Predicting Damselfly Mating Success

**Introduction**

Damselflies are predatory insects of the suborder Zygoptera that reside near freshwater habitats. They are closely related to dragonflies and are similar in their reproduction, life cycle stages, frequent sexual dimorphism and aggressive male competition, though are smaller and less agile, with wings that fold against their bodies when at rest as opposed to dragonflies which hold their wings out and away from their bodies. As less adept fliers, they hunt mostly by picking sitting prey off of low vegetation, rather than catching aerial prey as dragonflies do (*Damselfly*, Wikipedia).

This study includes data from a single population of two sympatric species of Calopteryx demoiselle damselflies, the banded demoiselle *Calopteryx splendens* and the beautiful demoiselle *Calopteryx virgo*, collected from a field monitoring project in Sweden over summer months for 5 years (from 2011 to 2015). Both *C. splendens* and *C. virgo* are large damselflies and are sexually dimorphic in coloration, where females have translucent wings and greenish bronze bodies while males have bright metallic blue-green and pigmented wings (*Banded demoiselle* and *Beautiful demoiselle*, Wikipedia). While *C. virgo* males have almost completely pigmented wings, *C. splendens* males have wing spots that vary in size and are considered a target of sexual selection. Wing pigment appears to be an honest indicator of thermoregulatory and immune capacity however appears to be a trade-off with increased predation risk, as the more pigmented *C. virgo* males are subject to stronger aerial predation pressure (Svensson).

The data contains several morphological traits for both species (linear measurements of body, abdomen, thorax, and wing), a sexually selected trait (forewing patch length and width) measured only in C. splendens, and two variables related to fitness (copulation status: a proxy for mating success and lifespan: a proxy for longevity), measured in both species. The goal of this analysis is to isolate predictors of mating success (vis a vis copulation status) for both species as well as analyze and compare the predictive value of patch size in *C. splendens* on mating success. We hypothesize that sex, species, and lifespan will each predict mating success, with females, *C. virgo*, and longer lifespans predicting increased mating success for all damselflies. We also predict increased patch size relative to wing size will predict increased mating success for *C. splendens* males.

**Methods**

We first analyzed the data for imbalances and relationships, looking at sex ratio, species ratio, and sampling effort over the duration of the study. The dataset includes 3,618 individuals (n=3618) of which 1234 are female and 2384 are male (1234F, 2384M), making the sex ratio 66% male (Figure 1). *C. splendens* individuals comprise the majority of the data with 3025 individuals, as compared to 593 *C. virgo* individuals, comprising 84% of the individuals sampled. Sampling effort was uneven across the 5 years of the study, increasing from 229 sampled individuals in 2011 to 1262 in 2015.

Percent mating success was calculated for these imbalanced variables, by dividing the total number of individuals by the sum of individuals who were observed copulating, which revealed the year 2012 had significantly higher mating success than all other years, therefore it was originally included in the global model and was also tested as a random effect. Mating success between species and among sexes was calculated similarly and they were also originally included in the global model (Figure 2).

Total body length was then plotted against mating success using a logistic regression (as copulation status is recorded as binomial data) and divided by species, however this proved to not be a promising metric, as nearly no variation was explained by total body length nor abdominal length, therefore they were dropped from the global model. When thorax length was similarly plotted against mating success, it appeared to have low explanatory value as well, but the thorax width proved to have significant explanatory value and so was added to the global model (Figure 3). Finally, wing length (both forewing and hindwing, individually) was also plotted against mating success using a logistic regression, indicating some explanatory value for wing length and was therefore added to the model as well (Figures 4 and 5).

The final model for all damselflies was tested by adding and removing variables and weights as well as testing year as a random effect in a mixed effect model. Ultimately, the year did not improve the AIC rank or explanatory value of the model in either a general linear model nor a mixed effect model and was therefore removed. While forewing length did significantly improve the model, hindwing did not, and the model’s AIC rank improved upon removing it from the model. Species also surprisingly did not have a strong explanatory effect and was removed from the final model. The formula for our general model is:

glm(all\_data$cop ~ all\_data$sex + all\_data$thorw + all\_data$fwl, "binomial")

For the male *C. splendens* model, patch size was tested against mating success in a number of ways. Forewing patch length and width were individually plotted against mating success, patch area was calculated as length \* width and plotted against mating success, and relative area was calculated by dividing the previously calculated area by the forewing length and also plotted against mating success. Patch width appeared to have the strongest effect, followed by relative size, and these were included in the final model.

Year was also tested for the male *C. splendens* model similarly as the general model, and was ultimately included as a normal predictor. Thorax width and forewing length were also strong predictors of the male model and were ultimately included. The predictors were all similarly tested in this model as the general model and the final formula for the male *C. splendens* model is:

glm(male\_CS$cop ~ male\_CS$year + male\_CS$thorw + male\_CS$fwl + male\_CS$fpw + male\_CS$ptw, "binomial")

**Conclusion**

The greatest predictor of mating success for all damselflies was thorax width, followed by sex, and forewing length.

Male *C. splendens* mating success was also predicted by thorax width but surprisingly, patch size seemed to indicate decreased mating success, contrary to our expectations as a sexually selected trait.

Future analysis could improve by normalizing sampling effort over the study years, by sampling longer than a handful of days for 2 months, and by including remating in copulation success.

Appendix

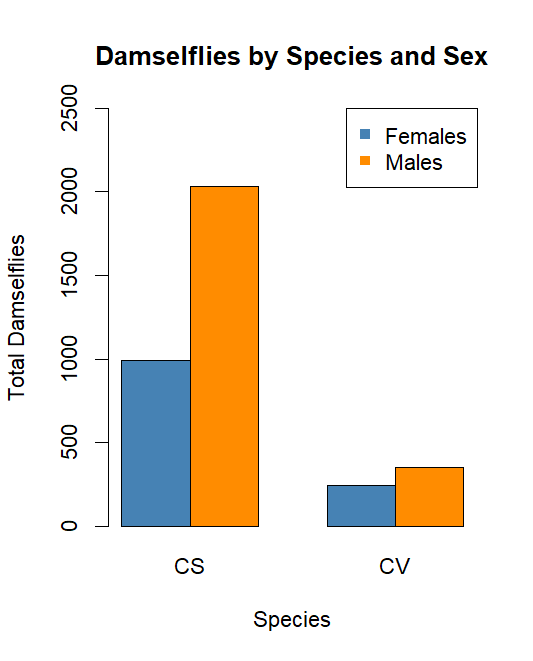
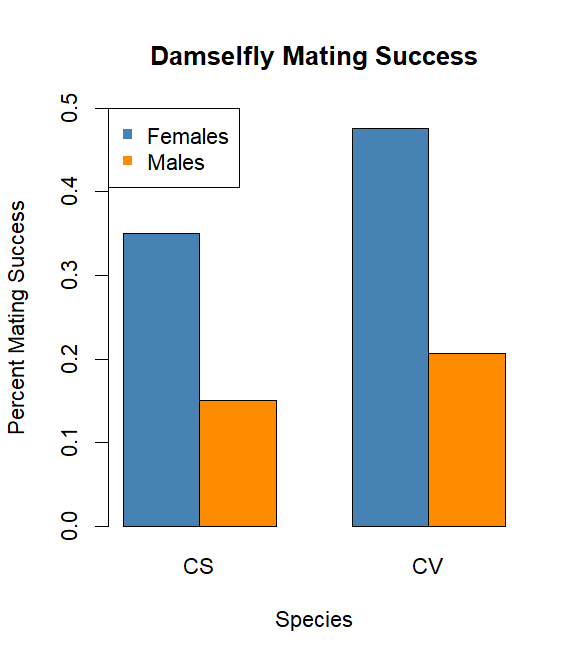


Figure 2

Figure 1

Percentage mating success for each sex out of the total number males/females per each species. C. virgo has higher mating success than C. splendens and females have higher success than males.

Far more C. splendens were captured than C. virgo and more than twice as many C. splendens males than C. splendens females.

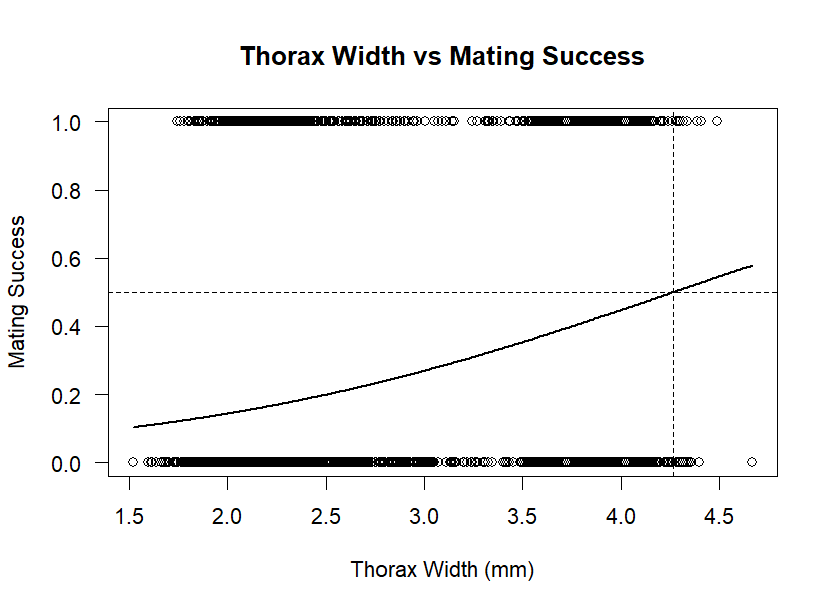
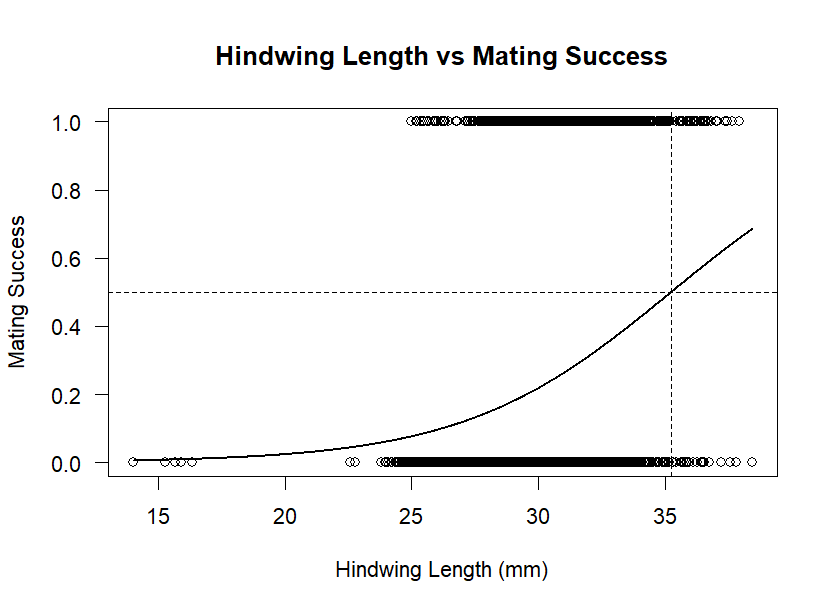
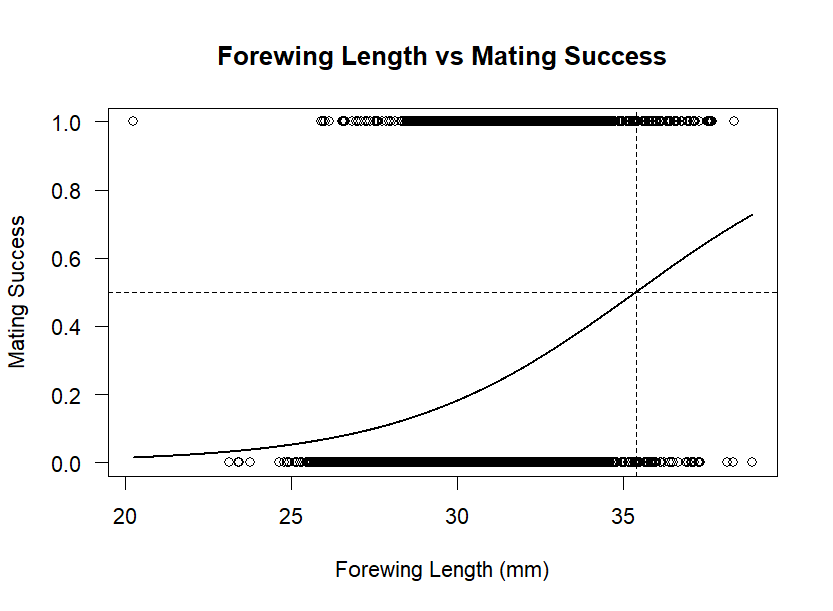


Figure 3

Increased thorax width predicted increased mating success for all damselflies studied. The intersection of the dashed lines represents the length at which predicted mating success reaches 50%.

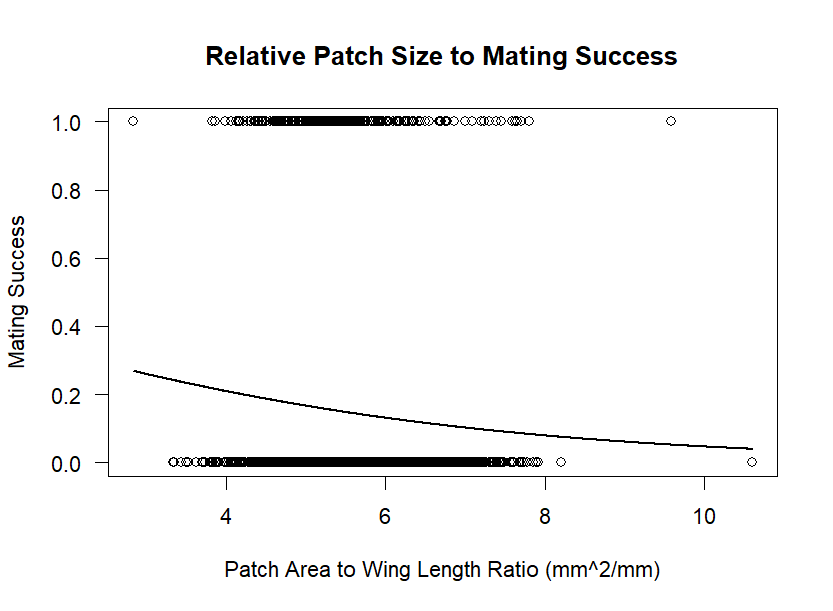
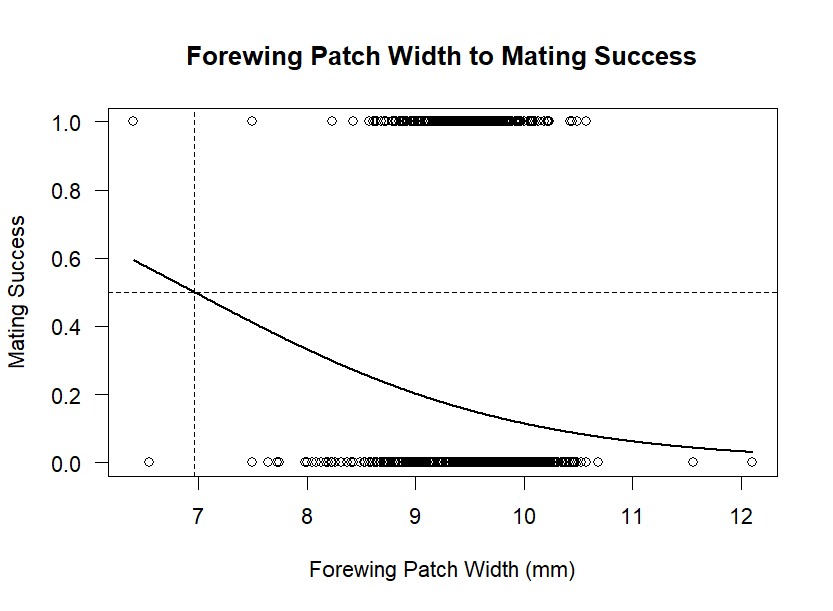


Increased forewing length predicted increased mating success for all damselflies studied. The intersection of the dashed lines represents the length at which predicted mating success reaches 50%.

Increased hindwing length predicted increased mating success for all damselflies studied. The intersection of the dashed lines represents the length at which predicted mating success reaches 50%.

Figure 5

Figure 4



Increased forewing patch width in C. splendens predicted decreased mating success. The intersection of the dashed lines represents the length at which predicted mating success reaches 50%.

Figure 7

In C. splendens, increased relative patch size weakly predicted decreased mating success. Relative forewing patch size for C. splendens was calculated by multiplying patch length (mm) by patch width (mm) and dividing by wing length (mm).

Figure 6

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 1. Model summary for all data** | | | |  |
| Formula: copulation status ~ sex + thorax width + forewing length, "binomial" | | | | |
| **Fixed effects** | **Estimate** | **Std. Error** | **P value** | **R2** |
| (Intercept) | -6.37 | 0.80 | 1.49e-15 | --- |
| SexM | -0.88 | 0.11 | 9.40e-15 | 0.052 |
| Thorax width | 0.75 | 0.06 | < 2e-16 | 0.058 |
| Forewing length | 0.12 | 0.03 | 3.08e-06 | 0.067 |

Estimates of mixed effect model where estimates are the regression coefficient (β) or the slope on the effect: copulation status (binomial). Sex is set relative to male (SexM). Percent variance explained is given by pseudo R2. Sample size n = 3,618.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 2. Model summary for *C. splendens* males** | | | |  |
| Formula: copulation status ~ year + thorax width + forewing length + forewing patch width + relative patch size, "binomial" | | | | |
| **Fixed effects** | **Estimate** | **Std. Error** | **P value** | **ΔR2** |
| (Intercept) | 490.42 | 134.93 | 0.00028 | --- |
| Year | -0.25 | 0.067 | 0.00027 | 0.066 |
| Thorax width | 0.47 | 0.12 | 0.00012 | 0.077 |
| Forewing length | 0.29 | 0.060 | 9.66e-07 | 0.027 |
| Forewing patch width | -0.97 | 0.21 | 3.15e-06 | 0.012 |
| Relative patch size | 0.44 | 0.13 | 0.00084 | 0.0076 |

Estimates of mixed effect model where estimates are the regression coefficient (β) or the slope on the effect: copulation status (binomial). Percent variance explained is given by pseudo R2. Sample size n = 2,035.

Code can be found in Github repository linked below:

<https://github.com/mtindall69/bios14/tree/damselfly-final>

References

*Banded demoiselle* (2024a, February 5). Wikipedia. https://en.wikipedia.org/wiki/Banded\_demoiselle

*Beautiful demoiselle* (2024b, August 11). Wikipedia. https://en.wikipedia.org/wiki/Beautiful\_demoiselle

*Damselfly* (2024c, December 4). Wikipedia. https://en.wikipedia.org/wiki/Damselfly

Kuchta, S. R., & Svensson, E. I. (2014). Predator-mediated natural selection on the wings of the damselfly*calopteryx splendens*: Differences in selection among trait types. *The American Naturalist*, *184*(1), 91–109. https://doi.org/10.1086/676043

Svensson, E. I., & Friberg, M. (2007). Selective predation on wing morphology in sympatric damselflies. *The American Naturalist*, *170*(1), 101–112. https://doi.org/10.1086/518181