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

EEB313 Group Project Fall 2023

Group D (Samina Hess, Yunhua Ren, Leslie Gao)

Introduction

- Collision with buildings causes bird mortality and disrupts migration (Loss 2019).

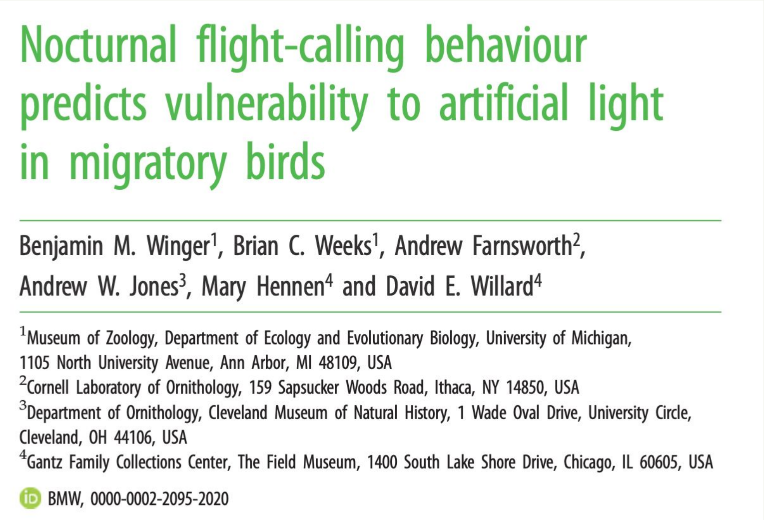
- Particularly well-documented in North American cities (Loss 2019).

- However, impact of **artificial lighting** at night on nocturnal migration not well documented, and vulnerabilities of different **species** not well understood (Loss 2019, Winger et al. 2019).

Photo credit: Wild About Nature Blog. Retrieved 30 November 2023 from howtoconserve.org.

Data source

Winger et al. 2019.



Nocturnal flight-calling behaviour predicts vulnerability to artificial light in migratory birds

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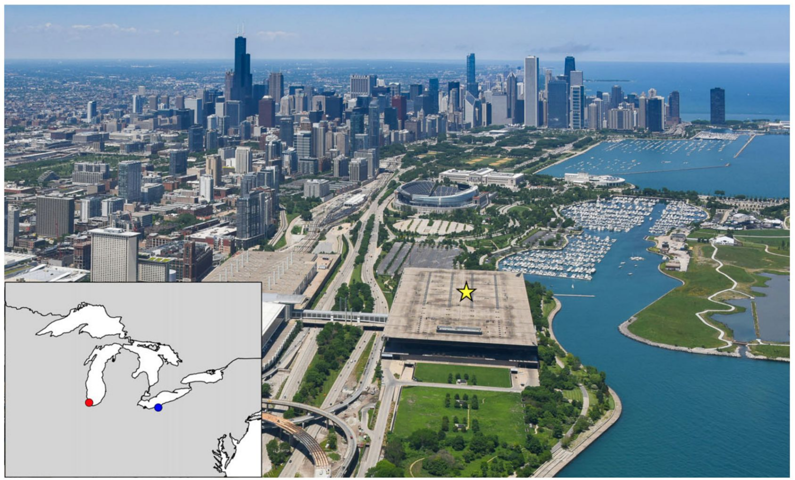


- Monitored lethal collisions and nightly light levels at study site (above).
- 90+ species of migratory birds.

Collisions observed:

	Genus	Species	Date	Locality
	<chr>	<chr>	<chr>	<chr>
1	Ammodramus	nelsoni	1982-10-03	MP
2	Ammodramus	nelsoni	1984-05-21	CHI
3	Ammodramus	nelsoni	1984-05-25	MP
4	Ammodramus	nelsoni	1985-10-08	MP
5	Ammodramus	nelsoni	1986-09-10	MP
6	Ammodramus	nelsoni	1986-09-12	MP

Light levels:

Date	Light_Score
<chr>	<int>
2000-03-06	3
2000-03-08	15
2000-03-10	3
2000-03-31	3
2000-04-02	17
2000-04-14	4
2000-04-15	4
2000-04-30	14
2000-05-01	14
2000-05-03	3

Species traits:

https://avibase.bsc-eoc.org/avibase.jsp?lang=EN

Hypotheses & Predictions

1. The **intensity of artificial light** at night affects the frequency of bird-building collisions (alpha = 0.05).

   The frequency of bird-building collisions ***increases*** with the intensity of artificial light.

2. The frequency of bird-building collisions varies among **species** (alpha = 0.05).

   a. The frequency of bird-building collisions ***increases*** in species with lower wing maneuverability.
   b. The frequency of bird-building collisions is ***lower*** in omnivore species than in non-omnivore species.

Part 1

Does the **intensity of artificial light** at night affect the frequency of bird-building collisions?

Toronto's Lights Out program with reduced light levels in spring and fall (lower photograph), which are important periods for bird migration.
Photo credit: WWF Canada. Retrieved 30 November 2023 from howtoconserve.org.

Hypothesis 1: The intensity of artificial light at night affects the frequency of bird-building collisions.

Attraction to lighted structures thought to contribute to bird mortality (e.g. Winger et al. 2019, Loss 2019).

So predicted that frequency of bird-building collisions ***increases*** with intensity of artificial light.

Data Cleaning

Collision data from 1978 to 2016.

Light intensity data from 2000 to 2018 for one building in Chicago.

Exclude collision data not at Chicago site, count total collisions on days when light intensity data available (about 1600 days).

Description: df [1,641 × 3]

Date <date>	Total_collisions <int>	Light_intensity <int>
2000-03-06	4	3
2000-03-08	15	15
2000-03-10	1	3
2000-03-31	2	3
2000-04-02	6	17
2000-04-14	11	4
2000-04-15	2	4
2000-04-30	1	14
2000-05-01	26	14
2000-05-03	4	3

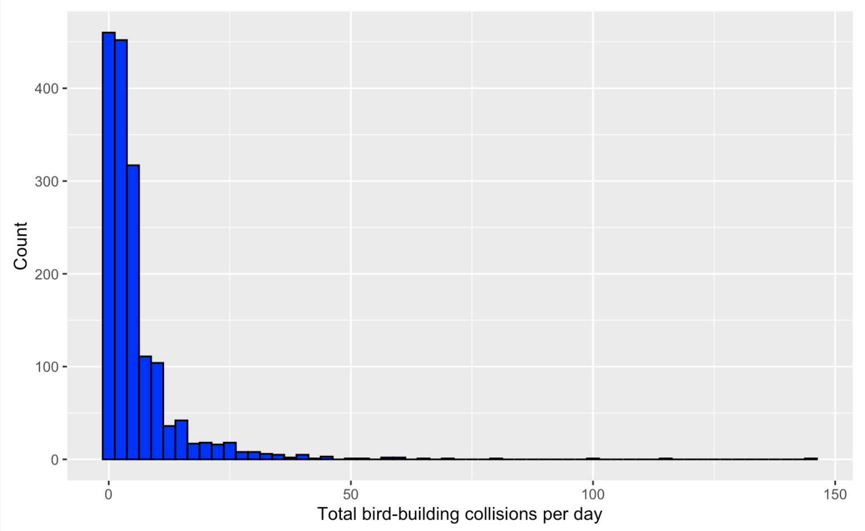
1–10 of 1,641 rows

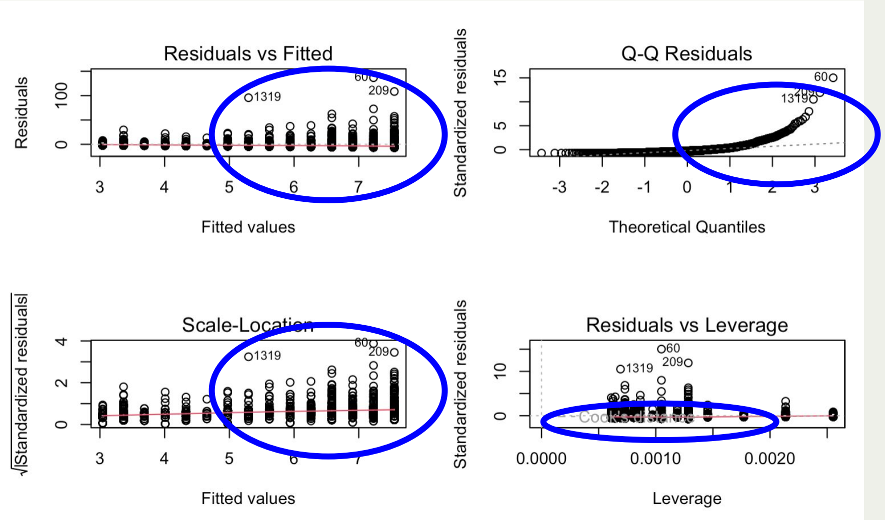
Previous 1 2 3 4 5 6 ... 100 Next

Exploratory Analysis

Count data, collisions not normally distributed... Poisson?

In a simple linear regression of collisions on light intensity, assumption of homogeneity of error variance is violated.





Data Analysis: GLM

GLM finds significant effect of light intensity on collisions.

```
Call:
glm(formula = Total_collisions ~ Light_intensity, family = poisson,
    data = data2)

Coefficients:
                Estimate Std. Error z value Pr(>|z|)
(Intercept)     1.008350   0.032242   31.27   <2e-16 ***
Light_intensity 0.061026   0.002328   26.21   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 12272  on 1640  degrees of freedom
Residual deviance: 11519  on 1639  degrees of freedom
AIC: 16601

Number of Fisher Scoring iterations: 5
```

Data Analysis: LMM

LMM with **Date** as random effect (non-independence).

```
Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: Total_collisions ~ Light_intensity + (1 | Date)
   Data: data2

     AIC      BIC   logLik deviance df.resid
 11910.8  11932.4  -5951.4  11902.8     1637

Scaled residuals:
     Min       1Q   Median       3Q      Max
-0.94382 -0.09632 -0.05131  0.01820  2.93650

Random effects:
 Groups   Name        Variance Std.Dev.
 Date     (Intercept) 79.815   8.934
 Residual              3.172   1.781
Number of obs: 1641, groups:  Date, 1639

Fixed effects:
                Estimate Std. Error       df t value Pr(>|t|)
(Intercept)       2.2230     0.5738 805.1143   3.874 0.000116 ***
Light_intensity   0.3097     0.0447 665.4004   6.929 1.01e-11 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
            (Intr)
Lght_ntnsty -0.920
```

Data Analysis: Model Selection

LMM selected based on AIC.

	df <dbl>	AIC <dbl>
model_glm	2	16601.33
model_lmm	4	$\boxed{11910.84}$

Results & Discussion

Hypothesis: the intensity of artificial light at night affects the frequency of bird-building collisions.

LMM *rejects null hypothesis of no effect* (p-value 1.01×10^{-11}) at alpha 0.05, and finds that increasing light intensity by 1 unit ***increases*** number of collisions by ~0.3.

Date accounts for ~98% of **residual** variance (after accounting for light intensity).

Part 2

Does the frequency of bird-building collisions vary among **species**?

Hypothesis 2: The frequency of bird-building collisions varies among species.

a. The frequency of bird-building collisions *increases* in species with lower wing maneuverability.

b. The frequency of bird-building collisions is *lower* in omnivore species than in non-omnivore species.

Prediction 2a: The frequency of bird-building collision increases in species with lower wing maneuverability.

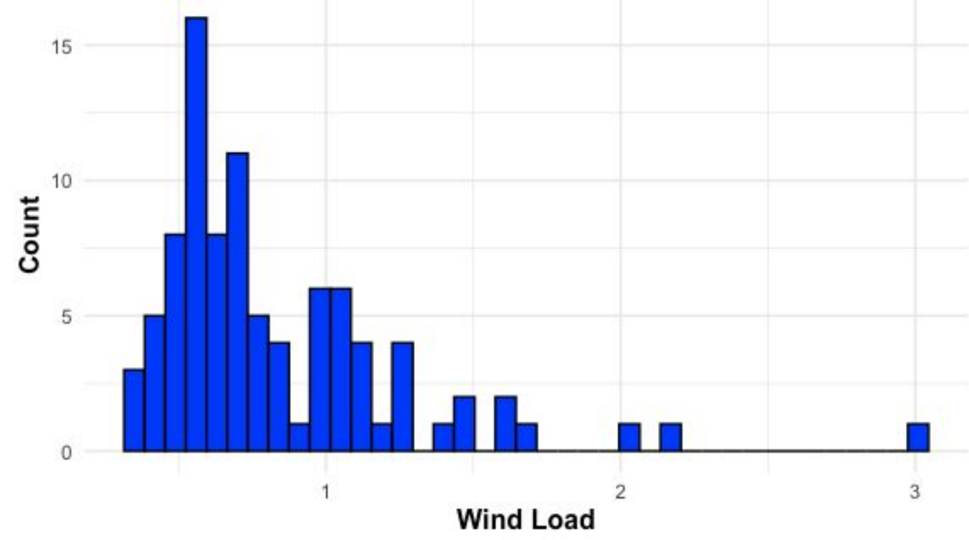
- Wind loading - A measurement related to body mass and wing area
  - Body mass (g)/Wingspan(cm)
- Higher wind loading -> Lower wing maneuverability (Fernández et al. 2018).

Data cleaning & Processing

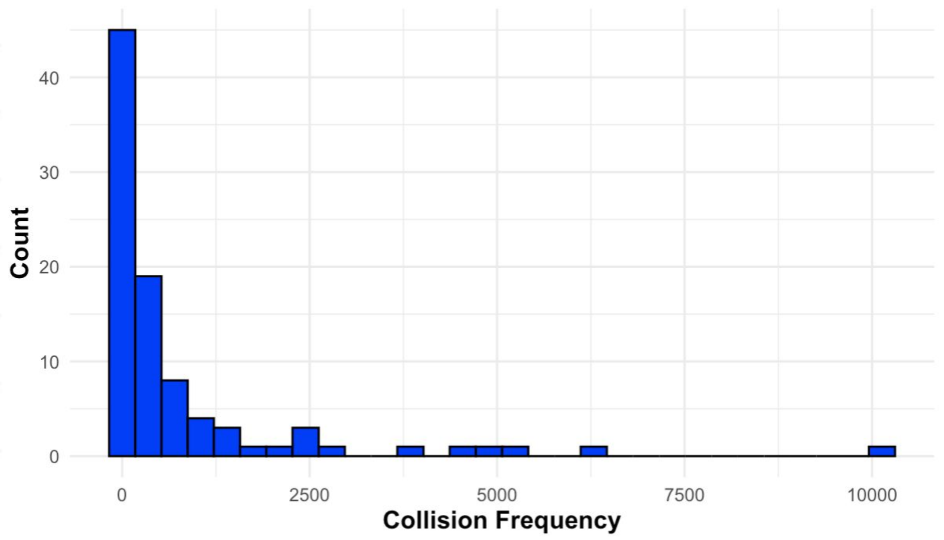
	Species_Name	Avg_Body_Mass_g	Avg_Wingspan_cm	Wind_Load	collision_freq
	<chr>	<dbl>	<dbl>	<dbl>	<int>
1	Ammodramus henslowii	12.5	18.00	0.69	9
2	Ammodramus leconteii	14.0	18.00	0.78	25
3	Ammodramus nelsoni	19.0	18.25	1.04	55
4	Ammodramus savannarum	17.0	17.50	0.97	106
5	Cardellina canadensis	11.0	19.50	0.56	241
6	Cardellina pusilla	7.5	15.50	0.48	185

6 rows

Descriptive Statistics

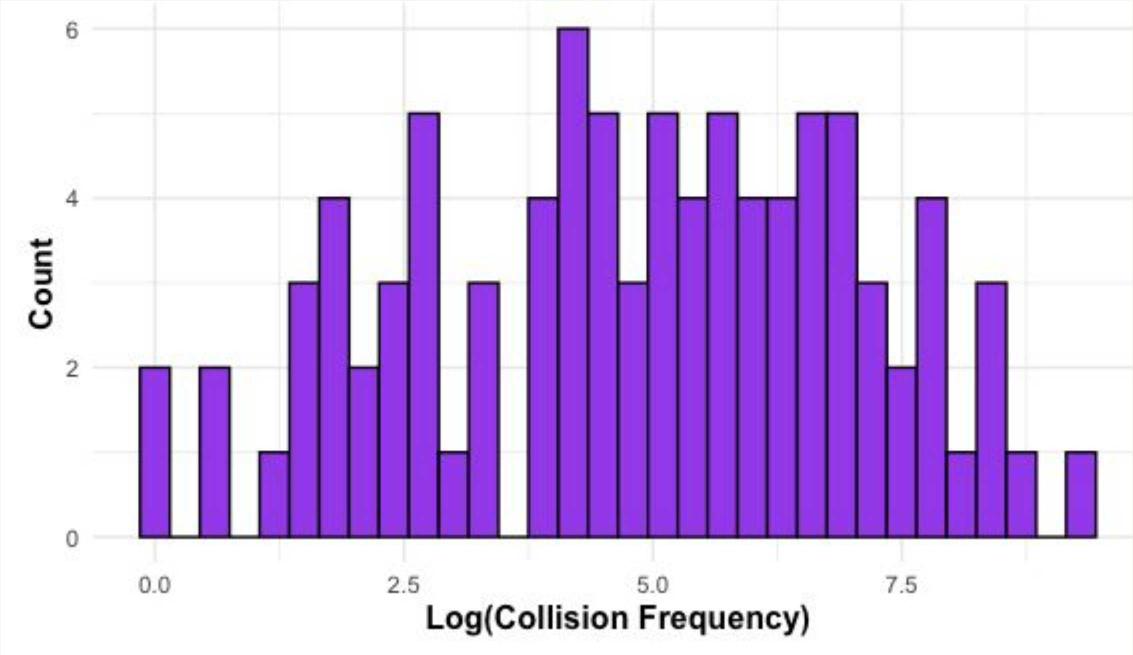


(a)

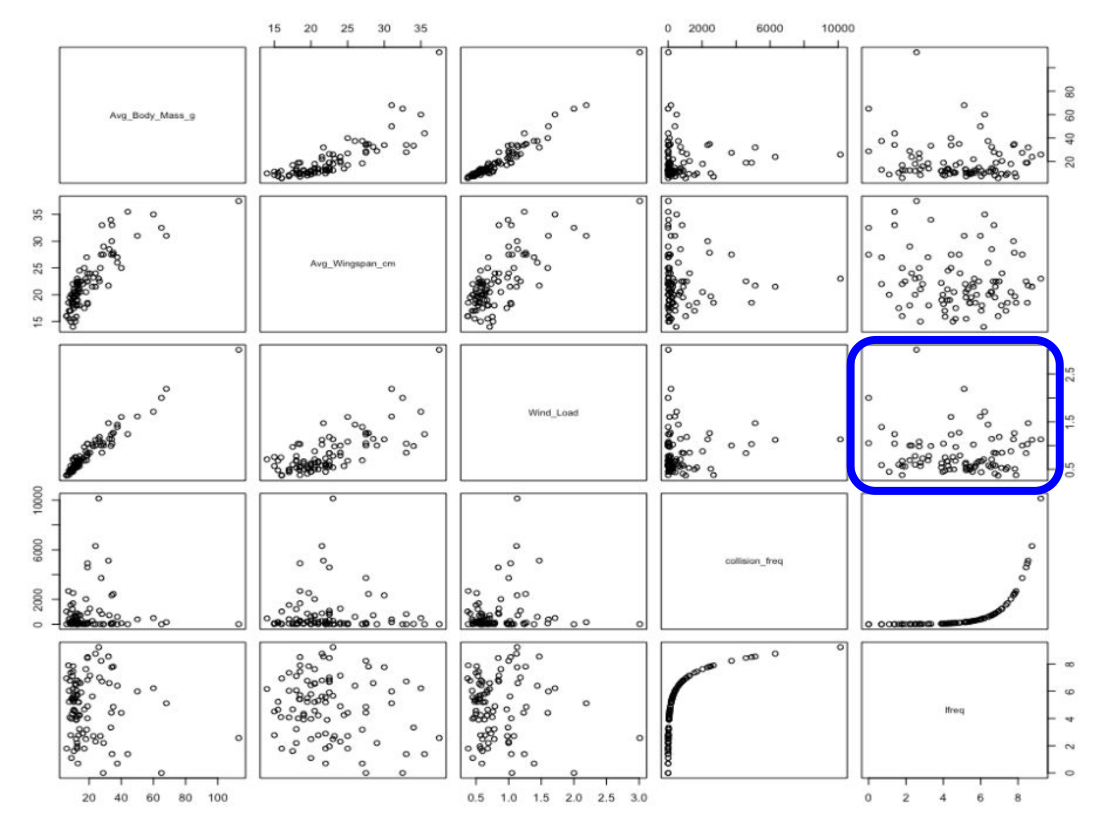


(b)

Results (Descriptive Statistics cont.)



Correlation Analysis



LMM & Hypothesis Testing

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: lfreq ~ Wind_Load + (1 | Date)
   Data: bird1

REML criterion at convergence: 201412.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-9.3101 -0.4252  0.1903  0.6512  2.6316

Random effects:
 Groups   Name        Variance Std.Dev.
 Date     (Intercept) 0.1914   0.4374
 Residual             0.9771   0.9885
Number of obs: 69784, groups:  Date, 5318

Fixed effects:
             Estimate Std. Error        df t value Pr(>|t|)
(Intercept) 6.500e+00  1.510e-02 2.421e+04  430.40   <2e-16 ***
Wind_Load   1.308e+00  1.331e-02 6.785e+04   98.28   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
          (Intr)
Wind_Load -0.836
```

Discussion

- Hypothesis test found low wing maneuverability (measured by `wind load`) has a significant effect on bird-building collision rate.

- Wind load positively correlates with collision frequency -> wind conditions intensify, birds may be more prone to collisions
  - Increased difficulty in maneuvering or disruptions to navigation cues

Prediction 2b: The frequency of bird-building collisions is lower in omnivore species than in non-omnivore species.

- Wittig et al. Omnivorous bird species have significantly lower bird-building collision frequency compared to non-omnivorous bird species.
- Bird species' trophic level data collected from Avibase.
- Categorical independent variables & two groups — T-test.

Data Cleaning

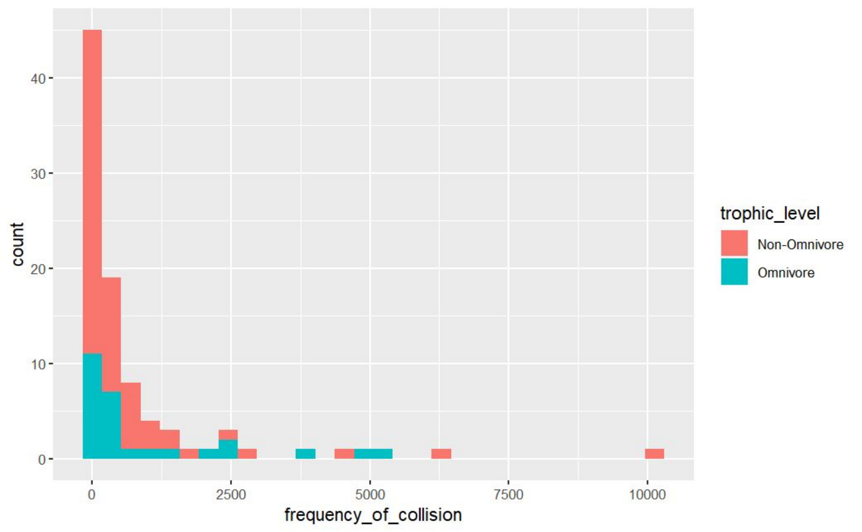
Merge two datasets (1: original dataset 2: trophic level) using merge().
Our dependent variable: frequency of collisions — group_by() and summarize().

full_name	frequency_of_collision	trophic_level
<chr>	<int>	<chr>
Ammodramus henslowii	9	Omnivore
Ammodramus leconteii	25	Omnivore
Ammodramus nelsoni	55	Omnivore
Ammodramus savannarum	106	Omnivore
Cardellina canadensis	241	Non-Omnivore
Cardellina pusilla	185	Non-Omnivore

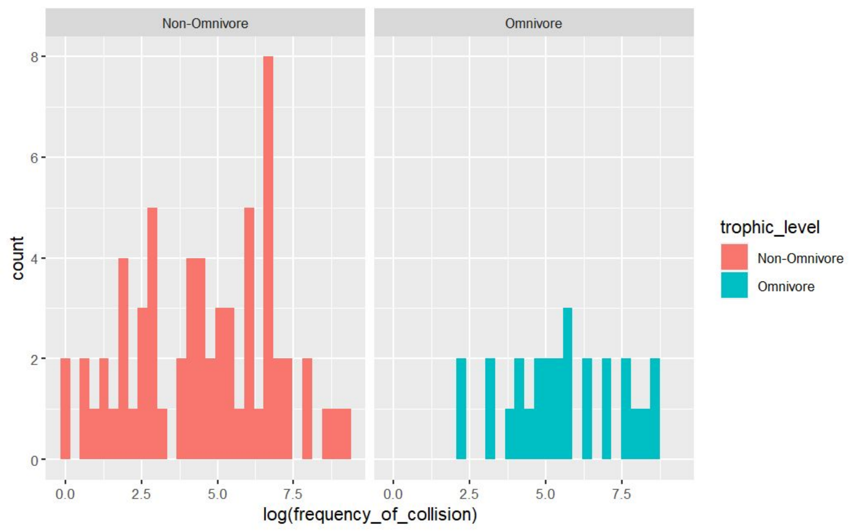
6 rows

Check Assumptions for t-test

Check for normality:



After log-transformation:



Left-skewed

Uniform distribution

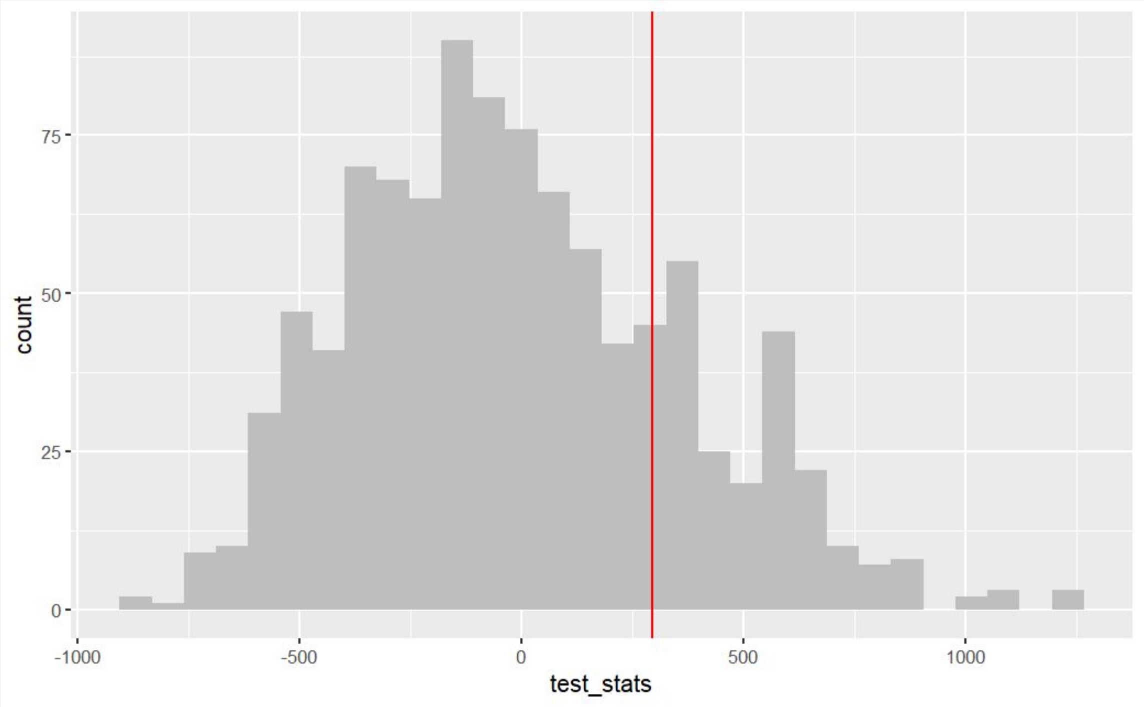
Permutation test

- Non-parametric test. No assumptions for normality or equal variances.

- Null hypothesis: There is **no difference** in the mean in omnivore and non-omnivore bird species' collision frequency.
  i.e., difference in mean collision frequency of the two groups of species is equal to 0.

- Alternative hypothesis: Omnivore species have **lower collision frequency** than non-omnivore species.
  i.e., Difference in mean collision frequency is smaller than 0 (collision frequency of omnivore species - non_omnivore species).

Permutation Test



Alternative hypothesis: **lower** collision frequency

Left-tailed test

P-value: **0.782**

Fail to reject the null hypothesis.

Discussion

- A p-value of 0.782. What could have caused such a large p-value?

Small sample sizes

trophic_level <chr>	count <int>
Non-Omnivore	64
Omnivore	27

Reduced statistical power.
It's possible that a **Type II error** occurred and the test fails to reject a false null hypothesis.

Conclusions

- Hypothesis tests detected significant effect of intensity of **artificial light** and **wing maneuverability** on bird-building collision rate, but limitations to data.
- Did not detect significant effect of **trophic level** on bird-building collision rate.

Important to understand species-specific vulnerability to inform bird conservation strategies in urban areas.

Limitations

Considerations for future analysis:

- Further investigation of multicollinearity between species traits.
- Accounting for local abundance of species groups.
- Consider more variables in construction of models to predict collision rates (e.g. flight behaviours).
- Generalisability: integrate data from other locations and a wider range of bird species.

References

Fernández-Juricic, E., Brand, J., Blackwell, B. F., Seamans, T. W., & DeVault, T. L. (2018). Species with greater aerial maneuverability have higher frequency of collisions with aircraft: A comparative study. Frontiers in Ecology and Evolution, 6, 324310. https://doi.org/10.3389/fevo.2018.00017

Loss SR, Lao S, Eckles JW, Anderson AW, Blair RB, Turner RJ. Factors influencing bird-building collisions in the downtown area of a major North American city. PLoS One. (2019). Nov 6;14(11):e0224164. doi: 10.1371/journal.pone.0224164. PMID: 31693699; PMCID: PMC6834121.

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

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

Wittig, T. W., Cagle, N. L., Ocampo-Peñuela, N., Winton, R. S., Zambello, E., & Lichtneger, Z. (2017). Species traits and local abundance affect bird-window collision frequency. *Avian Conservation and Ecology, 12(1).* https://doi.org/10.5751/ace-01014-120117