Male mate recognition and female phenotypes: testing for reproductive character displacement in demoiselle damselflies (Calopteryx spp.) (Ref IAP2-18-47)

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In partnership with the Centre for Ecology & Hydrology and the University of St. Andrews

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Key Words
1. Species interactions
2. Insect behaviour
3. Citizen science
4. Evolutionary ecology

Overview

Wasteful reproductive interactions between species, known as reproductive interference, impact numerous ecological and evolutionary processes (e.g., determining whether species can coexist) [1–3]. Theoretical models of reproductive interference largely focus on male signal traits and their impacts on female mating decisions. Nevertheless, male mating decisions are often the primary drivers of reproductive interference [3,4]. Demoiselle damselflies (Calopteryx spp.) are a model system for studying the evolutionary consequences of social interactions between species [5–8]. Yet, despite the fact that male damselflies initiate mating interactions, there has been little research into the mechanisms by which variation in female demoiselle phenotypes impact male sexual responses. Consequently, there remains much unexplained spatial and temporal variation in reproductive interference, even in this model system. To address this critical gap in our understanding of how male behaviour and female phenotypes impact the dynamics of reproductive interference, this PhD will employ a unique combination of behavioural experiments on damselflies in the field, public engagement through citizen science, and cutting-edge AI methods.

Specific Aims: To date, data from behavioural experiments suggest that there are low levels of reproductive interference between the two species of demoiselle damselflies in in the United Kingdom (C. virgo & C. splendens; Figure 1) where they coexist. To test the hypothesis that low levels of reproductive...
interference have resulted from selection driving divergence in traits that mediate interspecific reproductive interactions (i.e., reproductive character displacement [9]), the student will:

1. build on an ongoing citizen scientist scheme to quantify geographic variation in the wing coloration of female *Calopteryx* damselflies in the UK to test the prediction that females of the two species are more dissimilar in zones of sympatry than in allopatry; and

2. conduct behavioural experiments to map male mate recognition functions (i.e., the decision rules males use to determine if an individual is a potential mate) to test the prediction that males are more discerning in sympatry than in allopatry.

### Methodology

The student will collect data at several sites across a network of sympatry and allopatry in the UK. At each site, the student will (a) measure female wing colour using digital photography and reflectance spectroscopy [3] and (b) conduct behavioural experiments to measure male mate recognition by recording territorial males’ responses to live, tethered conspecific and heterospecific females [3]. Traditionally, studies of character displacement compare phenotypes in a few allopatric sites to those in a few sympatric sites to test the prediction that interspecific divergence is more pronounced in sympatry. For this project, the student will develop an ongoing collaboration with a citizen scientist network to create a national-scale map of female phenotypes, enabling a powerful test of the reproductive character displacement hypothesis that would not be possible with the traditional approach. Using a combination of reflectance spectra measurements and colour-calibrated photographs [10] taken in the field, the student will develop a protocol for extracting data on female wing colour from citizen scientists’ photographs uploaded to existing citizen science schemes (e.g., iRecord, iNaturalist [https://www.inaturalist.org/projects/british-demoiselles]; Figure 2). In parallel, the student will use a complementary AI approach and design image recognition algorithms, using cutting edge Convolutional Neural Networks (CNNs) [11] to determine whether species in sympatric populations are more visually distinctive, as predicted by the reproductive character displacement hypothesis.

### Timeline

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**Year 1:** Develop pipeline for analysing female phenotypes from photographs; analyses of citizen science dataset; fieldwork to collect phenotypic and behavioural data; **Year 2:** Develop and apply computer vision methods to year 1 data. Complete and submit female phenotype analysis for publication; conduct further behavioural experiments **Year 3-4:** Conduct additional fieldwork as needed, run analyses of geographic variation in male mate recognition; write up and submit thesis. **Note:** Funding ceases at the end of 3.5 years.

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**Figure 2:** Screenshot of British Demoiselles project page in the iNaturalist smartphone app.

### Training & Skills

The student will receive training in (1) the objective, quantitative measurement and analysis of colour using both reflectance spectroscopy and photography (Drury, Durham), (2) field behavioural ecology techniques (Drury, Durham; Shuker, St. Andrews), (3) designing and implementing machine learning algorithms to conduct automated species discrimination of citizen scientists’ photographs (August, CEH).

### References & Further Reading

3. Drury JP, Okamoto KW, Anderson CN,


Further Information

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