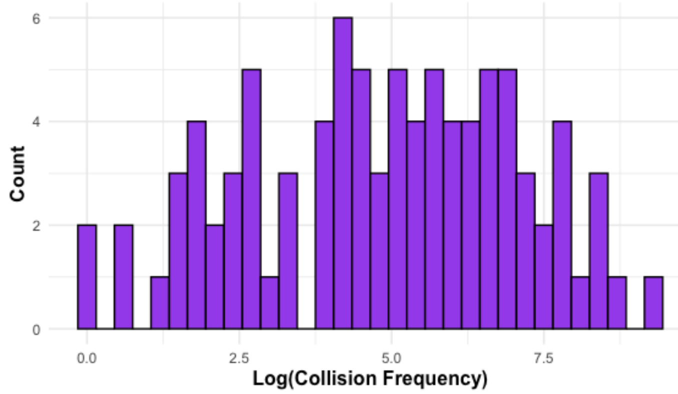


Figure S6. Distribution of the logarithmic transformation of collision frequency for various bird species. The Shapiro-Wilk test p-value = 0.1605, which fails to reject the null hypothesis that the data is normally distributed. A p-value less than a typical alpha level (e.g., 0.05) would suggest that the data is not normally distributed.

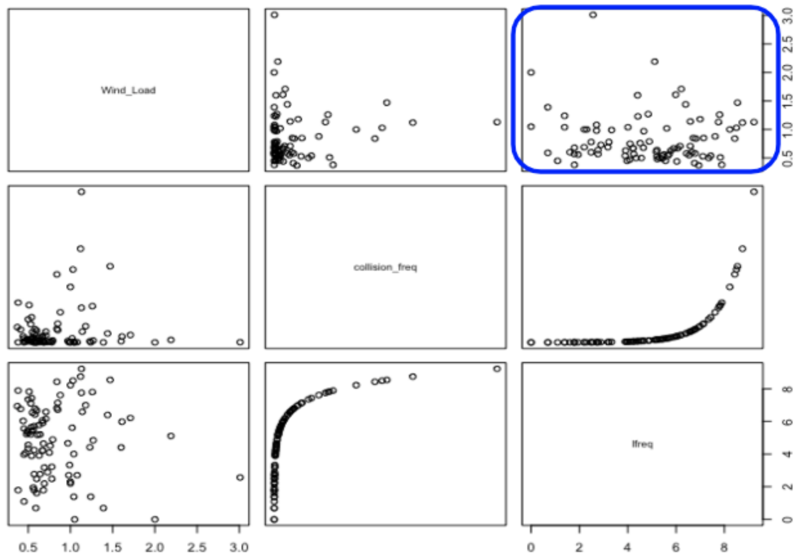


Figure S7. A pair plot. Visualizes the pairwise relationships between `Wind_Load` and `lfeq`.

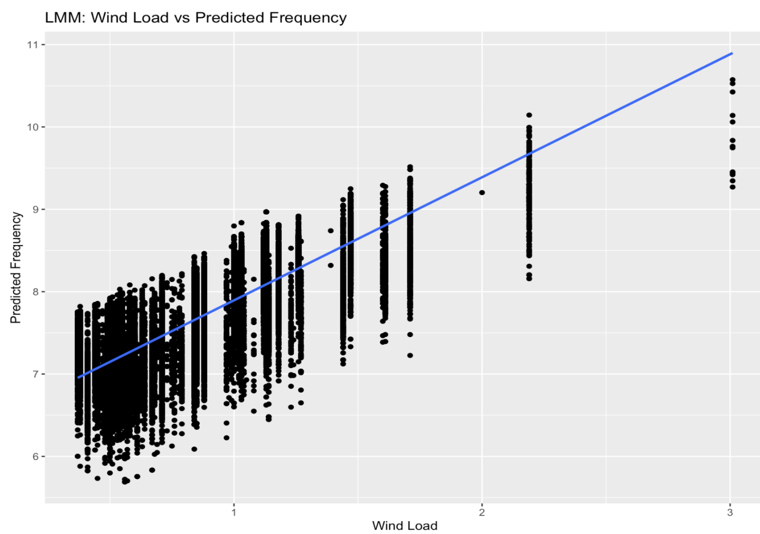
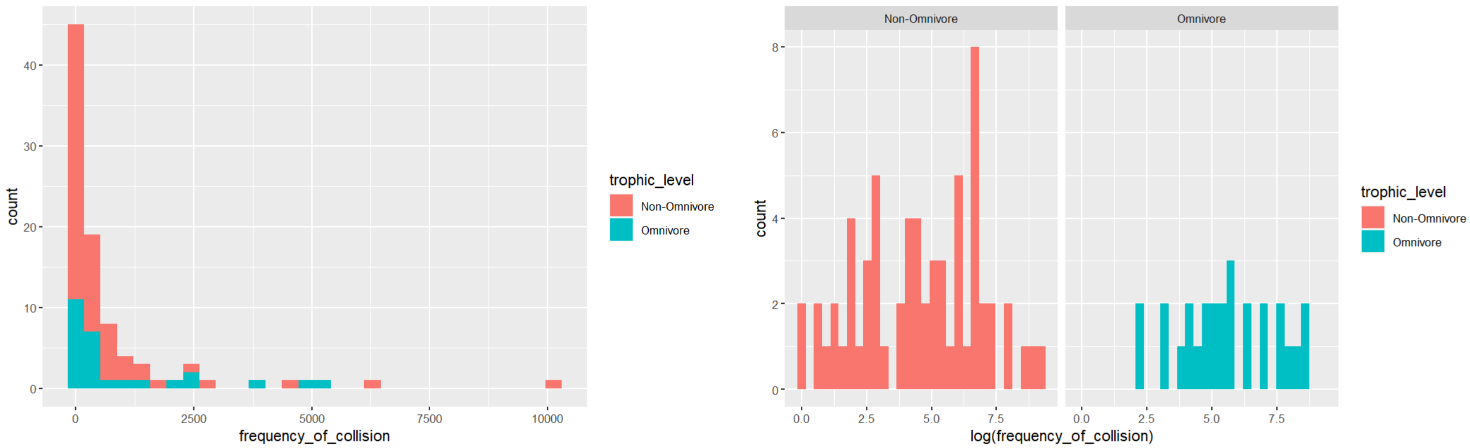


Figure S8. Scatter plot of the Linear Mixed Model's predicted frequency of bird collisions versus wind load. Each point represents the predicted collision frequency for a given wind load value, derived from the model. The blue line indicates the fixed effect of wind load on the predicted frequency, showing a positive relationship as suggested by the Linear Mixed Model. Data exhibit vertical banding due to discrete or categorical wind load values.



(a) (b)

Figure S9. (a) Distribution of collision frequency which is heavily right-skewed. (b) After log transformation, distribution of collision frequency for non-omnivore in the left panel which is left-skewed and omnivore in the right panel which is uniformly distributed.

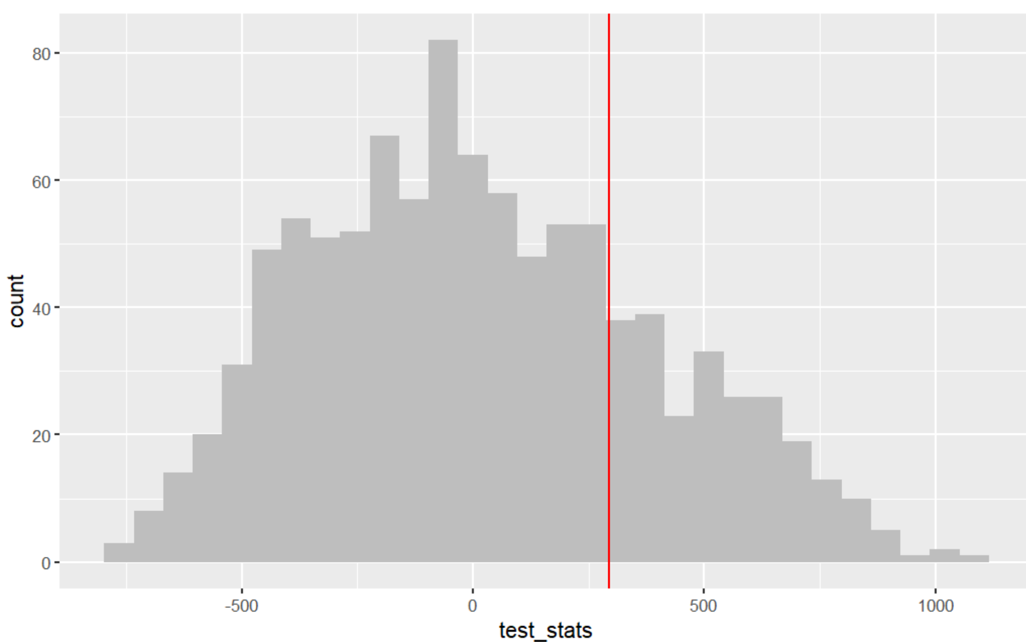


Figure S10. Result of permutation test, the distribution of simulated test statistics (difference in mean collision frequencies between omnivore and non-omnivore groups). Calculated p-value equals 0.782 which is larger than the significance level 0.05, so the test failed to reject the null hypothesis that there is no difference in mean collision frequencies between omnivore and non-omnivore groups.