



Quantifying geographic variation in flower color in *Mimulus ringens* using citizen science data.



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Introduction

Mimulus ringens (Phrymaceae), a flowering plant native to eastern North America, exhibits variation in floral color among populations. Previous observations indicate that annual and perennial populations of *M. ringens* exist in the northern part of the range, and flower color may vary with life history. It appears that annual populations present darker phenotypes, while perennial populations have lighter coloration (Royer et al., Preliminary Data). Life history also relates to flowering time and location in other plant species.

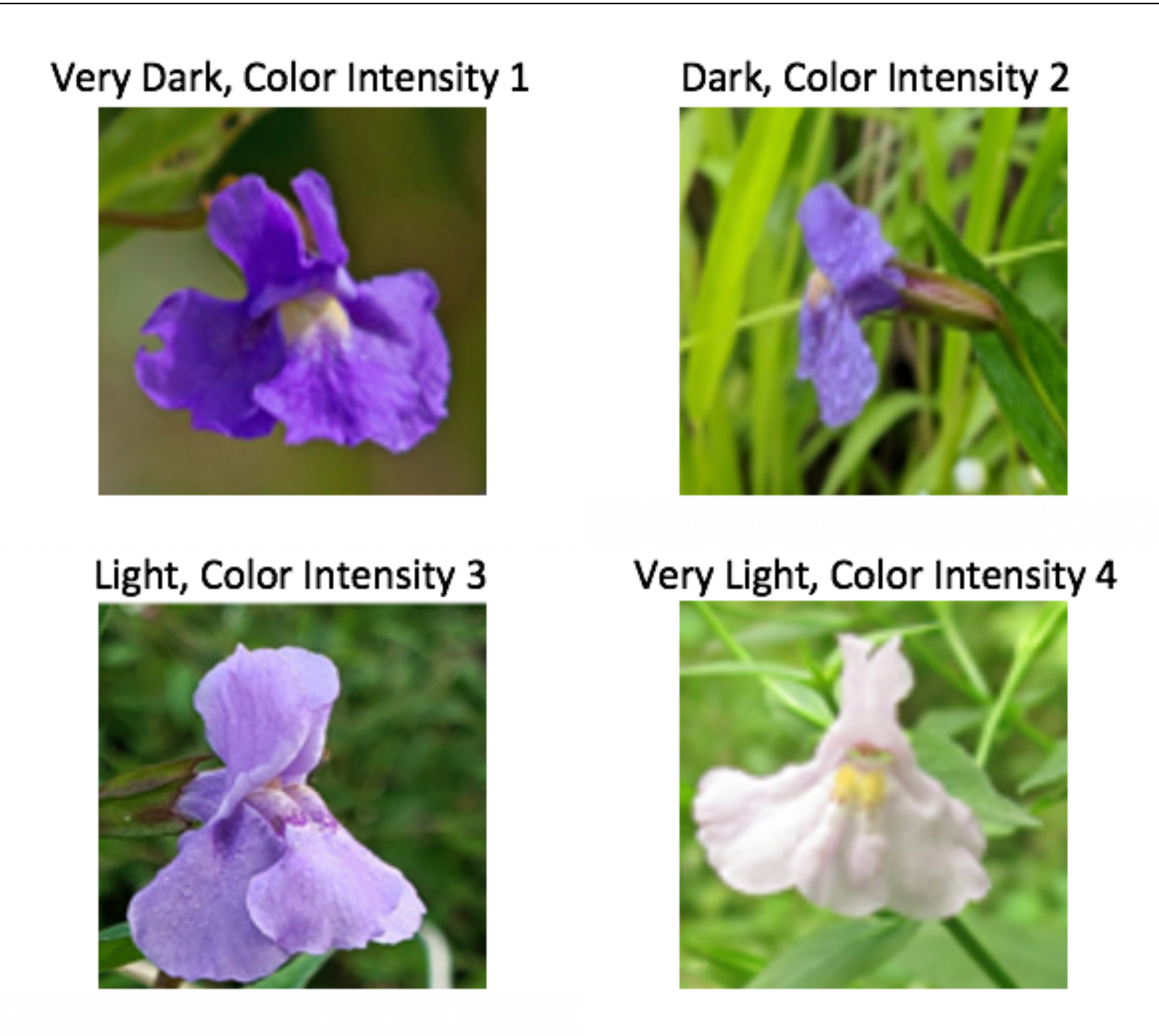


Figure 1: Color intensity examples.

Questions

- We ask:
- **Are earlier-flowering plants more likely to have dark flower color**, as might be expected if it is associated with annual life history?
 - **Does flower color covary with geographic location?**

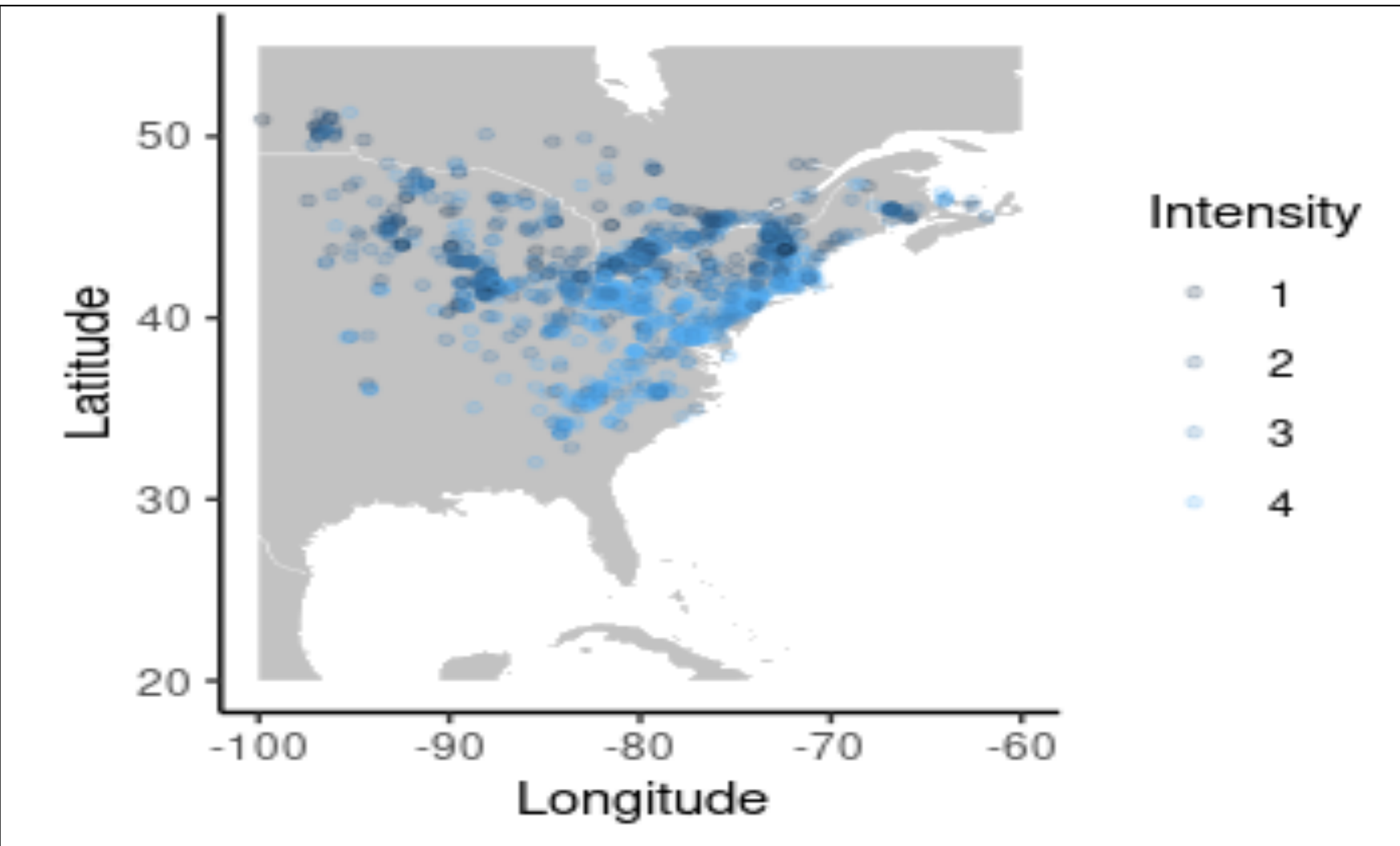


Figure 2: Color intensity by sample location.

Methods

To crowdsource data on flower color, flowering time, and location in *Mimulus ringens*, we used the iNaturalist application, which allows users to contribute photographs of living things to a citizen scientist dataset (GBIF.org, 2020).

We identified and analyzed 1450 photographic samples. We used two measures of color intensity: a categorical qualitative color intensity value (1-4; 1= “very dark,” 4= “very light”) (Fig. 1) and a continuous measure of mean gray value (0 = black, 255 = white) performed using ImageJ (Schneider et al., 2012).

We used R Studio (R Studio Team, 2020) to perform all statistical analyses. Correlations between all continuous variables were estimated using Pearson’s Correlation with a Bonferroni Correction ($p= 0.083$). Logistic regression was used to assess the relationship between color intensity and latitude.

Results

Table 1: Pearson’s Correlation results.				
Correlations between flower color, geography, and flowering time.				
Variable	Mean Gray Value	Latitude	Longitude	Flowering Time
Mean Gray Value				
Latitude	-0.304 ($p<0.001$)			
Longitude	0.083 ($p=0.002$)	-0.025 ($p=0.344$)		
Flowering Time	0.017 ($p=0.527$)	0.047 ($p=0.064$)	0.003 ($p=0.908$)	

Results and Conclusions

Lighter-flowered *Mimulus ringens* are more common throughout the range (Fig. 2; Fig.3). However, a logistic regression indicates that **as latitude increases, the number of dark flowers increases** (OR= 0.718, $n = 1443$, $p<0.001$). **We found no significant relationship between flowering time and flower color** (Table 1; $r=0.017$, $n=1443$, $p=0.527$).

As past research suggests an association between darker flower color and the annual life history, these results may indicate that annual *M. ringens* occur less frequently than perennial populations, and most commonly in the north.

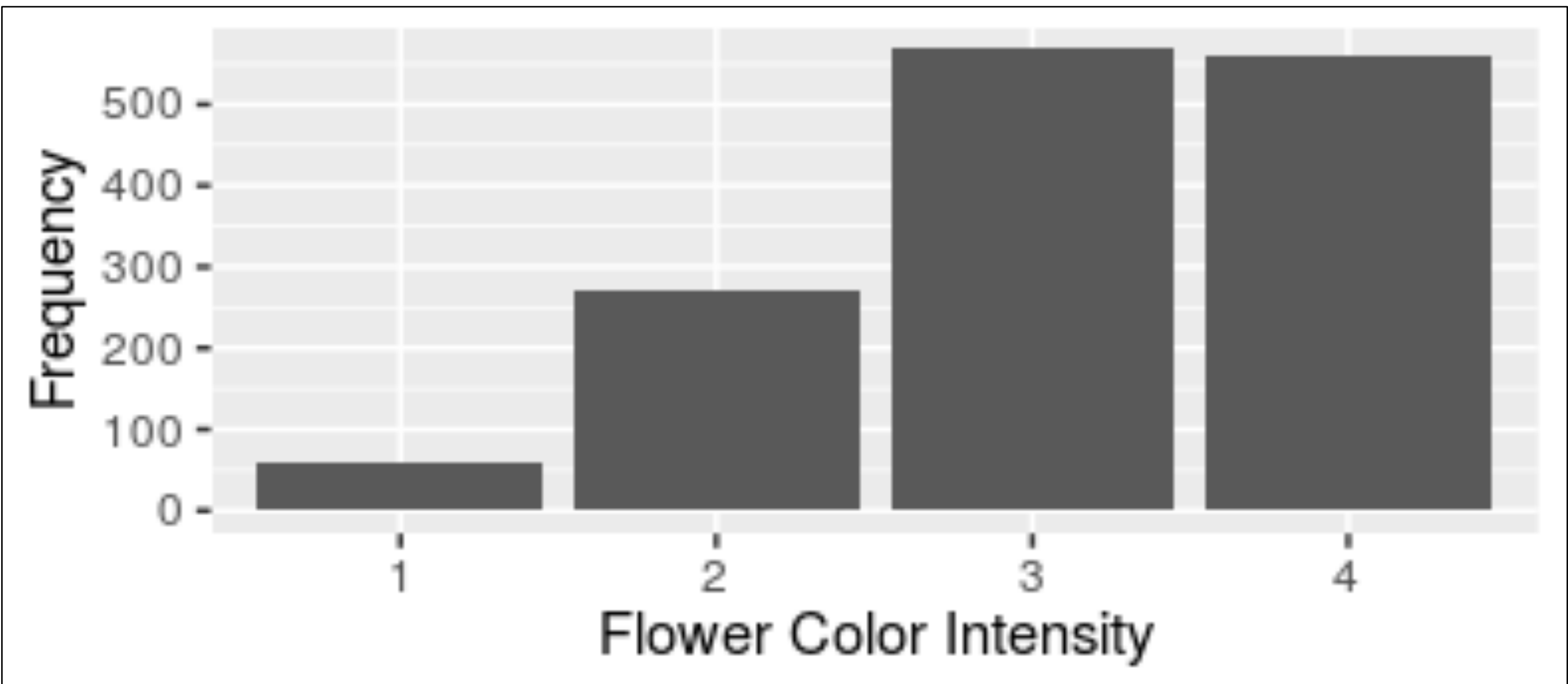


Figure 3: Color intensity frequency.

Future Directions

We are currently collecting floral color data from annual and perennial populations in the greenhouse to explicitly test for a relationship between life history and floral color, and in anticipation of QTL mapping of key floral and life history traits in an F_2 population.

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References:
GBIF.org (24 July 2020). GBIF Occurrence
RStudio Team (2020). RStudio: integrated development for R. *RStudio*, PBC, Boston, MA URL <http://www.rstudio.com/>
Schneider, C.A., Rasband, W.S., Eliceiri, K.W. (2012). NIH Image to ImageJ: 25 years of image analysis. *Nature Methods*, 9, 671-675