J. Br. Dragonfly Society, Volume 32 No. 1, April 2016

CONTENTS

Journal of the British Dragonfly Society

Volume 32 Number 1 April 2016

BDS

The aims of the **British Dragonfly Society** (BDS) are to promote and encourage the study and conservation of Odonata and their natural habitats, especially in the United Kingdom.

The Journal of the British Dragonfly Society, published twice a year, contains articles on Odonata that have been recorded from the United Kingdom and articles on European Odonata written by members of the Society.

Articles for publication should be sent to the Editor. Instructions for authors appear inside the back cover.

ADDRESSES
Editor:
P.J. Mill
8 Cookridge Grove
Leeds, LS16 7LH
email: gpmill@supanet.com

Secretary:
H.G. Curry
23 Bowker Way
Whittlesey
Peterborough, PE7 1PY
email: secretary@british-dragonflies.org.uk

Librarian / Archivist:
D. Goddard
30 Cliffe Hill Avenue
Stapleford
Nottingham, NG9 7HD
email: david.goddard8@ntlworld.com

Membership Secretary
L. Curry
23 Bowker Way
Whittlesey
Peterborough, PE7 1PY
email: membership@british-dragonflies.org.uk

Back numbers of the Journal can be purchased from the BDS Shop at £2.00 per copy to members or £5.50 per copy to non-members.
email: shop@british-dragonflies.org.uk

Species Reviews: Various species reviews are in the process of being written so if anyone is considering writing a review of their favourite species, please contact the Editor first.

Ordinary membership annual subscription £20.00.
Overseas subscription £25.00.
Benefactor membership £40 (minimum)
All subscriptions are due on 1st April each year.

Other subscription rates (library, corporate) on application to the Membership Secretary, who will also deal with membership enquiries.

BDS Website: www.british-dragonflies.org.uk

Cover illustration: A *Lestes sponsa* male attached to a pair of *Ceriagrion tenellum*. Photograph by Bryan Pickess.

The Journal of the British Dragonfly Society is printed by Artisan Litho, Abingdon, Oxford.
www.artisanlitho.co.uk

INSTRUCTIONS TO AUTHORS

Authors are asked to study these instructions with care and to prepare their manuscripts accordingly, in order to avoid unnecessary delay in the editing of their manuscripts.

- Word processed manuscripts may be submitted in electronic form either on disk or by e-mail.
- Manuscripts should be one and a half spaced, on one side of the page only and with margins at least 25mm on both sides and top and bottom. Footnotes should be avoided.
- Use of these terms is acceptable: 'exuvia' for cast skin (plural: 'exuviae'); 'larva' (instead of 'naiad' or 'nymph'); 'prolarva' to designate the first larval instar.
- Dates in the text should be expressed in the form: 24 July 2010.
- References cited in the text should be in the form '(Longfield, 1949)' or '...as noted by Longfield (1949)'. All references cited in the text (and only these) should be listed alphabetically at the end of the article in the following forms:

  Hammond, C.O. 1983. *The Dragonflies of Great Britain and Ireland* 2nd Edition (revised by R. Merritt), Harley Books, Colchester, 116pp.

  Longfield, C. 1949. The Dragonflies of the London area. *The London Naturalist* **28**: 90-98.
- Titles of journals should be written out in full.
- Figures, plates and tables should be presented on separate, unnumbered pages.
- Legends for figures, plates and tables should be presented together in sequence on separate, unnumbered pages.
- The legend for each table and illustration should allow its contents to be understood fully without reference to the text.

Please refer to a recent issue of the journal for further style details.

SCIENTIFIC AND ENGLISH NAMES OF BRITISH ODONATA

ZYGOPTERA	DAMSELFLIES
Calopteryx splendens	Banded Demoiselle
Calopteryx virgo	Beautiful Demoiselle
Ceriagrion tenellum	Small Red Damselfly
Chalcolestes viridis	Winter Emerald Damselfly
Coenagrion armatum	Norfolk Damselfly
Coenagrion hastulatum	Northern Damselfly
Coenagrion lunulatum	Irish Damselfly
Coenagrion mercuriale	Southern Damselfly
Coenagrion puella	Azure Damselfly
Coenagrion pulchellum	Variable Damselfly
Coenagrion scitulum	Dainty Damselfly
Enallagma cyathigerum	Common Blue Damselfly
Erythromma najas	Red-eyed Damselfly
Erythromma viridulum	Small Red-eyed Damselfly
Ischnura elegans	Blue-tailed Damselfly
Ischnura pumilio	Scarce Blue-tailed Damselfly
Lestes barbarus	Southern Emerald Damselfly
Lestes dryas	Scarce Emerald Damselfly
Lestes sponsa	Emerald Damselfly
Platycnemis pennipes	White-legged Damselfly
Pyrrhosoma nymphula	Large Red Damselfly
Sympecma fusca	Winter Damselfly
ANISOPTERA	DRAGONFLIES
Aeshna affinis	Southern Migrant Hawker
Aeshna caerulea	Azure Hawker
Aeshna cyanea	Southern Hawker
Aeshna grandis	Brown Hawker
Aeshna juncea	Common Hawker
Aeshna mixta	Migrant Hawker
Anaciaeshna isoceles	Norfolk Hawker
Anax ephippiger	Vagrant Emperor
Anax imperator	Emperor Dragonfly
Anax junius	Green Darner
Anax parthenope	Lesser Emperor
Brachytron pratense	Hairy Dragonfly
Cordulegaster boltonii	Golden-ringed Dragonfly
Cordulia aenea	Downy Emerald
Crocothemis erythraea	Scarlet Darter
Gomphus flavipes	Yellow-legged Club-tail
Gomphus vulgatissimus	Common Club-tail
Leucorrhinia dubia	White-faced Darter
Leucorrhinia pectoralis	Large White-faced Darter
Libellula depressa	Broad-bodied Chaser
Libellula fulva	Scarce Chaser
Libellula quadrimaculata	Four-spotted Chaser
Orthetrum cancellatum	Black-tailed Skimmer
Orthetrum coerulescens	Keeled Skimmer
Oxygastra curtisii	Orange-spotted Emerald
Pantala flavescens	Wandering Glider
Somatochlora arctica	Northern Emerald
Somatochlora metallica	Brilliant Emerald
Sympetrum danae	Black Darter
Sympetrum flaveolum	Yellow-winged Darter
Sympetrum fonscolombii	Red-veined Darter
Sympetrum pedemontanum	Banded Darter
Sympetrum sanguineum	Ruddy Darter
Sympetrum striolatum *	Common. Darter *
Sympetrum vulgatum	Vagrant Darter

* Includes dark specimens in the north-west formerly treated as a separate species, *Sympetrum nigrescens* Highland Darter

Registered Charity No. 800196

Norman Winfrid Moore (1923 - 2015)

Brian N. K. Davis

Book House, Church Road, Easton, Huntingdon, PE28 0TU

Norman Moore, who died in October, was one of our best-known and most highly respected naturalists. He had a wide knowledge of and interest in many aspects of British wildlife and pursued a distinguished career in nature conservation. He has been variously described as 'one of the 20th century giants of nature conservation', 'one of the most influential figures in nature conservation over half a century', and 'one of the principal architects of present day policies of wildlife conservation in Britain'. He was a keen naturalist from boyhood, keeping a diary from the age of six until he died. In his teens he became fascinated by dragonflies, which he called the 'bird-watcher's insect', and published his first paper on 'Rare Lepidoptera and Odonata in East Sussex' in 1934. The son of a doctor, Sir Alan Moore, he went to Eton, 'before it became the preserve of the very rich'. With two friends, including David Snow, he formed what they called the Eton Ornithological Union, and spent their free time bird-watching at the Slough sewage farm. In 1940, he went up to Cambridge at 17 to read Natural Sciences and joined the Cambridge Bird Club where he immediately became secretary as the existing secretary was called up. In this capacity, he again became a frequent visitor to the local sewage farm, and also to Wicken Fen and Adventurers' Fen.

He joined up in 1942 and trained as a mountain gunner in the Cairngorms, ostensibly in preparation for attacking the German heavy water plant in Norway – but then being glidered into the Low Countries in 1944 to join the assault on Germany. Here he was wounded and captured and spent time in a German prison camp, mainly for Russians with hundreds dying every day from starvation. The story of his unit is beautifully recalled by a fellow officer, Geoffrey Tudor, in *Hoofprints in the Clouds – Jeep Tracks in the Mud* in which Norman first appears on page 3 where he is credited with saying, 'We've got two hours before dinner at eight, come and look for some capercaillie'.

After the war Norman returned to Cambridge to complete his degree, meeting and later marrying Janet Singer who was doing her Ph.D. After a three month zoological trip to The Gambia, he took up a lectureship at Bristol. His research on dragonflies led to a Ph.D. in 1953, and later to joint authorship with Philip Corbet and Cynthia Longfield of a New Naturalist book on *Dragonflies*. He was offered a post as Regional Officer in the Nature Conservancy covering south-west England from Herefordshire to Scilly, and here he was responsible for

Plate 1. Norman on the coast path on the island of Herm, Channel Islands in 1971.

selecting the first National Nature Reserves to protect habitats such as the Dorset heathlands, which were threatened with tree planting; a commemoration stone is now erected to him there, and his landmark paper on the fragmentation of Dorset heathlands was later published in 1962. With the help of the British Trust for Ornithology, Norman undertook a study of the buzzard whose populations had been declining. He showed that this was largely due to persecution from gamekeepers and not just to the reduction in rabbit populations from myxomatosis.

During the 1950s, there was increasing concern about the effects of some new pesticides such as Schradan and DNOC killing partridges. The Nature Conservancy was also becoming concerned about the use of herbicides by some county councils to manage road verges. The Director General invited Norman to head up a Toxic Chemicals and Wildlife Section in a new research station to be built near Cambridge, and Norman was on the committee that chose Monks Wood as the site for this. I was the first member of his Section in 1960. On one occasion I noticed a letter addressed to Sir Norman Moore and when I pointed this out he coughed apologetically and explained that he had indeed inherited the title when his father died, but that he didn’t wish to adopt it; Laurie Friday has described a similar gentle correction in her first contact with him.

His first task was to visit places like the Fisons and ICI pesticide research stations to decide which chemicals posed the most significant wildlife problems. The director of Monks Wood, Kenneth Mellanby, later said that Norman had a genius for picking those problems that would yield the greatest benefits from research. But at the time the pesticide industry claimed that Norman had been appointed 'to do placatory research' and need not be taken seriously. His modest demeanour, however, belied a steely resolve backed by firm belief in the importance of nature conservation backed by good science. He saw the chlorinated hydrocarbons (as they were then known), such as aldrin, dieldrin and heptachlor, as the most important candidates for research because of their persistence. From the outset, though, Norman wanted to demonstrate that the Nature Conservancy was not against pesticides per se. He saw that herbicides could be a valuable tool for curbing scrub growth in nature reserves, and so he set up two experiments to examine the side effects of treating cut stumps, in Wicken Fen and at High Halstow in Kent. I was involved with both of these where we compared the plant diversity and the soil faunas in replicated plots.

The next few years saw a burgeoning of research staff at Monks Wood. Norman put together a multidisciplinary team of zoologists, botanists, toxicologists and chemists. The personal affection and unified efforts that he generated, made the station one of the most stimulating and productive research environments in the country. He was acutely aware that agriculture itself was changing the face of the countryside through the loss of hedgerows, and that one must evaluate this against the use of pesticides. He appointed Max Hooper and Ernie Pollard to look into this question and set up a series of experimental hedges in the fields beside Monks Wood, which were used to study nesting birds and insect colonisation in relation to hedge management – and years later to study spray drift. Together they wrote a New Naturalist book on *Hedges*, the first comprehensive study of one of the most important agricultural habitats.

In 1965 he obtained funding from NATO for an international conference on pesticides and wildlife at Monks Wood. The topic had now become international news through the publication in 1962 of Rachel Carson's seminal book *Silent Spring*, but this was the first time that many scientists in America and Europe had met each other. Norman's main rôle during the following years was feeding the results of his team's research into the government's interdisciplinary Advisory Committee on Pesticides. It took years of constant argument to persuade the committee that DDT and other organochlorines should be phased out 'on the precautionary principle': one could not wait for absolute proof before taking action. Derek Ratcliffe's independent work on the effects of DDT on eggshell thinning, and the consequent decline of the peregrine falcon, was immensely significant at this juncture in persuading the government to take action, though even these results faced violent criticism from vested interests.

Plate 2. Norman by his pond in 2002. Photograph by Andy McGeeney.

Concerned over the widening gulf between farmers and conservationists, Norman organised a conference at Silsoe in 1969 and helped to found the Farming and Wildlife Advisory Group (FWAG), encouraging farmers to make the most efficient use of their land while protecting wildlife interests. Several regional Advisors were appointed gradually and Norman became the first chair and judge for the Silver Lapwing Award for conservation in farming.

Norman always believed strongly in the value of constantly talking over research ideas and policy questions with other members of staff during informal times such as lunch breaks. This often occurred while walking along the southern edge of Monks Wood, and it was during these walks that he started making regular counts of butterflies. His 'butterfly transects in a linear habitat' were

Plate 3. Norman in his garden at Swavesey, Cambridgeshire in 2010.

subsequently developed by Pollard and widely adopted in the country-wide Butterfly Monitoring Scheme. Likewise, he initiated a study on the numbers of bird species in relation to woodland size. Ever open to new initiatives, Norman spotted an opportunity to monitor the effects of building the new town of Bar Hill on the fauna and flora, and the results of his 23-year study were published in 'Nature in Cambridgeshire' in 1990. He continued his interest in dragonflies with the digging of 20 ponds at Woodwalton Fen to study colonisation and published the results of a long term study in 1991 and, when he retired, he asked for a large pond to be dug in his field at Swavesey, which provided information for his last book *Oaks, Dragonflies and People* – creating a small nature reserve and relating its story to wider conservation issues', published in 2002.

Meanwhile Janet Moore had joined New Hall (now Murray Edwards College), Cambridge, in 1971. She was a world authority on nemertine worms, and wrote an acclaimed textbook *An Introduction to the Invertebrates*. She loved teaching and her warmth, enthusiasm and dedication as Director of Studies and Senior Tutor at New Hall, and provider of informal pastoral care to graduate students, made her a greatly loved figure. She died in 2014.

Plate 4. Norman in 2011. Photograph by Caroline Moore.

In 1973 the Nature Conservancy was split into a government advisory body, the Nature Conservancy Council (NCC), with land management and advisory responsibilities, and a research body, the Institute of Terrestrial Ecology, under the Heath government's 'customer – contractor' principle. Norman fought hard against this as he believed passionately that the two should go together. Within the new NCC Norman was given a specially created post as Chief Advisory Officer until he retired in 1983. Here he produced guidelines on the designation of sites of special scientific interest (SSSI), which still underpin the protection of sites in the UK, and he developed the NCC strategy towards agriculture, which strongly influenced the shape of the Wildlife and Countryside Act of 1981.

On retirement, Norman was offered an OBE but considered that this was inappropriate for a civil servant 'just doing his job'. He published his personal philosophy towards science and nature conservation as an obligation to future generations in *The Bird of Time*, which was runner up for the Sir Peter Kent Conservation Prize in 1987 and should be considered essential reading for anyone interested in conservation, particularly in Britain. He was elected an Honorary Member of the British Dragonfly Society (BDS) in 1988. He was a member of the Dragonfly Conservation Group of the BDS for many years, chairing the group for around a decade, and his broad knowledge of conservation issues was highly valued by the members. He chaired meetings of the Odonata specialist group in the IUCN Species Survival Commission, and locally of the Wicken Fen management committee. Here his long knowledge of the fen was critical in setting proposals in a historical context. Laurie Friday, who succeeded him as chair, says that 'he steered the Committee through some distinctly bumpy times with an authority that was extraordinarily wise and gentle, but also firm and decisive'. He was very keen to re-establish Water-Soldier (*Stratiotes aloides*) and then the Norfolk Hawker (*Anaciaeschna isoceles*). The rest of the committee considered this doubtful but he 'pursued his dream right to the end of his long and wonderful life'. In 2001 he was honoured by the Zoological Society of London with the Stamford Raffles Award for his distinguished contributions to the ecology and behaviour of Dragonflies. He was also honoured by the Royal Entomological Society, both with an Honorary Fellowship, and with the Marsh Entomological Award for Insect Conservation, of which he was the first recipient.

Norman and Janet remained our close friends for 55 years. They are survived by three children and eight grandchildren. I thank Jeremy Greenwood, Ernie Pollard, Laurie Friday and William Foster for their contributions to this obituary.

Reproduced with minor changes from 'Nature in Cambridgeshire' with kind permission of the editors of that publication.

Applying novel digital visualization tools and traditional morphometrics to the analysis of wing size and asymmetry and to male wing spot size in *Calopteryx splendens* (Harris) (Banded Demoiselle)

Laura Upton[1], Ben Price[2], Diana Percy[2] & Steve Brooks[2]

[1]University College London, Gower Street, London, WC1E 6BT
[2]Department of Life Sciences, Natural History Museum, Cromwell Road, London SW7 5BD

Abstract

The Banded Demoiselle (*Calopteryx splendens*) has sexually dimorphic wing pigmentation: males have a wing spot which is lacking in females. We investigated the relationship between wing size, wing asymmetry and, in males, the size of the pigmented area, against latitude, longitude, mean winter and summer temperatures and the time of year the specimen was collected. A total of 270 specimens were analysed, using Pearson's product moment correlation, from museum collections in England and Scotland. Wing size was significantly positively correlated with latitude and mean winter temperature, in both males and females, and wing spot size was positively correlated with collection day in males. Increasing wing size with latitude follows Bergmann's Rule and increasing wing size with increasing mean winter temperature may reflect increased larval growth during warm winters. Increase in wing spot size through the summer probably does not reflect a temperature response, since increasing summer temperature might be expected to lead to smaller wing spots if these had a thermoregulatory function. It is more likely that enhanced pigmentation of the wing spots may lead to increased reproductive success, which becomes a premium as the summer advances.

Introduction

Calopteryx splendens (Banded Demoiselle) is a large Eurasian damselfly within the family Calopterygidae. Males are identified by their metallic blue bodies and a dark spot (or band) across the centre of each wing, while females have green-bronze bodies and a white pseudopterostigma near the tip of each wing. The Banded Demoiselle is present throughout Eurasia, from northwestern China to the Atlantic coast, and a variety of subspecies are recognized across its range (Dijkstra & Lewington, 2006). Formerly, in Britain, the Banded Demoiselle was restricted to rivers in central and southern England. However, in recent decades the species has spread further north and there are now populations on the Solway Firth (between Cumbria and Dumfries and Galloway) and on a number of rivers in Northumberland (Lowdon, 2015). The northeast populations are relatively well connected to other populations but the northwest populations are more isolated (Hassall & Thompson, 2009).

The pigmentation of damselfly wings has been of research interest due to its link to the male immune system and its role as an 'honest signal' of male quality (Hassall & Thompson, 2009). The wing pigmentation develops during maturation and is caused by the deposition of melanin, which requires energy expenditure (Hassall, 2014). The condition of the melanin-based colouration in calopterygids is another indication of the energetic cost of the wing spots (Hooper *et al*., 1999; Talloen *et al*., 2004). There is often substantial within and between population variation in the wing spot colour from near black/blue to a pale brown (Siva-Jothy, 1999). This variation is influenced by a range of factors including sexual selection and climate (Hassall, 2014), and the presence of other species of damselfly (Tynkkyen *et al*., 2004) (see below).

Hassall (2014) concluded that, in *Calopteryx* species, sexual selection is the primary driver of wing pigmentation. The wing spots play an important role in the courtship 'dances' that males perform for females (Hassall & Thompson, 2009). Since 60.3% of males of *Calopteryx splendens* are rejected by the female after the courtship, and the pigmentation does not change in reproductively active males (Siva-Jothy, 1999), it is a logical hypothesis that the females prefer certain wing pigment variations. However, the functional role of these variations is yet to be ascertained. Another potential driver of wing spot variation in *C. splendens* is the presence of a congeneric species, *Calopteryx virgo*, in which males have bands covering most of the wing. On some rivers the distribution of *C. virgo* and *C. splendens* overlaps and, where this occurs, there is evidence that interspecific interactions result from poor species recognition. This poor recognition results in female *C. virgo* mistaking large-spotted *C. splendens* for conspecifics (Tynkkynen *et al*., 2004). Hybridization then leads to a decline in the size of the *C. splendens* wing spot; this is positively correlated with the density of *C. virgo* (Tynkkynen *et al*., 2004). A similar trend was observed between the North American species *Calopteryx maculata* and *Calopteryx aequablis* (Hassall, 2014).

The other drivers of wing variation are climate or temperature related. The pigmentation of the wing spots is thought to increase the thermoregulatory capacity (Hassall, 2014); the darker the pigmentation the more solar radiation is absorbed. *Calopteryx virgo* have bigger, darker wing bands than *C. splendens*. *Calopteryx virgo* emerge earlier in the year and maintain a higher body temperature in lower ambient temperatures than *C. splendens* (Svensson & Waller, 2013). This indicates that the individuals possessing more melanin in the wing benefit by being able to absorb more solar radiation. This might be expected to result in a positive correlation between pigmentation and increase in latitude and a negative correlation between pigmentation and the date the insect is on the wing. There is some evidence for a negative relationship between degree of pigmentation and temperature in *Calopteryx* damselflies (Outomuro & Ocharan, 2011). However, in a study of English populations of *C. splendens* Hassall & Thompson (2009) found that a population in Northumberland, northern England, had significantly smaller wing spots than a population in Hampshire, in southern England, resulting in a negative correlation between wing pigmentation and latitude, and suggesting that pigmentation was not involved in thermoregulation. Further evidence that pigmentation may not be involved in thermoregulation was found by Tsubaki *et al*. (2010), who showed that pigmented wings are often cooler than the body temperature, suggesting no heat transfer is occurring.

Bergmann's Rule suggests that organisms decrease in size as temperature increases, although there are exceptions (Chown & Gaston, 2010). Hassall (2013) studied growth and development in response to changes in temperature in the North American species *C. maculata* and found that body size increased closer to the northern range margin where the temperature was lower (Hassall, 2013).

Hassall & Thompson (2009) found that wing asymmetry in *C. splendens* (length or area) did not vary between the northern and southern populations in England. In our study of the English population of *C. splendens* we examine how wing spot size, pigmentation, asymmetry and size vary with latitude, longitude, mean winter temperature, mean summer temperature and the day of year the specimen was collected. Temperature is lower both at high latitudes and earlier in the flight season. In contrast to the study of Hassall & Thompson (2009), we analyse specimens from throughout most of the distribution range of the species in England rather than from two discrete populations.

The hypothesis tested in this research follows the results of Hassall & Thompson (2009) that *Calopteryx splendens* will deposit less melanin in the wings at lower temperatures where energy is needed to survive the harsher conditions. We also hypothesise that, following Bergmann's Rule, wing size will be larger in lower temperatures, since the lower surface area to volume ratio means the individual radiates less body heat per unit of mass, therefore staying warmer (Blackburn *et al*., 1999).

The main questions we address are:

1) Is there a positive or negative correlation between male wing spot

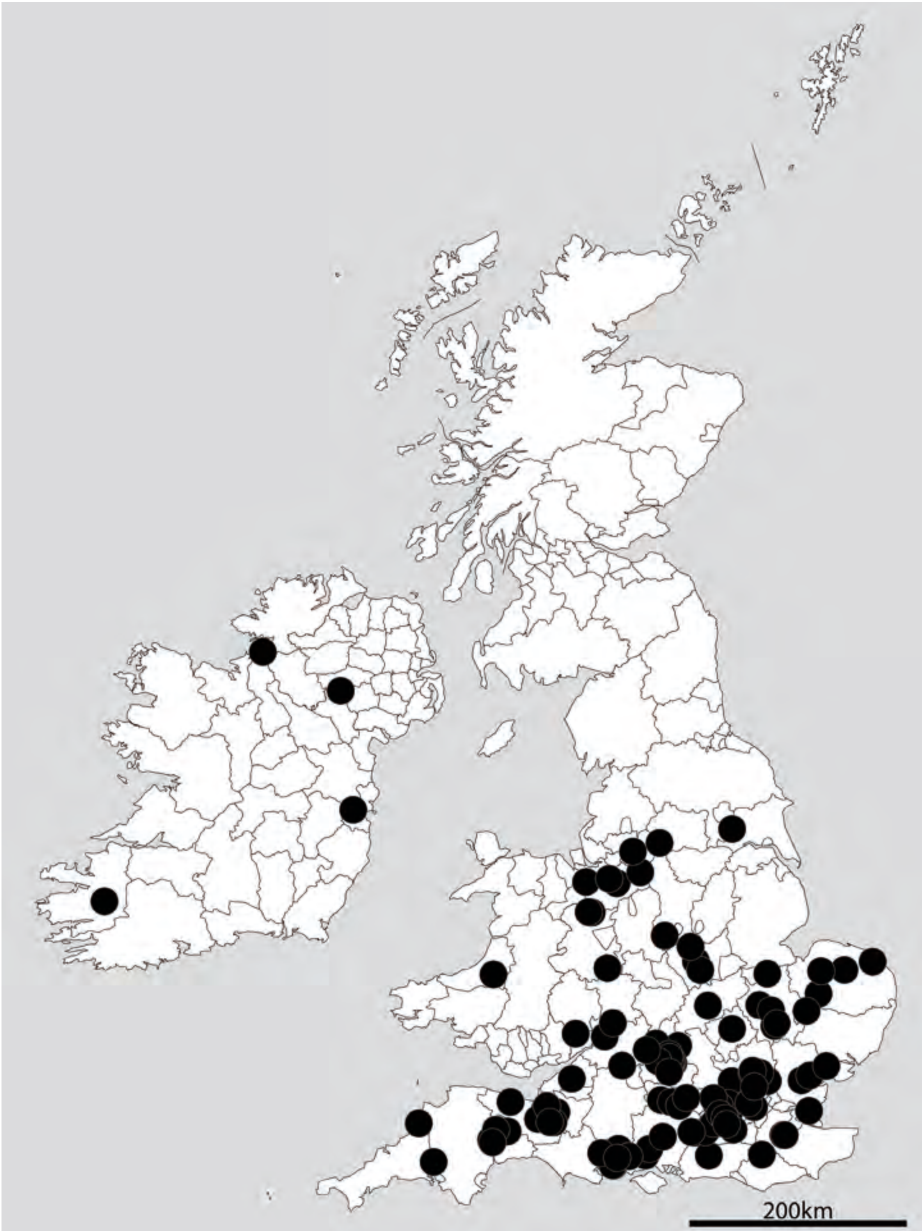

Figure 1. The distribution of *Calopteryx splendens* specimens used in this study.

size and latitude?
2) Does wing asymmetry change with latitude in both males and females?
3) Does wing size change with latitude in both males and females?
4) Does longitude or day of collection have any influence on wing size?
5) Do mean annual winter and summer temperatures affect wing size?

Materials and Methods

A total of 270 (94 females and 176 males) specimens of *Calopteryx splendens* was analysed from 119 sites across much of their distributional range in Britain (Fig. 1). Material was sourced from the following museums: Natural History Museum, London: 82; Natural History Museum, Oxford: 74; National Museums of Scotland: 43; World Museum Liverpool: 46; Manchester Museum: 25.

Wing Imaging

The hind wings of all specimens were imaged using a standard setup consisting of a colour checker, scale, designated point for the specimen pin to be placed and a shelf for the specimen labels (Fig. 2). The camera (Nikon D5300) was secured 11 inches above the specimen with consistent lighting provided by a light box fitted with a daylight fluorescent ring-light. To ensure exposures did not change between images the camera was operated in manual mode (ISO 100, aperture f11, shutter speed 1/50 second). Each specimen was given a unique code (a seven character code 168#### [NHMUK] or a five character code LU### [other museums]). Label data was transcribed and each specimen was georeferenced using LatLong.net (2016). The mean winter (January, February and March) and summer (June, July and August) temperatures of the collection year were derived from the Central England Temperature record (Parker *et. al*., 1992).

After imaging, the hind wings were cropped and placed on a white background with a 1-pixel border between the extremes of the wing and the edge of the canvas. Hind wings were chosen to enable imaging of papered material where the forewing was obscured. The right wings were flipped over so that they were in the same orientation as the left ones. To analyse wing size and asymmetry, the cropped images were left at full resolution (Fig. 3). For spot size and colour analysis the image resolution was reduced to 60 pixels along the longest edge (Fig. 4). To keep the proportions equal to the original image the shorter edge was not set to a fixed value. All the edits described above were carried out in

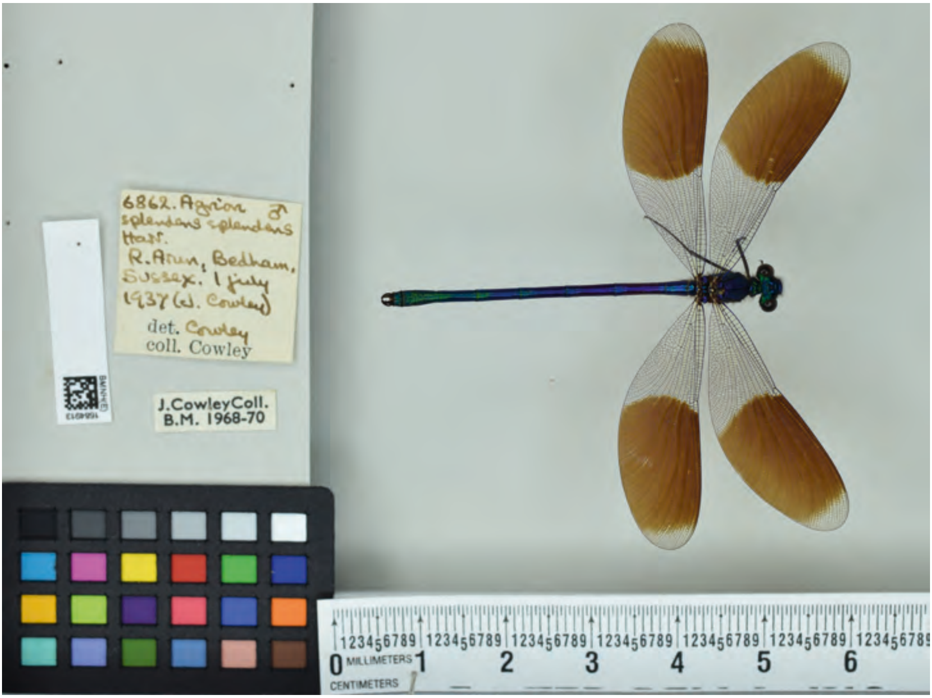

Figure 2. An example of the template used to image each *Calopteryx splendens* specimen.

Adobe Photoshop CS5 version 12.0 x64 (Adobe Systems Inc).

Image analysis – wing size and asymmetry

To determine the hind wing size and left-right symmetry, 'landmarks' were defined on each wing using ImageJ (Rasband, 2014) corresponding to five intersections of veins that were easily located on each wing (Fig. 5) and providing the horizontal and vertical dimensions of the wing. All hind wing images were individually rotated to ensure 'landmarks' 1 and 3 were horizontally aligned. The 'landmarks' were exported as an x, y coordinates dataset and analysed using Procrustes (GLS) Superposition (MacLeod, 2014), in a Mathematica script that plots the coordinates on a 2D grid and calculates the size of the centroid containing all five points. To analyse the asymmetry of the wings, differences between the coordinates of all five landmarks for the left and right hind wing of each specimen were summed to provide an asymmetry value. The larger this value, the more asymmetric were the specimen's wings. This analysis was performed separately for males and females.

Figure 3. An example of a full resolution image of a male *Calopteryx splendens* hind wing used for wing size and asymmetry analysis.

Figure 4. An example of a scaled image of a male *Calopteryx splendens* hind wing used for wing spot colour and size analysis. The longest edge is reduced to 60 pixels.

Image analysis – wing spot size and colour in males

The second part of the analysis, on left hind wings, used principal component analysis (PCA) to identify distinct groupings and to reduce the number of dimensions analysed to the minimum required to contain at least 95% of the information. Standard eigenanalysis (the decomposition of the coordinates matrix into its eigenvectors and eigenvalues) was used for the landmark analyses, and singular value decomposition was used for the wing image analyses (MacLeod, 2005a). Analyses were performed on the Wolfram Mathematica script for PCA 4.10 (MacLeod, 2005b). We used the Pearson product-moment correlation coefficient (PPMCC) as a measure of the linear correlation between variables (where 1 is total positive correlation and 0 is no correlation).

The third and final part of the analysis is similar to the method used by Hassall

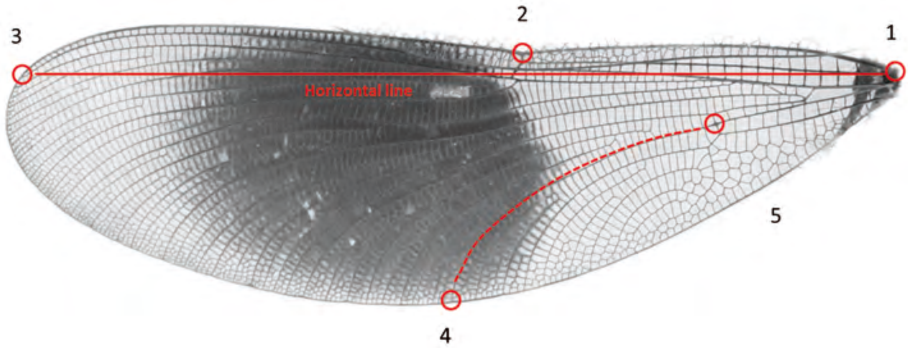

Figure 5. The 'landmarks' (highlighted by red circles) used to define the wing dimensions of *Calopteryx splendens*. The distance between points 1 and 3 gives the horizontal dimension and provides the horizontal alignment used for all wing images. The distance between 2 and 4 gives the vertical dimension.

& Thompson (2009). The matrix of pixel values for each wing was used. The number of pixel values below a threshold value of 140 was divided by the total number of values to give a ratio between pigmented and non-pigmented area. This value represented the size of the spot; the larger the value the larger the wing spot.

Results

Wing size and asymmetry

Procrustes analyses (Figs 6-9) showed there to be little variation between the shape and size of the left hind wings, with males showing similar variation to females. However, right wings showed greater variation, particularly in females.

The most significant result for wing size was the dependence of wing size on latitude for both females (PPMCC = 0.447; $p < 0.001$) (Fig. 10; Table 1) and males (PPMCC = 0.39; $p < 0.001$) (Fig. 11; Table 2). The second strongest correlation was between wing size and the mean winter temperature, again for both females (0.404; $p<0.002$) and males (PPMCC = 0.407; $p<0.003$) (Tables 1, 2).

The variation in the overlay of the coordinates of the right hind wings onto those of the left hind wings indicates there can be high asymmetric values. The wings of the male specimens showed less variation and less asymmetry than those of

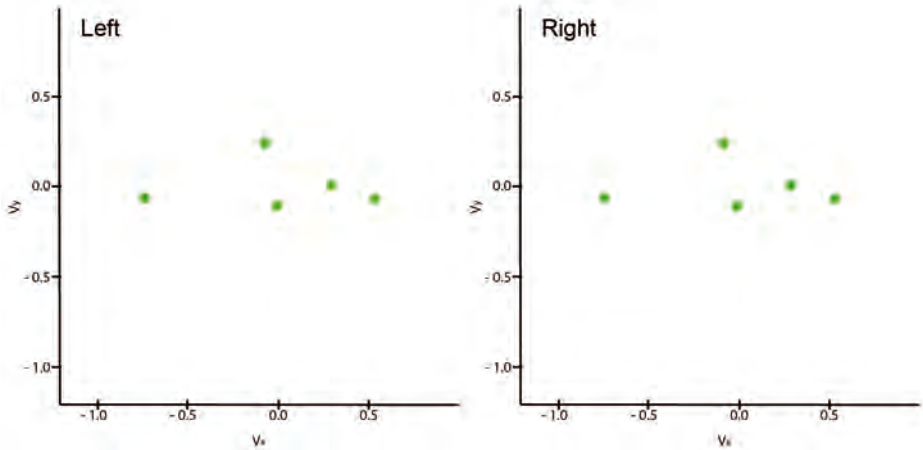

Figure 6. The relationship between the five coordinates (Vy,Vx) of the left and right hind wings of female specimen LU015. Note the landmarks are inverted in the analyses.

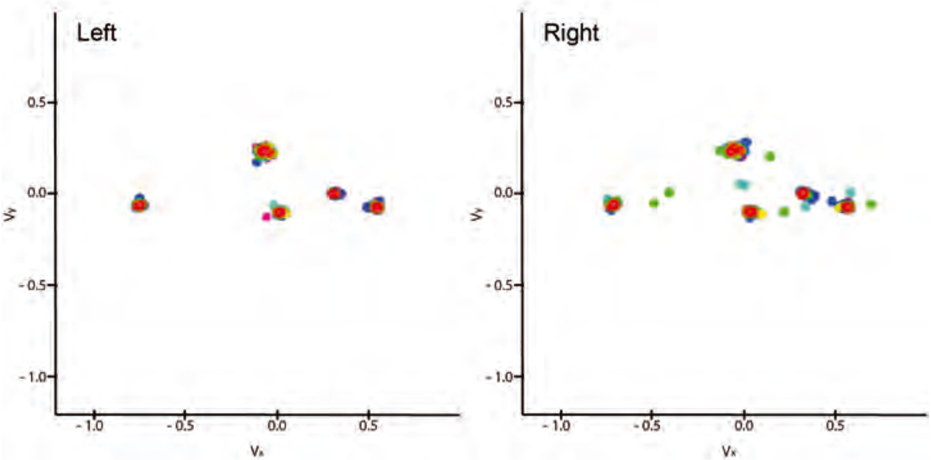

Figure 7. The relationship between the five coordinates (Vy,Vx) for all of the female left and rightwings. A higher degree of variation can be seen in right wings compared to left wings. Note the landmarks are inverted in the analyses.

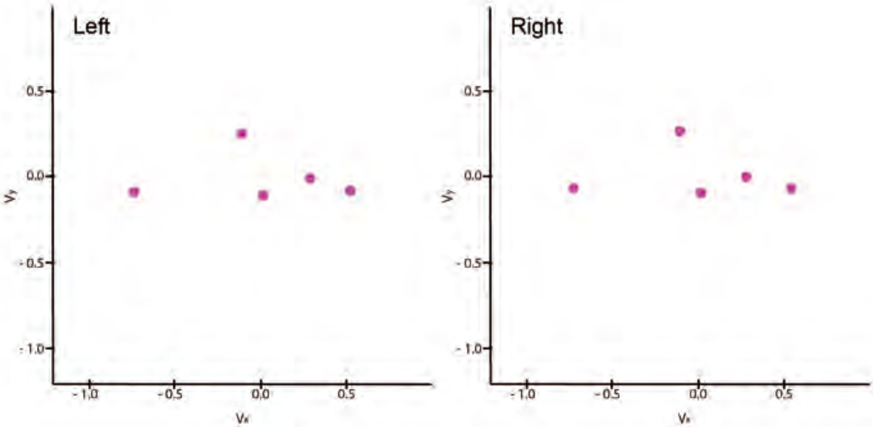

Figure 8. The relationship between the five coordinates (Vy,Vx) of the left and right hind wings of male specimen LU049. Note the landmarks are inverted in the analyses.

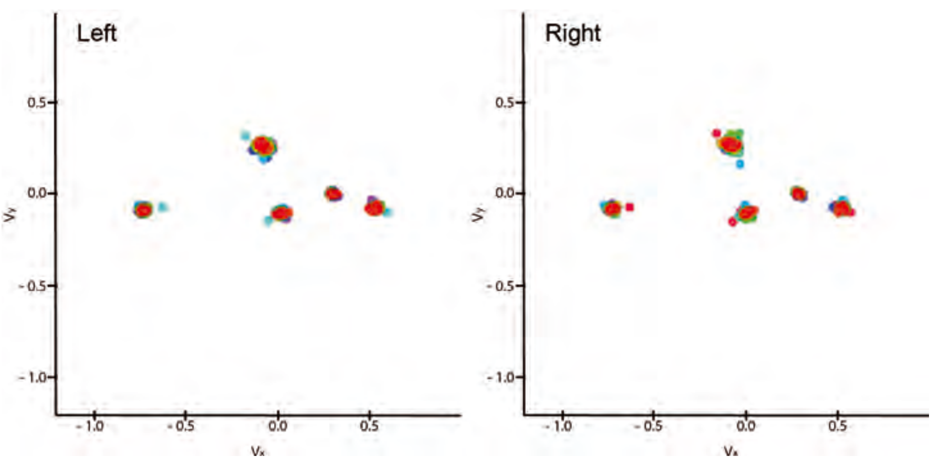

Figure 9. The relationship between the five coordinates (Vy,Vx) for all of the male left and right plot) wings. Although the right wings vary more than the left, the difference is not as obvious as for the female wings (Fig. 7). Note the landmarks are inverted in the analyses.

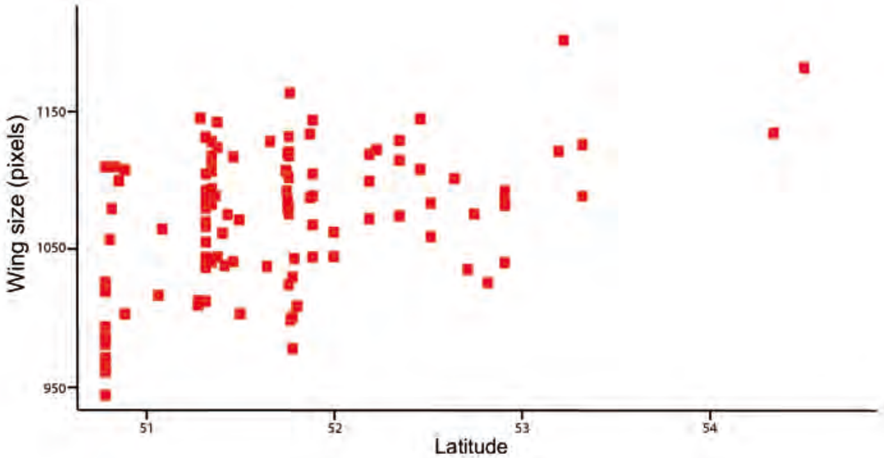

Figure 10. The relationship between wing size and latitude for females, showing that wing size increases as the latitude increases (i.e. northern specimens have a larger wing size).

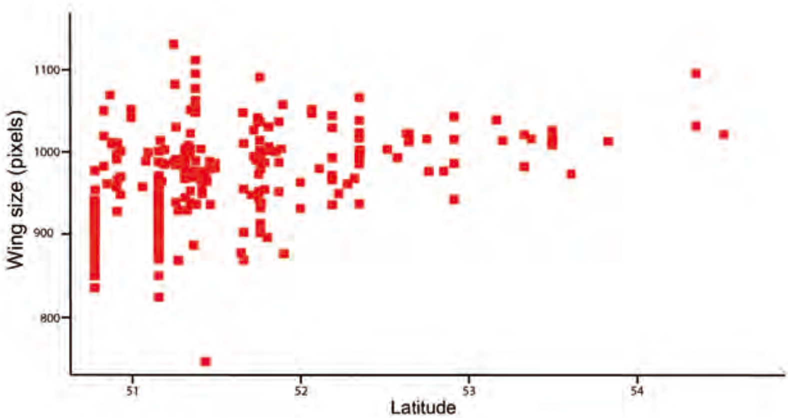

Figure 11. The relationship between wing size and latitude for males. As with the females, the mean male wing size increases with latitude, indicating that more northern specimens have larger wing sizes.

Table 1. Correlations of wing size and asymmetry against latitude, longitude, collection day and mean winter and summer temperatures for females. P-values below 0.05 are highlighted in bold.

Female Specimens			
Dependent Variable	Variable	PPMCC	P-value
Wing Size	Latitude	0.447	**<0.001**
	Longitude	-0.18	0.05
	Day of year	-0.165	0.08
	Mean Winter Temperature	0.404	**0.002**
	Mean Summer Temperature	-0.189	0.16
Asymmetry	Latitude	-0.143	0.13
	Longitude	0.085	0.37
	Day of year	0.041	0.67
	Mean Winter Temperature	-0.121	0.38
	Mean Summer Temperature	-0.09	0.51

females (Fig. 12). There were no significant correlations between the asymmetry of the wings and the latitude, longitude, collection day of the specimens and mean winter and summer temperatures (Tables 1, 2), the strongest relationships being between asymmetry and latitude in females (r = -0.143 and between asymmetry and mean summer temperature in males (r = -0.249).

Wing spot size and colour in males

The PCA analysis showed that the first Principal Component (PC1) accounted for 74.3% of the variation, PC2 accounting for a further 12.6%. Plotting PC1 against PC2 shows that the PC2 score defines two groups (Fig. 13), although what causes this difference is unclear as both groups contain all the variants of the wing spots from large and dark to small and faint. The PPMCCs (Table 3) indicate that all the correlations for PC1 against latitude, longitude, collection day and mean winter temperature are significant. PC1 versus collection day shows a positive correlation with a high PPMCC (0.525), the other three significant variables all showing negative correlations. For PC2, the only significant correlation is a positive one between PC2 and longitude. However, the correlation is poor, with a PPMCC value of only 0.211. When the two groups within PC2 were separately analysed for any correlation with latitude and longitude, no significant correlations were present.

Table 2. Correlations of wing size and asymmetry against latitude, longitude, collection day and mean winter and summer temperatures for males. P-values below 0.05 are highlighted in bold.

Male Specimens			
Dependent Variable	Variable	PPMCC	P-value
Wing Size	Latitude	0.39	**<0.001**
	Longitude	0.039	0.55
	Day of year	-0.137	0.03
	Mean Winter Temp	0.407	**0.003**
	Mean Summer Temp	0.098	0.5
Asymmetry	Latitude	0.095	0.14
	Longitude	-0.039	0.54
	Day of year	0.051	0.43
	Mean Winter Temp	0.111	0.44
	Mean Summer Temp	-0.249	0.08

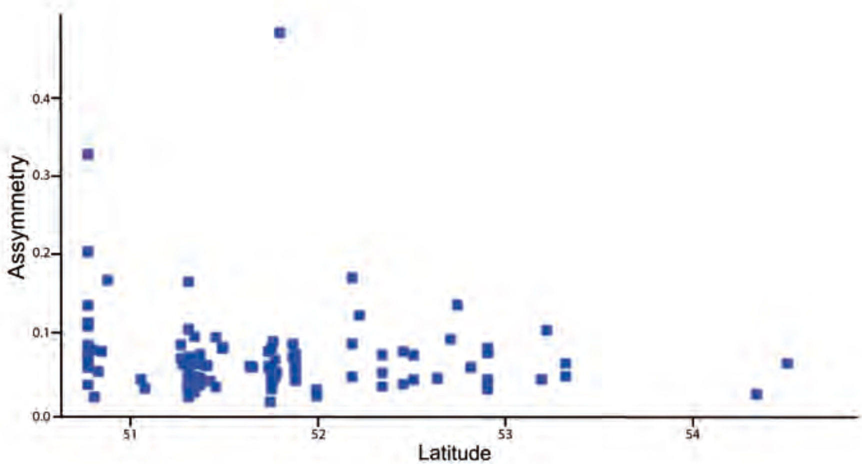

Figure 12. The relationship between the asymmetry of female wings and latitude.

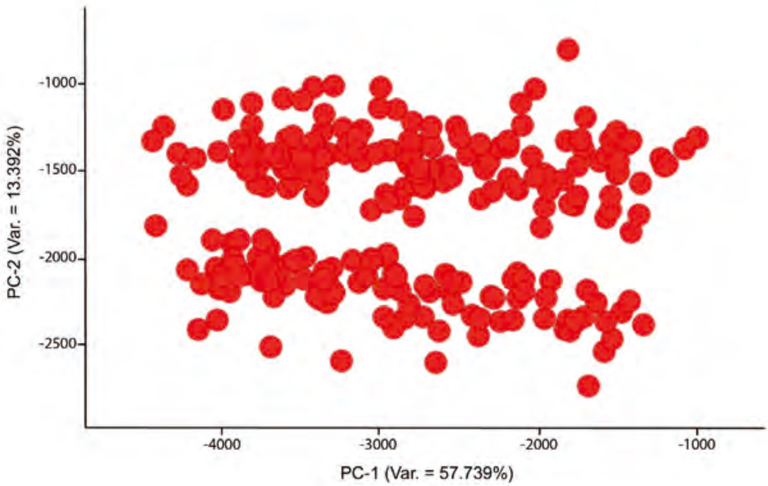

Figure 13. The relationship between PC1 and PC2 scores for spot size and colour for the left hind wings of males. This plot demonstrates two distinct groups in PC2.

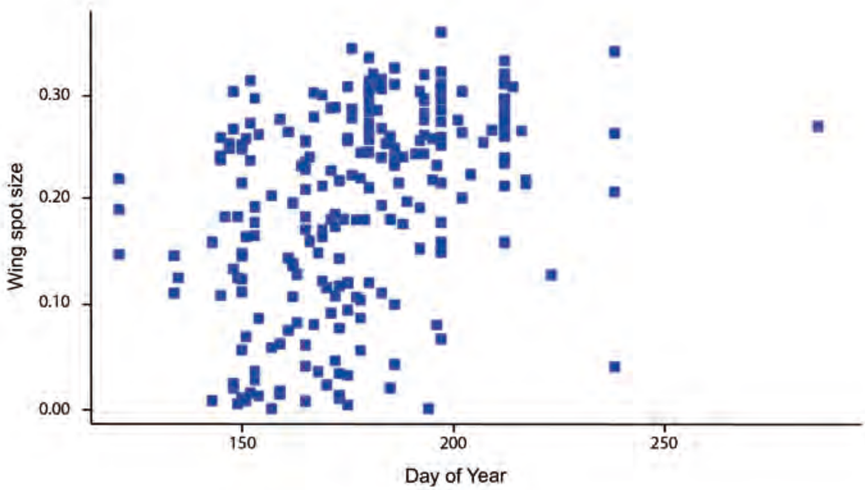

Figure 14. The relationship between the size of the wing spot on left hind wings of males and the day of collection .

Table 3. Correlations of PC1, PC2 and wing spot size for the left hind wings of males against latitude, longitude, collection day and mean winter and summer temperatures . P-values below 0.05 are highlighted in bold. The Higher PC2 and Lower PC2 scores refer to the two groups in PC2 when PC2 is plotted against PC1 (Fig. 13).

Male Specimens			
Dependent Variable	Variable	PPMCC	P-value
PC1 score	Latitude	-0.22	**<0.001**
	Longitude	-0.231	**<0.001**
	Day of collection	0.525	**<0.001**
	Mean Winter Temp	-0.392	**0.004**
	Mean Summer Temp	0.045	0.752
PC2 score	Latitude	0.06	0.35
	Longitude	0.211	**<0.001**
	Day of collection	0.009	0.89
	Mean Winter Temp	0.19	0.18
	Mean Summer Temp	0.209	0.141
Higher PC2 score	Latitude	0.143	0.08
	Longitude	0.18	0.028
Lower PC2 score	Latitude	-0.022	0.82
	Longitude	0.171	0.095
Wing spot size	Latitude	-0.116	0.07
	Longitude	-0.164	**0.01**
	Day of collection	0.374	**<0.001**
	Mean Winter Temp	-0.111	0.43
	Mean Summer Temp	0.108	0.45

The final dependent variable to be investigated was the ratio between dark and light pixels defining the spot size. This yielded no significant correlation with latitude and only a weak correlation with longitude ($p = 0.01$). However, with a PPMCC of 0.374, the positive relationship between wing spot size and collection day was highly significant ($P<0.001$) (Fig. 14; Table 3), although the single data point to the right of the plot may be skewing this result.

Discussion

The aim of this project was to identify relationships between wing size, wing asymmetry, spot size and colour with latitude, longitude, mean winter temperature, mean summer temperature and collection day. The results indicate a significant relationship between wing size and latitude for both males and females. This trend of the wing size increasing with increasing latitude supports the findings of Hassall (2013) and is in agreement with Bergmann's rule (Blackburn *et al*., 1999). Conversely, the significant positive correlation between wing size and mean winter temperature, although weaker than that between wing size and latitude, contradicts Bergmann's Rule. However, high winter temperatures may allow the larvae to continue to feed and grow more quickly than in cooler winters, leading to larger adults in the following summer.

Although results show there is asymmetry in the wings (Figs 7, 11), this was as a result of either wing damage or wing droop in a few specimens and there were no significant correlations between wing asymmetry and latitude, longitude or day of collection, once these outliers were removed (Fig. 8). These findings agree with the results of Hassall & Thompson (2009).

Principal Component Analysis of wing spot size and colour of the male left hind wings indicated two clearly defined groups in PC2 when PC2 was plotted against PC1. However, the physical attributes that defined these groups were not clear since both groups contained wing spots of the same intensity and size from specimens across the whole latitudinal range. PC1 correlated significantly with the day of collection. Hence we hypothesised that, as spot size was related to thermoregulation (Hassall, 2014), it would decrease later in the year as temperature increased. However, our results showed that spot size increased later in the year. This suggests that other factors may influence spot size, such as competition for mates (Hooper *et al*., 1999; Hassall, 2014).

Our study would have been improved if more specimens from the northern range boundary of *C. splendens* had been available for analysis, including specimens from Northumberland and the Solway Firth. Another interesting variable that could be studied is the influence of predator abundance. The dominant predator of *Calopteryx splendens* and *Calopteryx virgo* is the wagtail (genus *Motacilla*) (Svensson & Friberg, 2007). The darker and larger the wing spots are, the more apparent the damselfly would be to avian predators. As a result *C. virgo* is more visible to predators, which results in selective predation (Svensson & Friberg, 2007). This selective predation could potentially have an indirect effect on wing spot size in *C. splendens*.

Conclusion

The results of this study contradict the previous findings of the study by Hassall *et al*. (2009) as we found no distinct relationship between the spot size of male *C. splendens* wings with latitude, although it should be noted that, unlike Hassall *et al*. (2009), we did not examine any specimens from Northumberland or Scotland. However, the results from the two studies agree that there is no relationship between wing asymmetry and latitude. Our results indicated an agreement with Bergmann's Rule that wing size increased with increasing latitude. However, we also found that wing size increased with increasing winter temperature, possibly because this allowed larvae to continuing growing through the winter, resulting in larger adults in the following summer.

Acknowledgements

We would like to extend special thanks to Dr Graham Rotheray (The National Museums of Scotland, Edinburgh), Dr Tony Hunter (World Museum Liverpool), Dr Darren Mann (Natural History Museum, Oxford) and Dr Dmitri Logonov (Manchester Museum) for providing access to the Odonata collections they curate. We thank Prof. Norman Macleod for advice on morphometric analyses.

References

Blackburn, T.M., Gaston, K.J. & Loder, N. 1999. Geographic gradients in body size: a clarification of Bergmann's rule. *Diversity and Distributions* **5:**165–174.

Chown, S.L. & Gaston, K.J. 2010. Body size variation in insects: A macroecological perspective. *Biological Reviews* **85:**139–169.

Dijkstra, K.-D. B. & Lewington, R. 2006. *Field Guide to the Dragonflies of Britain and Europe*. British Wildlife Publishing, Gillingham. 320 pp.

Hassall, C. 2013. Time stress and temperature explain continental variation in damselfly body size. *Ecography* **36:** 894–903.

Hassall, C. 2014. Continental variation in wing pigmentation in *Calopteryx* damselflies is related to the presence of heterospecifics. *PeerJ* **2**: 438. https://peerj.com/

Hassall, C. & Thompson, D.J. 2009. Variation in wing spot size and asymmetry of the Banded Demoiselle *Calopteryx splendens* (Harris, 1780). *Journal of the British Dragonfly Society* **25:** 7–15.

Hooper, R.E., Siva-Jothy, M.T. & Tsubaki, Y. 1999. Expression of a costly, plastic secondary sexual trait is correlated with age and condition in a damselfly with two male morphs. *Physiological Entomology* **24:** 364–369.

Lowdon, J. 2015. The habitat requirements and changing distribution of *Calopteryx splendens* (Harris) (Banded Demoiselle) in Northumberland. *Journal of the British*

Dragonfly Society **31:** 1-13

MacLeod, N. 2005a. Principle components analysis (eigenanalysis & regression 5). *Palaeontological Association Newsletter* **59:** 42–54.

MacLeod, N. 2005b. Regression 4: going multivariate. *The Palaeontological Association Newsletter* **58:** 44–53.

Outomuro, D. & Ocharan, F.J. 2011. Wing pigmentation in *Calopteryx* damselflies: a role in thermoregulation? *Biological Journal of the Linnean Society* **103:** 36–44.

Parker, D.E., Legg, T.P. & Folland, C.K. 1992. A new daily Central England Temperature Series, 1772-1991. *International Journal of Climatology* **12:** 317-342.

Siva-Jothy, M.T. 1999. Male wing pigmentation may affect reproductive success via female choice in a calopterygid damselfly (Zygoptera). *Behaviour* **136:** 1365–1377.

Svensson, E.I. & Friberg, M. 2007. Selective predation on wing morphology in sympatric damselflies. *The American Naturalist* **170:** 101–112.

Svensson, E.I. & Waller, J.T. 2013. Ecology and sexual selection: evolution of wing pigmentation in calopterygid damselflies in relation to latitude, sexual dimorphism, and speciation. *The American Naturalist* **182:** 174–95.

Talloen, W., Van Dyck, H. & Lens, L. 2004. The cost of melanization: butterfly wing coloration under environmental stress. *Evolution* **58:** 360–366.

Tsubaki, Y., Samejima, Y. & Siva-Jothy, M.T. 2010. Damselfly females prefer hot males: Higher courtship success in males in sunspots. *Behavioral Ecology and Sociobiology* **64:** 1547–1554.

Tynkkynen, K., Rantala, M.J. & Suhonen, J. 2004. Interspecific aggression and character displacement in the damselfly *Calopteryx splendens*. *Journal of Evolutionary Biology* **17:** 759–767.

Web sites

LatLong.net. 2016. http://www.latlong.net/

MacLeod, N. 2014. *Procrustes (GLS) Superposition (2D or 3D).* https://www.palass.org/sites/default/files/media/palaeomath_101/article_16/article_16.pdf

Rasband, W. 2013. *Image J 1.48v*. http://www.techworld.com/download/audio-video-photo/imagej-148v3328545/

Received 4 January, 2016; accepted 16 February 2016

Emerald Damselflies (Family Lestidae) in the Weald

David Chelmick[1] & John Luck[2]

[1]Macromia Scientific, 31 High Beech Lane, Haywards Heath, West Sussex, RH16 1SQ www.macromiascientific.com

[2]4 Mill View, Ringmer, East Sussex

Abstract

The Weald is a geologically isolated region in south-east England. All four species of Lestidae recorded in the UK have been observed here. *Lestes sponsa* is a locally common resident, *Lestes dryas* has been shown to be breeding in the High Weald after many years of absence, while *Lestes barbarus* remains a vagrant but breeding colonies may exist. Finally, *Chalcolestes viridis* is now known to breed and is probably under recorded. The Wealden Dragonfly Group was created to coordinate recording in this region.

Introduction

The Weald is an area of south-east England comprising the eroded remains of an anticline or dome of layered Lower Cretaceous rocks cut through by weathering to expose sandstone ridges and clay valleys. It is bordered by the chalk escarpments of the North and South Downs and, to the west, by the Hampshire basin. The eastern border is provided by the English Channel. The chalkland and maritime borders make for an isolated geological region. The region encompasses the counties of East and West Sussex, Kent and Surrey and a small part of Hampshire in the far west. It is drained by five major rivers flowing south to the English Channel and four flowing north into the Thames and the Thames Estuary (Figs 1, 2).

Emerald damselflies (Lestidae) in Europe

The family Lestidae in Europe consists of nine species in three genera (Boudot & Kalkman, 2015). In the UK we have only four species in two genera (Cham *et al*., 2014), all of which have been recorded from the Weald; their current status and distribution is the subject of this paper. The Lestidae in Europe all have large and conspicuous larvae (Plate 1). One of the authors (DC) has observed larvae of *Lestes dryas* along the Thames estuary. On warm spring days the larvae are conspicuous in shallow water, remaining quite motionless. When disturbed

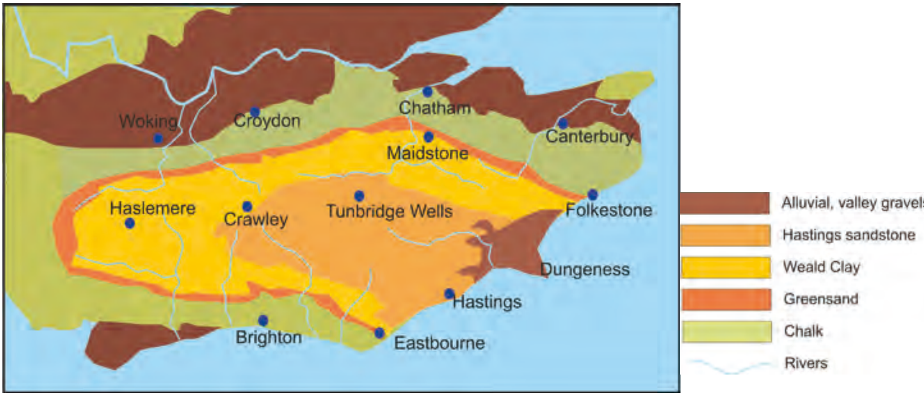

Figure 1. The Weald, showing its location in south-east England.

they do not move away or make any attempt to hide. In addition, the larvae do not bury themselves in the substrate, as evidenced by the exuviae, which are invariably found clean. In summary, lestid larvae have a poor response to predators, especially large fish, and the species survive by:

- Breeding in habitats where large predators do not occur
- Spending much of their life out of the water either as an egg or an adult

The various habitats of Lestidae in the Weald reflect this life history.

Southern Emerald (*Lestes barbarus*) (**B** in Fig. 2)
Lestes barbarus breeds sparingly along the Kent coast of the Thames Estuary in densely choked ditches where rushes (*Juncus* spp.) and Club rush (*Bulboschoenus maritimus*) predominate (J & G Brook, pers comm.). It has been found on only two occasions in the Weald. The first record (B1) was of an adult male photographed at a small pond adjacent to Ditchling Common in West Sussex by Corey Cannon, an MSc student at Sussex University, on 7 August 2011. The authors have visited the locality and the main Ditchling Common Ponds on a number of occasions since, but with no success. The second record (B2), again based on a photograph, was by Simon Rayburn at a pond along the Upper Cuckmere valley on 17 July 2013 (Fig. 2). Again this observation has never been repeated.

Both sites are permanent ponds and, whilst they have emergent rushes (*Juncus* spp.), they would not appear to be suitable breeding habitat and the sightings must be thought of as vagrants. The Ditchling site is close to the Eastbourne to London rail line, which passes through the Lewes levels which have an

Plate 1. *Lestes dryas* final instar larvae.

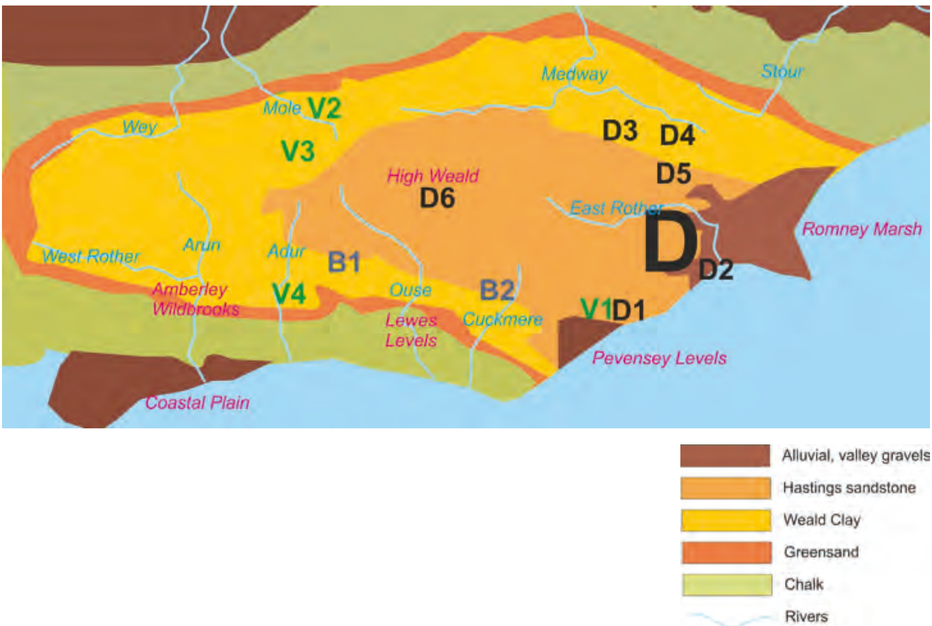

Figure 2. The Weald, showing the approximate locations of three of the species of lestid found there. The localities shown are not precise; they are intended to demonstrate general distribution of the species. B, *Lestes barbarus*; D, *Lestes dryas*; V, *Chalcolestes viridis*. Locations of *Lestes sponsa* are not shown as this species is more widespread and has a scattered distribution in the Weald. Major rivers and habitats are shown.

abundance of suitable habitat. Was this vagrant carried by train? Further observations are needed.

Scarce Emerald (*Lestes dryas*) (**D** in Fig. 2)

The first records for this species in the Weald were those of Norman Moore (NWM) (Fig. 2 - large symbol D) The individual records, which covered the period 1940 to 1952, are discussed in detail in Chelmick & Moore (2009). The original NWM localities have been searched exhaustively for many years by DC and other observers. In 1990 Simon Davey observed an isolated male at Coombe Haven (D1) and then, on 11 August 2006, a female was photographed at Rye Harbour Local nature Reserve (Chelmick & Moore, 2009) (D2). Neither of these observations has ever been repeated.

In October 2009 Peter Dear (National Trust Conservation Manager) created a small area of wetland at the bottom of a valley at Sissinghurst Castle by clearing scrub and creating small ponds and scrapes to attract dragonflies. In the summer of 2011 the area was alive with Ruddy darters (*Sympetrum sanguineum*) then, in August 2012, two species of lestid (*Lestes dryas* and *Lestes sponsa*) were recorded (D4). John and Gill Brook and the authors visited the locality and Gill Brook photographed a pair of *L. dryas* ovipositing. *L. dryas* is locally common in Kent along the Thames Estuary but this was the first record for, what is essentially the High Weald, since the nearby NWM records of the 1950s. The habitat (Plate 2) is dominated by Reedmace (*Typha latifolia*), dense clumps of rushes (*Juncus* spp.) and Alder (*Alnus glutinosa*). The object of management since the creation of the wetland has been to keep the alder scrub in check and the area open. Water levels are very variable as the habitat is completely reliant upon rainfall.

The real question following this discovery was where did the colonisation come from? The wetland had been in existence for two and half years when *L. dryas* was discovered. Had the species come from an unknown colony nearby? As if to provide further evidence, a single female had been photographed at Horsmonden on 30 July 2012 by John Webley (D3). It was clear that further research was needed and, in an attempt to stimulate interest, the authors formed the Wealden Dragonfly Group (WEDG) at a meeting held at Scotney Castle by courtesy of the National Trust in early 2013.

In November 2013 Carl Sayer of UCL gave a paper at the BDS Annual Meeting on the restoration of Marl Pits in Norfolk. One of the outcomes of the work was the reappearance of *Lestes dryas*. The project is described in Sayer *et al*. (2013). The talk and paper spawned an idea. An examination of Ordnance Survey Explorer maps 125 and 136 showed that the High Weald is peppered

A

B

Plate 2. Wetland at Sissinghurst Castle. (A) Peter Dear standing in the midst of the wetland. (B) John Luck amongst the rushes at the edge of the scrape.

with Marl or similar pits, mostly now neglected and overgrown like those in Norfolk. Could *Lestes dryas* be in these pits? Was this the unknown stronghold? The problem is that, whilst these pits still exist, public access in this area of the High Weald is very poor with few public footpaths, most pits being isolated in inaccessible farmers' fields. John Luck took it upon himself to study the maps, locate the farms and knock on doors. He found a willing farmer, who was very interested in wildlife and who would be delighted to provide access to his fields. The farmer was most anxious that he and his land remained anonymous and this paper abides with his wishes. John visited the farm on a number of occasions searching out suitable habitat; both authors visited on 22 and 29 July 2014. Most of the old pits were choked with scrub and mature oaks; quite unsuitable for dragonflies (Plate 3). However two pits, for reasons that are far from clear, still had open areas (Plate 4). In both these ponds *Lestes dryas* was present and in Pond 2 we found a pair in copula. It would appear that these High Weald ponds are indeed the stronghold for *Lestes dryas* in the region. However, the habitat must be considered as under threat as the vast majority of these pits are neglected and overgrown. We attempted to visit the farm during the winter and spring of 2014/2015 in order to see how the pits flooded. Our attempts failed as the entire farm was waterlogged and inaccessible. Clearly the pits would be sufficiently flooded during most winters.

Plate 3. Overgrown marlpit on the High Weald not suitable for dragonflies.

A

B

Plate 4. Marlpits on the High Weald (A) Pond 1, almost dry and choked with Sedges (*Carex* spp.) and Reedmace (*Typha latifolia*), (B) Pond 2 almost dry but choked only with Sedges (*Carex* spp.).

The discovery of these High Weald pits as a habitat for *Lestes dryas* must be considered as a success for WEDG; but there is yet more to the story of this species in the Weald. In the 1960s, the Honourable Simon Stuart used to visit lakes in Ashdown Forest and recorded *Lestes dryas* on one lake regularly until it was drained in 1971; DC included this record in his survey of Sussex Dragonflies (Chelmick 1979). DC visited the lake with Simon in the 1970s but they were not successful. In July 2014 Nigel Kemp visited Old Lodge, a nature reserve close to the Ashdown Forest lakes mentioned above and photographed a male *Lestes dryas* (D6). He sent the photograph to John Luck, who was able to identify it easily from the anal appendages. Again we visited the area with no success. Perhaps Simon's original record was sound and the species is still present somewhere in the Forest. It is hoped that in 2016 WEDG can survey the area and locate the missing colony.

In summary, *Lestes dryas* is proving to be one of our most enigmatic dragonflies, surviving by dispersal into an ever-decreasing supply of temporary pits and newly created wetlands. The National Trust at Sissinghurst provides a wonderful example of habitat creation which must, in the long term, be the future for this insect. It is understood that the costs for creating the Sissinghurst wetland were less than £1,000 and that there has been a modest loss in rent for the land that is now flooded. Such costs are minimal when we consider that the biodiversity of the High Weald is so greatly enhanced.

Common Emerald (*Lestes sponsa*) – (locations not shown on Fig. 2)

This nationally common species has a scattered distribution in the Weald. It is common on the acid heaths of Surrey (Follett, 1996) but more local in both Kent (Brook, 2009) and Sussex (Belden *et al*., 2004). The species is absent from the large fishing lakes of the High Weald and is only present in large numbers in lowland marshes such as Pevensey Levels, Amberley Wildbrooks and some of the coastal levels. The upland acid wetlands of Ashdown Forest on the Hastings Beds are another stronghold. Cham *et al*. (2014) suggested that the species is in significant decline on the Weald. However, I have no evidence to back up this view.

Willow Emerald (*Chalcolestes viridis*) (**V** in Fig. 2)

The first record for this species in the Weald was from a clay pit in East Sussex on 22 September 1979 (V1) (Belden *et al*., 2004). This specimen was obtained in rather strange circumstances. The claypit had been designated as a landfill site; there was much local objection. Late one evening David Chelmick, then Sussex Recorder for dragonflies, heard a knock on the door. One of his East Sussex colleagues on the Scientific Committee of the Sussex Trust for Nature

A

B

C

Plate 5. (A, B, C) *Chalcolestes viridis* ovipositing in willow (*Salix* sp.) at Nutfield Marsh.

A

B

Plate 6. *Chalcolestes viridis* egg cuts – (A) On the River Mole in 2015 in Willow (Salix sp.), (B) On the Thames Estuary in 2012 in Hawthorn (*Crataegus* sp.). (A) photograph by Linda Pryke.

Conservation thrust into his hand a small box containing a specimen of this insect. The visitor stated that it had been taken at the clay pit. DC, of course, visited the locality and found nothing. It is now a landfill site.

Chalcolestes viridis is a very common damselfly in Europe; probably the most common lestid in Western Europe and its colonisation of UK has been progressing for a number of years. It breeds in permanent waters and even rivers; it is locally common in the Thames Estuary and in the eastern counties north of the Thames. It often oviposits in branches of Willow (*Salix* spp.) (Plate 5, 6A) and Hawthorn (*Crataegus* spp.) (Plate 6B) which overhang the water. This activity leaves tell-tale cuts in the wood, which persist and provide proof of breeding (Plate 6).

On 28 August 2014, the authors visited Nutfield Marsh and the Moors Nature Reserve near Redhill in Surrey with Simon Elson of Surrey County Council. The area is dominated by large lakes created by gravel and mineral extraction but there are also shallow open pools bordered by Reedmace (*Typha latifolia)* and with willow scrub (*Salix* spp.) that had recently regrown following management (Plate 7A). Late in the afternoon we found a small colony of *Chalcolestes viridis* consisting of isolated males and pairs ovipositing on the new willow branches (V2). We walked back along the willow edge to one of the large lakes (Plate 7B) and found egg cuts showing that the species was breeding in both habitats.

At the weekend following this discovery, DC was leading a group along the River Mole near Gatwick Airport organised by Rachel Bicker, an ecologist at the airport. DC particularly asked recorders to look out for any egg cuts indicating the presence of this insect. That day produced no results but we were rewarded

A

B

Plate 7. Nutfield marsh. (A) Pool where *Lestes viridis* was found ovipositing, (B) Willow (*Salix* sp.) at the edge of one of the main lakes.

as, on Rachel's Wildlife Recording day in August 2015, egg cuts were found and photographed by Lynda Pryke ((Plate 6A) along the banks of the River Mole (V3).

This insect is clearly overlooked. It emerges in late spring and aestivates away from the water, often in nearby trees, returning sexually mature in the late summer (usually mid August onwards) to breed. When ovipositing this insect can be very hard to spot. It is completely green with no typical lestid blue pruinescence, moves very little and closely matches the foliage. To give an idea of how this species can be missed, David Sadler wrote following his find at Woods Mill, Henfield in August 2015 (V4) "it seemed to me that the habitat (willows overhanging still water) at Wood's Mill is ideal, but it was quite a surprise, after a few fruitless visits, to actually spot one! Unfortunately, it was just a lone male, but a lot of the site is inaccessible and I would be surprised if they don't colonise if they haven't already."

The isolation of the records (Fig. 2) indicates that this is indeed a much under recorded species. It is hoped that this paper will encourage more observers to go out from August through to late October and hunt out this elusive insect.

Summary of Status and Conclusion

The family Lestidae is probably the most threatened of European dragonflies. All but one of our species rely on a high water table for the maintenance of their temporary wetland habitats. Water extraction for intensive agricultural poses a real threat to these insects. The distribution of the Lestidae in the Weald, despite the fact that we live in one of the most recorded countries in the world, is still poorly known. This paper attempts to provide guidance for future research to assist with the conservation of this family and maintain the biodiversity of this region.

References

Belden, P. A., Downer, V.J., Luck, J. C., Prendergast H.D.V. & Sadler D. 2004. *The Dragonflies of Sussex*. Essendon Press, Wych Cross. 81 pp.

Boudot, J.-P. & Kalkman, V.J. (eds) 2015. *Atlas of the European dragonflies and damselflies*. KNNV Publishing, Zeist, The Netherlands. 384 pp.

Brook, J. & Brook, G. 2009. *Dragonflies of Kent*. 2nd ed. Kent Field Club Publications, Doddington. 130 pp.

Cham, S., Nelson, B., Parr, A., Prentice, S., Smallshire, D. & Taylor, P. (eds) 2014. *Atlas of Dragonflies in Britain and Ireland*. Field Studies Council, Telford. 280 pp.

Chelmick, D. G. 1979. *A survey of the Odonata of Sussex (1965-1978)*. Internal document

produced on behalf of the Sussex Wildlife Trust. 50 pp.
Chelmick, D.G. & Moore, N.W. 2009. The Scarce Emerald Damselfly *Lestes dryas* Kirby in East Sussex 1940 to 2007: an account of species extinction through changing agricultural practice. *Journal of the British Dragonfly Society* **25:** 27-40.
Follett, P. 1996. *Dragonflies of Surrey*. Surrey Wildlife Trust, Pirbright 87pp.
Sayer, C., Shilland, E., Greaves, H., Dawson, B., Patmore, I., Emson, D., Alberton, E., Robinson, P., Andrews, K., Axmacher, J. & Wilk, E. 2013. Managing Britain's Ponds – conservation lessons from a Norfolk farm. *British Wildlife* **October 2013:** 21-28.

Received 2 February, 2016, accepted 3 February, 2016

Lestes sponsa (Hansemann) (Emerald Damselfly) and mixed couplings

Bryan P. Pickess

8 Shaw Drive, Sandford, Wareham, Dorset. BH20 7BT

Summary

Details are given of the records involving mixed coupling between male *Lestes sponsa* with six different species of Zygoptera in the UK from 2010 to 2015. A total of 11 couplings are recorded, one with another species of *Lestes*, the other 10 with species from other families - four with single females, three with males and three with pairs. As to why this behaviour occurs is still unclear. Possible reasons for it are discussed.

Observations

For nearly half a century I have been observing dragonflies and was aware that mixed couplings between different species had been observed (Corbet, 1999). It was not until 2012 that I observed mixed pairings, not once but twice, both involving male *Lestes sponsa* (Emerald Damselfly) (Pickess, 2012a, b). I found that Miller & Fincke, (2004) had gathered together records of this behaviour, which included couplings of both Nearctic and Palaearctic species of lestids, not only with other species of *Lestes* but also with species belonging to other genera. Dijkstra & Lewington (2006), in describing lestids in general, made the following comment - Males are very forward, often forming tandems with other species or other males", suggesting that this behaviour is regularly observed amongst the European species of lestids but whether this applies to all species is unclear.

If this behaviour of *Lestes sponsa* occurred with any frequency in the U.K., it was thought that a request to members of the British Dragonfly Society to report such sightings might yield further records. An appeal was made in the BDS Newsletter No 63 (Pickess, 2013). From this appeal only five records were received, rather fewer than might have been expected based on Dijkstra's comments (Dijkstra & Lewington, 2006). A literature search yielded no new records since those given in Miller & Fincke (2004) but a Web search did produce one further record (Ashton, 2012) and two further records came from other BDS sources (Smith, 2013; Kirby & Kirby, 2014). Thus, during the past six years (2010 – 2015) eleven records have been traced recording this behaviour (Table 1). There is only one recorded incidence of intrageneric coupling, in this case with a female *Lestes barbarus* (Southern Emerald Damselfly). Coupling with *Lestes dryas* (Scarce Emerald Damselfly) was not observed during the period of this study but this is not surprising as *L. dryas*, as the common name implies, is not common in Britain, being restricted to East Anglia and the southeast (Cham *et al*., 2014). It would be tempting to conclude that, in the British Isles, this behaviour by *L. sponsa,* whether intrageneric or with species from different families (intergeneric) is very infrequent but that it may occur with more regularity on the Continent.

Although these 11 records constitute a very small data set, they do involve six species of Zygoptera in these mixed couplings! Dragonflies have exceptional eyesight and Bybee *et al.* (2012) suggested that dragonflies appear to use visual clues for mate recognition. Although Miller & Fincke (2004) were principally concerned with *Enallagma* spp. they suggest that these mixed couplings are

Table 1. Records of Mixed Couplings by male *Lestes sponsa* both Intrageneric and intergeneric in the UK since 2010.

Male	Female	Date	Source
Intrageneric			
L. sponsa	*Lestes barbarus*	08/09/2012	Smith (2013)
Intergeneric			
L. sponsa	*Pyrrhosoma nymphula*	27/07/2011	Natress (2013)
L. sponsa	*Pyrrhosoma nymphula*	17/07/2012	Pickess (2012a, b)
L. sponsa	*Ceriagrion tenellum*	11/07/2014	Kirby & Kirby (2014)
L. sponsa	*Ischnura elegans*	17/07/2012	Ashton (2012)
Male	Male		
L. sponsa	*Coenagrion puella*	21/08/2013	Clark (2013)
L. sponsa	*Enallagma cyathigerum*	12/07/2010	Spencer (2013)
L. sponsa	*Enallagma cyathigerum*	13/09/2012	Pickess (2012b)
Male	Pairs		
L. sponsa	*Pyrrhosoma nymphula*	08/07/2012	Winter (2013)
L. sponsa	*Ceriagrion tenellum*	31/08/2014	Nattress (2015)
L. sponsa	*Ischnura elegans*	11/07/2015	Routledge (2015)

Plate 1. A *Lestes sponsa* male attached to a pair of *Ceriagrion tenellum*, 31 August 2014, Morrish Fire Pond, Slepe Moor, nr. Arne, Wareham, Dorset.

probably mistakes in sexual recognition. So how do these mixed couplings come about? What is a little puzzling to the human eye is that the females of the species that have been grabbed do not even resemble female *L. sponsa*! In observations involving male *L. sponsa* attaching to males of other species, three had blue and black abdomens and in a fourth case, involving a pair of *C. tenellum* (Small Red Damselfly) (Plate 1), the male was red. Apart from other *Lestes* species, possibly the species most resembling *L. sponsa* is *Ischnura elegans* (Blue-tailed Damselfly) and here misidentification may be possible. However, it is difficult to reconcile this behaviour with the exceptional eyesight of odonates. I would like to proffer a further thought, arising from my observation on 31st August 2014, and that is that it may be borne out of sexual frustration, possibly due to a shortage of females of the same species (Nattress, 2015).

Acknowledgements

I would like to thank Mark Tyrrell of the British Dragonfly Society for publishing in Dragonfly News my request to seek further records of observations of this behaviour. I am most grateful to the observers who responded to me with their observations. I must thank Pam Taylor for drawing my attention to a recent intrageneric record and David Chelmick for putting me in contact with the recorder of a mixed coupling observation.

References

Cham, S., Nelson, B., Parr, A., Prentice, S., Smallshire, D. & Taylor, P. (eds) 2014. *Atlas of Dragonflies in Britain and Ireland*. Field Studies Council, Telford. 280 pp.

Clark. T. 2013. A mixed pairing between Emerald Damselfly *Lestes sponsa* and Azure Damselfly *Coenagrion puella*. *Atropos* **50:** 84-85.

Corbett, P.S. 1999. *Dragonflies: Behaviour and Ecology of Odonata*. Harley Books, Colchester. 829 pp.

Dijkstra, K.-D.B. & Lewington, R. 2006. *Field Guide to the Dragonflies of Britain and Europe*. British Wildlife Publishing, Gillingham. 320 pp.

Kirby, D & Kirby, M. 2014. Mixed pairing between Emerald Damselfly *Lestes sponsa* and Small Red Damselfly *Ceriagrion tenellum*. *Atropos* **52:** 75.

Miller, M.N. & Fincke, O.M. 2004. Mistakes in sexual recognition among sympatric Zygoptera vary with time of day and color morphism (Odonata: Coenagrionidae). *International Journal of Odonatology.* **7:** 471-491.

Nattress, B. 2013. Mixed pairing by Emerald Damselfly *Lestes sponsa*. *Atropos* **50:** 83.

Nattress, B. 2015. A male Emerald Damselfly *Lestes sponsa* seizing a pair of Small Red Damselfly *Ceriagrion tenellum. Atropos* **53:** 89.

Pickess, B.P. 2012a. In: Notes and Observations. *Dragonfly News* **62**: 18.

Pickess, B.P. 2012b. Mixed pairings: Are male Emerald Damselfly *Lestes sponsa* short-sighted or desperate? *Atropos* **47:** 76-78.

Pickess, B.P. 2013. Mixed pairings and lestids – request for help. *Dragonfly News* **63:** 6.

Routledge, S. 2015. In: *Dragonfly News*. **68:** 15.

Smith, M.S. 2013. Another mixed damselfly pairing. *Atropos* **48:** 85-86.

Spencer, T 2013. Another mixed damselfly pairing. *Atropos* **50:** 83-84.

Winter, P. 2013. A mixed pairing between Emerald Damselfly *Lestes sponsa* and Large Red Damselfly *Pyrrhosoma nymphula*. *Atropos* **50:** 85.

Web sites

Ashton, P. 2012. Wild East Yorkshire http://www.erdragonflies.co.uk/?p=381 and Flickr https://flic.kr/p/cyjc51

Bybee, S.M., Johnson, K.K., J., Gering, E.J., Whiting, M. F. & Crandell, K. A. 2012. All the better to see you with: a review of odonate color vision with transcriptomic insight into the odonata eye. *Organisms, Diversity & Evolution*. **12:** 241-250. http://link.springer.com/article/10.1007/s13127-012-0090-6#/

Received 1 January 2016, accepted 2 January, 2016