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CONTENTS

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BDS

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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.

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Cover illustration: Teneral male *Libellula fulva*. River Ouse, East Sussex, 2008. Photograph by John C. Luck..

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- 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.
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- 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	Willow 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

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Discovery of new populations of *Libellula fulva* Müller (Scarce Chaser) in East Sussex

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Summary

Although *Libellula fulva*, Scarce Chaser, is known to have established populations on the two main West Sussex rivers the Arun and the Adur, it was thought to be absent in East Sussex. With sightings on both the Cuckmere and Ouse rivers in 2006, it was decided to conduct surveys on both rivers to establish the extent of the populations. This was carried out by the author for the first three years and, for the following three years, with the assistance of a team of helpers. *Libellula fulva* was shown to be present on the Cuckmere River from the White Horse (TQ514007) upstream to Michelham Priory (TQ565099), and on the River Ouse from Hamsey Weir (TQ415127) upstream to Sutton Hall Weir (TQ440187), as well as on some of the tributaries of the River Ouse. Whereas, uniquely, the abdomen of a male *L. fulva* displays clear evidence of mating, it does not, of course, reveal the location. To resolve this, various methods were deployed using larval survey, exuviae search and field observations. It was determined that the species has a preference for breeding in slow moving or still areas of water. This held true even where the male may be holding territory on faster, moving stretches of river. Copulation was observed on several occasions, supporting this theory, but rarely observed ovipositing was only seen on one occasion.

Introduction

When the “Dragonflies of Sussex” was published (Belden *et al*., 2004), it was believed that whilst there were established populations of *Libellula fulva* Muller Scarce Chaser on two West Sussex rivers – the Arun and the Adur – the species was absent from East Sussex. However, *L. fulva* was recorded in East Sussex in 19th century. Writing in the Naturalist, Unwin (1853) noted “One specimen only, taken on the [Lewes] Downs; I supposed it at the time to have been a variety of *L depressa*, but upon close examination it proved to be this species [*Libellula conspurcata* Fab.]”. It appears that the Scarce Chaser was also described as *L*. *conspurcata* by Fabricius in 1798, having originally been described as *L. fulva* by Muller in 1764, Fabricius possibly believing the female to be a different species. Either way, the picture in Unwin (1853) clearly shows

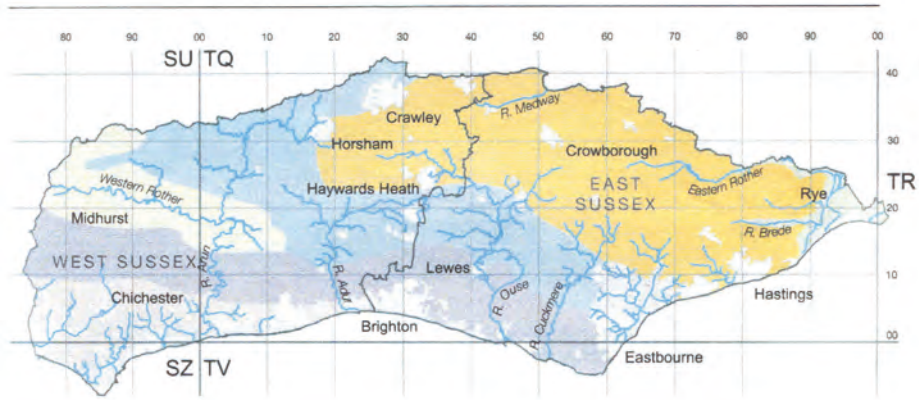

Figure 1. The four main rivers in Sussex. From west to east, the Arun, Adur, Ouse and Cuckmere. Yellow, High Weald; blue, Low Weald; purple, South Downs. From Belden *et al.* (2004).

a female *L. fulva*, recorded a short distance from the River Ouse. This raises the interesting possibility that there has been a population on the Ouse since at least 1853.

The four main rivers in Sussex are the Arun and Adur (West Sussex) and the Ouse and Cuckmere (East Sussex) (Fig. 1). The nearest breeding population on the River Adur is 24 km from the River Ouse and 35 km from the Cuckmere River. Following surveys on the River Arun in West Sussex in 2005 and 2006, the Cuckmere River in East Sussex was visited on 18 June 2006 where I was surprised to discover a small colony of *L. fulva*, although I discovered later that the species had been seen by Geoff Gowlett, further upstream on 11 June 2005. This prompted the question 'Was this species also present on the River Ouse?', which is nearer to the West Sussex rivers. The question was immediately answered in the affirmative with sightings by Phil Belden on 25 June 2006 and by David Chelmick on 8 and 28 July 2006.

To confirm that the sightings of *L. fulva* reflected populations located in East Sussex, and not chance sightings, a sampling regime was set up over a number of years on the rivers Cuckmere and Ouse. Its purpose was to determine the current extent of the populations.

Figure 2. The catchment area of the Cuckmere River. Reproduced with permission from the South East Rivers Trust.

Methods

Much of the land to be surveyed was on private property, doubtless explaining why the species had not been previously recorded. In the Spring of 2007, various landowners between Alfriston and Arlington were approached to obtain permission to visit their land so that the Cuckmere River could be surveyed (Fig. 2). For the next three years (2007-2009) during May and June, surveys were conducted for adults and exuviae and additional sightings of *Libellula fulva* obtained from other observers. Similar surveys were conducted on the River Ouse (Fig. 3) from Barcombe Mills up to Newick on the A272 and also further upstream at Sheffield Park.

In addition, on 7 July 2007, an attempt was made to access the source of the Cuckmere. This proved impossible due to the overgrown vegetation on the footpath. However, access was achieved slightly further downstream at Marle Green, south-east of Horam. The river is especially fast-flowing in the upper reaches as it falls 100 m in its first 6.4 km. As one would expect, the only species able to cope with these conditions is *Calopteryx virgo* Beautiful Demoiselle, which proved to be the case. Further accesses were made at various other

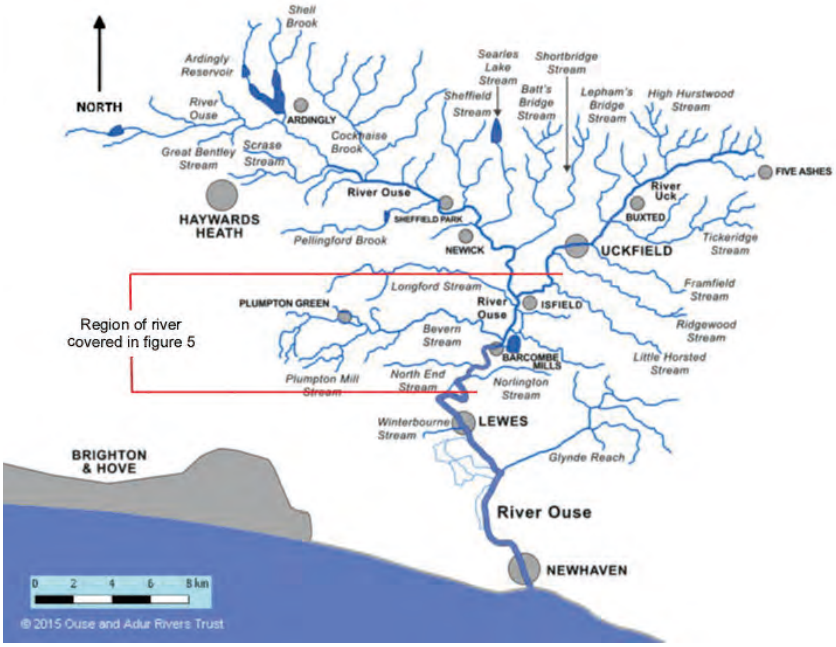

Figure 3. The catchment area of the River Ouse. Reproduced with permission from the Ouse & Adur Rivers Trust.

points down to Hellingly, about 4 km to the south of the Marle Green. The only other species found were a lone *Sympetrum sanguineum* Ruddy Darter and an *Aeshna grandis* Brown Hawker. Whilst the survey date was outside the *L. fulva* flight period, it is inconceivable that it would have found this section of the river to its liking.

From 2010 onwards, a team of helpers was recruited to assist with surveying the two rivers; a stretch of river being allocated to each person. From 2010 to 2012 the survey of the Cuckmere River extended from near Boship roundabout on the A22 (TQ573109) down to south of the Litlington White Horse (TQ514007) (Figs 2,4). On the River Ouse, the survey was carried out from Barcombe Mills (TQ431148) up to Isfield, (TQ444173), including three of its tributaries, Bevern Stream, Iron River and River Uck (Figs 3,5). But, from 2013 to 2017, the survey was restricted to the Barcombe Mills area of the River Ouse, extending to just south of the Anchor Inn.

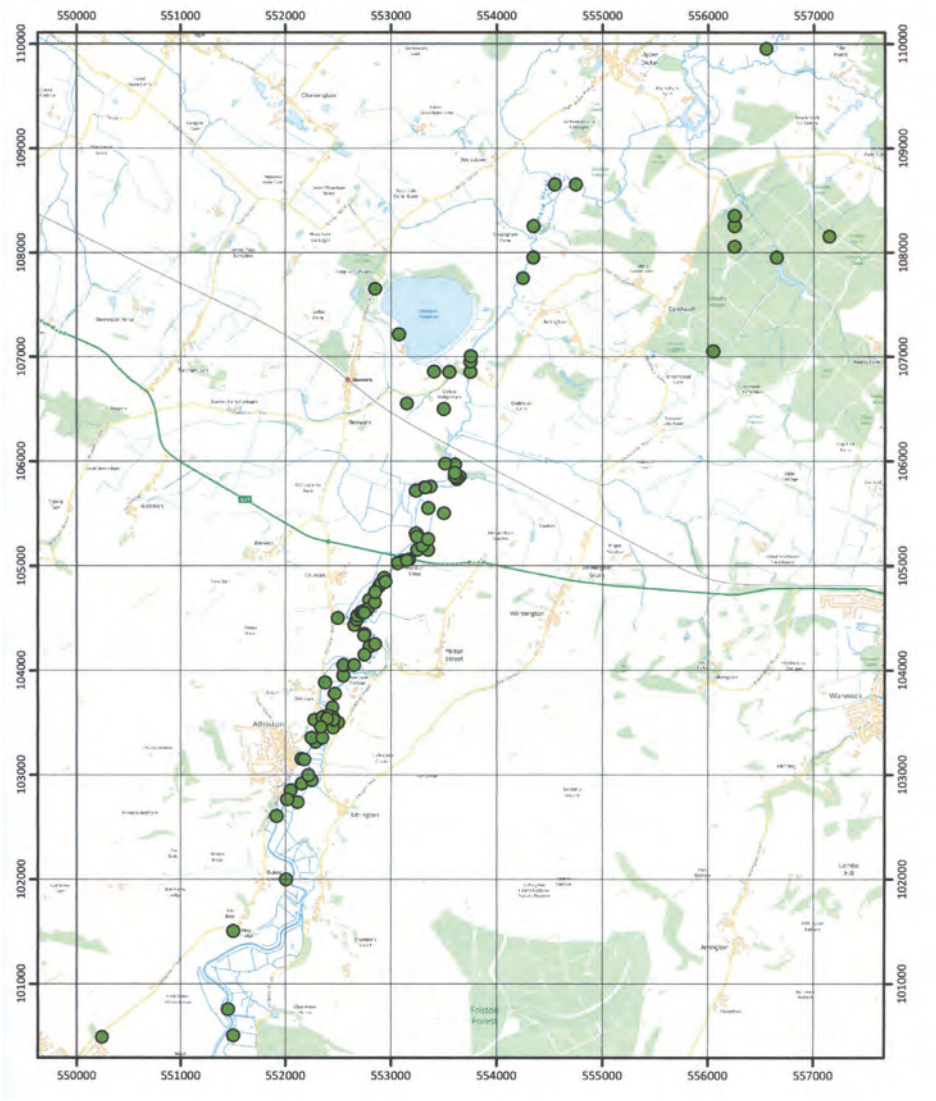

Figure 4. *Libellula fulva* records on and near the Cuckmere River from 2005-2017. 1 km squares. This map contains Ordnance Survey Open data © Crown copyright and database rights 2018 Ordnance Survey. Species data are provided to the Sussex Biodiversity Record Centre by a range of individual recorders, recording groups, private, public and charitable sector organisations. Data remain the property of the original recorder and are reproduced with thanks. Reproduced with permission from the Sussex Biodiversity Record Centre.

Table 1. Number of adults and exuviae recorded on the Cuckmere River. The numbers of adults include pairs in cop. Note that a team carried out the survey from 2010.

Year	Adults	Exuviae
2007	23	0
2008	4	0
2009	38	0
2010	121	0
2011	167	61
2012	53	0

Results

Cuckmere River

The Cuckmere River rises near Heathfield in East Sussex on the southern slopes of the Weald. It flows into the English Channel at Cuckmere Haven, between Seaford and the Seven Sisters cliff face (Wikipedia, River Cuckmere, 2018) (Figs 1, 2).
Sightings were made on the Cuckmere River between the White Horse (TQ514007), the furthest downstream, up to a lone sighting at Starnash Farm, 1 km north of Michelham Priory (TQ565099), the furthest upstream (Fig. 4).

In 2007 the survey was conducted between 22 May and 14 July and one pair in cop was seen in addition to 21 individuals (Table 1). The following year very few individuals were recorded due to inclement weather but there were good numbers recorded in 2009. Following the recruitment of a team of observers there was a notable increase in the numbers observed, with two pairs in cop being recorded in both 2011 and 2012. The figure for 2011 included 79 sightings on 20 May on a 2 km stretch of the river. Three of these were immature females, in the process of colouring up, perched in a hedgerow 200m from the river. Also, in 2011, 61 exuviae were found (Table 1).

Wanderers were noted on a footpath at Arlington Park, Seaford in 2009 (TQ502005) and at Abbot's Wood on two dates in 2012 and on top of the South Downs at Bo-peep Bostal in 2017. Distances were between 2 km and 3 km from the Cuckmere River.

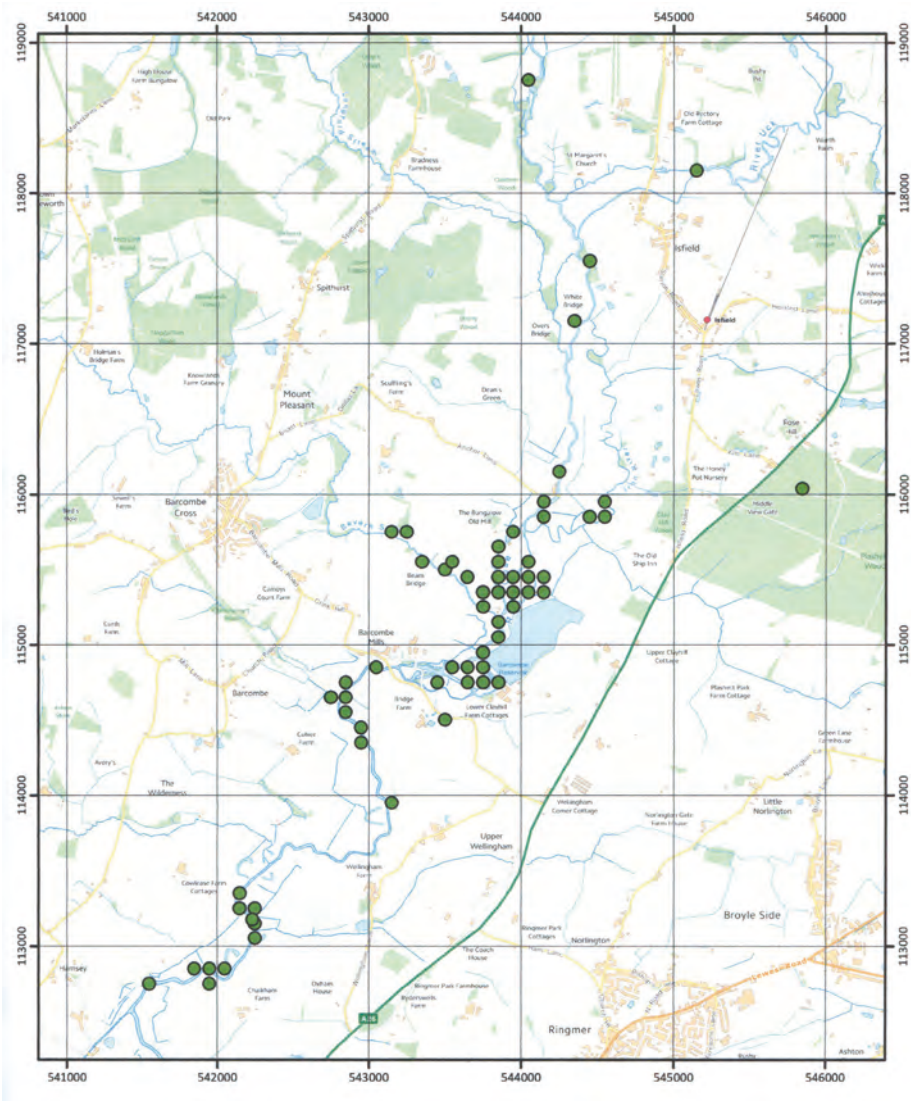

Figure 5. *Libellula fulva* records on and near the River Ouse from 2005-2017. 1 km squares. This map contains Ordnance Survey Open data © Crown copyright and database rights 2018 Ordnance Survey. Species data are provided to the Sussex Biodiversity Record Centre by a range of individual recorders, recording groups, private, public and charitable sector organisations. Data remain the property of the original recorder and are reproduced with thanks. Reproduced with permission from the Sussex Biodiversity Record Centre.

Table 2. Number of adults and exuviae recorded on the River Ouse. The numbers of adults include pairs in cop and a single ovipositing female. Note that a team carried out the survey from 2010. From 2013, surveying was restricted to the Barcombe Mills area.

Year	Adults	Exuviae
2007	1	0
2008	98	8
2009	0	0
2010	172	
2011	10	
2012	94	
2013	29	
2014	10	
2015	19	
2016	37	
2017	12	

River Ouse

The River Ouse runs from Lower Beeding in West Sussex down through Barcombe Mills. From here, the river is tidal to the sea at Newhaven (Figs 1, 3). This lower section of the river has strong currents and has been susceptible to flooding. The upper section is fairly slow flowing (South East Fishery Guide, River Ouse, Sussex, 2018). The River Uck is one of the main tributaries, starting near Crowborough and feeding into the Ouse at Isfield (Figs 3, 5). The Iron River and Bevern Stream join the Ouse east of Barcombe Cross

No pairs in cop were recorded until 2010, when two pairs were seen. In 2012 eight pairs in cop were recorded. As noted above, surveying was restricted to the Barcombe Mills area from 2013 and two pairs in cop (Plate 1) were recorded that year, when both pairs were observed mating on adjoining reeds in a quiet, well vegetated ditch from 13.02 – 13.31 BST. At this point one pair separated and the female disappeared behind the reeds and was assumed to be ovipositing out of sight. A further pair was recorded in 2015. In the whole of the survey period only one female was seen ovipositing. Sightings were made between Hamsey Weir (TQ415127), the furthest downstream up to Sutton Hall

Weir (TQ440187), the furthest upstream (Fig. 5).

The most remarkable sightings were south of Barcombe Mills to Hamsey Weir, a tidal stretch. The previous year, I had dismissed the idea of surveying this section, but then on 22 June 2010 I corrected my oversight and was amazed by the results: 28 individual males, three showing mating scars, and two copulating pairs; also one pair 1 km north of Hamsey Weir close to two ox-bows and a quiet backwater heading east to Scuffling Bridge. There was good emergent vegetation, but the ripples in the river indicated a flow which could never be described as slow-flowing (Plate 2). This demonstrated perfectly that, whilst males may hold territory on fast flowing stretches of water, oviposition takes

Plate 1. Two mating pairs of *Libellula fulva* on adjacent reeds in a quiet well-vegetated ditch at Barcombe Mills near the River Ouse in June 2012.

Plate 2. The River Ouse at Cowlease Farm south of Barcombe Mills in June 2010 with fast moving water showing the extent of the emergent vegetation.

place on still or slow moving water. The answer to the question as to why males would hold territory on fast flowing water is answered by the fact that all the slow flowing stretches are occupied by other males.

Libellula fulva had also made inroads into some of the tributaries of the River Ouse. Thus, it was found along about a 1 km stretch of the Bevern Stream before it joined the Ouse and similarly along about 0.5 km of the Iron River. It was also recorded on the River Uck at the weir just before this river divides into two branches (TQ451181).

Wanderers were reported at Park Corner Heath Butterfly Reserve (7 km distant) and at Saltdean, where two males were seen flying in short bursts and then perching beside a small pond. The latter record is too far distant from the nearest river population and may have come from a nearby large pond, or they may even have been migrants.

It is interesting that the years 2007, 2009, 2011 and 2013 produced far fewer records than the alternate years 2008, 2010 and 2012, which suggests that this may well be a newly established population shown by the 2-year larval life cycle. This pattern was less clear from 2014 onwards, although a larger number were recorded in 2016 compared to the years either side of this (2015 and 2017) (Table 2).

Plate 3. A female and a male *Libellula fulva* resting on a dead branch after copulating and prior to egg-laying beside the River Ouse at Barcombe Mills in June 2015.

Other Rivers and Ponds

Searches were also made further east on the Eastern River Rother and its tributary the River Brede, but without success. Visits to numerous ponds whilst doing other survey work did not produce any *Libellula fulva* sightings.

Larval Survey

Following the absence of adults in 2009, it was decided to hold a larval survey the following year. The team of six people included three members of OART, whose organisation is dedicated to the environmental enhancement and protection of the rivers Ouse and Adur. The survey took place on 27 March 2010 at the main breeding site at Barcombe Mills, resulting in the capture of two

larvae. Given the ability of *Libellula fulva* larvae to burrow deep into the mud, the low count was not surprising and it was presumed that many more were hidden in the mud. This proved to be correct as the 2010 survey produced a record number of adults.

Breeding

Whilst mating was observed on several occasions, including two pairs in cop on adjacent reeds in 2012, an ovipositing female was seen on just one occasion throughout the whole survey period, on 25 June 2015. It was seen on a quiet section of the River Ouse. The pair had copulated from 15.30 – 15.35 BST before resting on a dead branch beside the river for three minutes (Plate 3). Thereafter, the female took off and was seen egg-laying in the river, guarded by the male hovering overhead.

As a result of the sightings of copulating pairs, most breeding appears to take place in ditches or very slow running sections of the rivers. Thereafter, males holding territory disperse along the rivers once the ditch territories have been occupied.

On the River Ouse, exuviae were principally found in ditches and only occasionally nearby in the main river. Although the ovipositing female mentioned above was laying eggs in the main river, this particular stretch of water was very slow moving.

Based on the occurrence of pre-flight emergents, copulating pairs, ovipositing females and exuviae found, the River Ouse catchment appears to contain several breeding areas:

- Barcombe Mills - ditches and adjoining part of the River Ouse;
- River Ouse - field immediately north of Barcombe Reservoir, where the river rejoins itself, forming a circle around the field boundary and creating a quiet back-water - this was where the female was observed ovipositing;
- Iron River east of the Anchor Inn;
- Bevern Stream east of Barcombe Cross;
- River Ouse north of Hamsey Weir;
- River Uck east of Isfield Mill (if population is established).

On 27 May 2011, a separate survey was conducted in an inflatable dinghy by David Chelmick (Plate 4) searching the main Cuckmere River, as opposed to the adjoining ditches, in the most populated section. No exuviae were found, confirming the theory that the Scarce Chaser will select still or slow moving water for egg-laying.

Plate 4. Surveying emergent vegetation for exuviae on the Cuckmere River in May 2011.

Plate 5. A short section of the old Cuckmere River (now a quiet backwater) south of Arlington reservoir in May 2011.

Plate 6. Pre-flight emergent (teneral) of *Libellula fulva* and its exuvia on *Equisetum* on the Old Cuckmere River south of Arlington Reservoir in May 2011.

Plate 7. A ditch at the side of the Cuckmere River close to Long Bridge in May 2011.

The most concentrated breeding area on the Cuckmere River was discovered on 12 May 2011 to the south of Arlington Reservoir on a short section of the old river (TQ535068) (Plate 5), where a remarkable 50+ exuviae were found, with a further five exuviae nearby on the main river just to the north of the pumping station. Four more exuviae were found the following day. A pre-flight emergent was seen perched on *Equisetum* (Plate 6). The main population is located on the 2 km stretch between Sherman Bridge on the A27 (TQ531050) all the way through to Long Bridge, north of Alfriston (TQ524035). Various breeding activities (pre-flight emergents (tenerals) and copulating pairs) were seen throughout this area, where suitable side ditches and quiet backwaters for breeding are located close to the main river, with slow moving water and abundant bankside vegetation available for males holding territory (Plate 7). Heading further down to Alfriston and beyond, the river is too fast flowing, but suitable ditches permit occasional breeding.

Discussion

The Red Data List (Daguet *et al*., 2008) classifies the Scarce Chaser as Near Threatened, noting it as "a rare species with slow rate of increase, although locally abundant". In the new 'Atlas of Dragonflies in Britain and Ireland' (Cham *et al*., 2014), *Libellula fulva* is now accepted as having expanded its range into East Sussex and the Atlas confirms that the species is now "firmly established long the Rivers Ouse and Cuckmere". Thus the species has improved in its status and is apparently becoming more successful, or being recorded more effectively.

Our surveys showed that, where the ideal habitat is found, the species will occur in large numbers to the degree that some survey team members were renaming it the 'Dead Common Chaser'. As regards its rarity, perhaps it is under-recorded and if dragonfly spotters were to turn their attention to contacting land-owners to gain access to private land, it may well prove to be more common than we are currently aware.

The two rivers make an interesting comparison, where the continuous section of suitable habitat of the Cuckmere results in the colony mainly occupying a single area, whereas the differing habitats of the Ouse result in fragmented populations.

The species "is usually found inhabiting slow flowing rivers…….Observations suggest that *L. fulva* sometimes shows a preference for smaller, quieter streams" (BDS, 2003) (Goodyear, 1995: Winsland, 1997; Cham, 2000) It is considered to be mainly present where there is extensive, high and dense riverside vegetation

Plate 8. Larval Survey Team – Lesley Williams, David Chelmick, Dave Mitchell, Mark Davis and Sam St Pierre – in March 2010.

(Kalkman, 2014). For example, it is associated with vegetation such as beds of common reed (*Phragmites australis*), reedmace (*Typha latifolia)*, common club rush (*Schoenoplectus lacustris*) or sedges. The larvae inhabit the silt and mud at the base of such emergent vegetation. In East Sussex it would seem to be colonising the tributaries, ponds and backwaters to establish breeding populations. *Libellula fulva* appears to be a fairly tolerant species but has a preference for mesotrophic non-acidic waters. Its continued success requires that the preference for slow moving water is considered and population requirements are supported when potential and known habitats are managed, This is particularly important in terms of riverside vegetation management and dredging of the river mud and sediment.

There is no doubt that the species prefers still or slow moving water, particularly when breeding. It was noticeable that the species diverted along the smaller, quieter tributaries (Bevern Stream, Iron River and River Uck) rather than continuing upstream along the busier section of the River Ouse up to and beyond the Anchor Inn at Barcombe.

One item that will require close monitoring in the future is, given that both rivers flow into the sea, any future rise in sea levels will impact on breeding.

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Particular thanks are due to the landowners for granting permission to access their land. It has been assumed that they will wish to remain anonymous and their privacy respected.

Many thanks also to Sussex Biodiversity Record Centre for producing the distribution maps and to Ouse & Adur Rivers Trust and South East Rivers Trust for providing respectively the Ouse and Cuckmere catchment maps.

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Migrant and dispersive dragonflies in Britain during 2017

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Summary

In Britain, the year 2017 proved to be a highly eventful one for migrant and dispersive dragonflies; indeed it was to be one of the best years on record. Several dispersive species showed notable range expansions (e.g. the first record of *Libellula fulva* for Wales was made at Porthkerry Country Park, Glamorgan, on 7 June), and many of our recent colonist species faired well. The major highlights, however, referred to longer distance migrants, with immigration being noted throughout much of the year. Significant arrivals of *Anax ephippiger* were noted both in early spring 2017 and again in autumn. *Anax parthenope* had a good year, with records from over 30 sites during the summer, and presumed immigrant *Aeshna affinis* were seen at a few localities in southern England well away from the species' breeding stronghold around the greater Thames Estuary. Perhaps the most significant events of the year involved various members of the Libellulidae. *Sympetrum fonscolombii* appeared in very good numbers, with records from almost 100 sites around the UK. Many individuals stayed around to breed, and a locally-bred second generation was noted during late summer/autumn at sites as far north as Yorkshire, though productivity was in general low. The other highlights relate to *Crocothemis erythraea*, where a male was present at Longham Lakes in Dorset over 8–9 July; this followed late news, only recently received, of a male seen at Hickling Broad in Norfolk on 5 July 2016. These are the first confirmed British records for over a decade.

Account of species

Notable sightings reported to the BDS Migrant Dragonfly Project during 2017 are detailed below; for information on events during 2016, see Parr (2017).

Calopteryx virgo (L.) – Beautiful Demoiselle

A number of unusual sightings were made in central England, well away from traditional sites. A female at Kirby Fields, Leicestershire, on 18 June (LB) is thus

one of very few county records, while another female seen at Woodwalton Fen, Cambridgeshire, on 19 June (AR) is probably the first record for that county. Sightings at the Letcombe Brook in East Hanney, Oxfordshire, at the beginning of June (BW) are also unusual. The species is known to currently be expanding its range (e.g. Cham *et al*., 2014; Reeve, 2014), and many of the above records are likely related to this. With mid June being unusually warm in the UK (Met Office, 2018) a weather-driven dispersive event of some kind is perhaps also involved in some sightings.

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Chalcolestes viridis **(Vander Linden) – Willow Emerald Damselfly**

Since first colonising Britain in 2007 (Brame, 2008), *Chalcolestes viridis* has spread throughout large parts of southeast England. During 2017, the species was again recorded in good numbers, even at sites at the edge of its range only colonised very recently. Unlike the situation over the past few years, relatively little fresh range expansion was, however, noticed. Records near Kirdford in West Sussex on 27 September (ABa) represent a small westward shift, but only in Kent were sightings made significantly outside the previous range margin, with numerous reports from the Royal Military Canal in the south of the county (JGB, AD, JL *et al*.) being most important. The number of individuals seen and the extent of canal over which they were noted does, however, rather suggest that this area has been colonised for some while, but it is only now that the damselflies have been discovered. Quite why range expansion appeared to stall somewhat during 2017 currently remains unknown. Certainly the species did not do at all badly during the year, with significant range infilling still being noted, particularly in Cambridgeshire. Important new records here included sightings at Cambourne on 28 August (per VP), Fen Drayton RSPB Reserve on 29 August (LW) and Godmanchester on 12 September (JWi). Elsewhere, recent egg scar tracts (though no adults) were also noted at Sandy in Bedfordshire (BC). Perhaps recent range expansion has been so rapid that the species has overstretched itself, and populations near the range boundary now need to build up before further expansion takes place.

Lestes barbarus **(Fab.) – Southern Emerald Damselfly**

Lestes barbarus has maintained a rather precarious presence in Britain since its first appearance in 2002 (Nobes, 2003), but in many ways 2017 was the species' best year yet, with records from at least six sites and with signs of continuing immigration. Breeding was again noted at the now traditional site at Cliffe in north Kent (JGB), and an additional breeding site was discovered further east on the Hoo Peninsular towards the Isle of Grain, with adults being noted on 28 June (DSu) and with at least one exuvia being found. Importantly, a breeding site was also discovered on the northwest coast of the Isle of Wight,

with several tenerals being seen during late May (PHu). This site appears to already be well established, as retrospective examination of photographs taken during June 2016 showed immatures to have also been present then, though they had been misidentified at the time.

Despite the favourable events in north Kent and on the Isle of Wight, no records were received during 2017 from the species' well known site at Winterton Dunes in Norfolk, though it is fair to say that the exact status of *L. barbarus* here has never been fully established. Nearby, a tandem pair was, however, seen at Eccles-on-Sea, Norfolk, on 16 August (NBo). Further south, in Essex, single individuals were also photographed at Holland Haven Country Park on 20 June (per CAt) and near St Osyth on 7 & 9 July (CAt). These various East Anglian records rather suggest that small scale arrivals took place during the summer; indeed, given the fact that *L. barbarus* can be quite easily overlooked, such immigration events may be more frequent and widespread than currently appreciated.

Erythromma viridulum (Charp.) – Small Red-eyed Damselfly

While range expansion by this relatively recent colonist, which first appeared in Britain during 1999 (Dewick & Gerussi, 2000), has slowed considerably over the last decade (Cham *et al*., 2014), the current reporting year saw significant new records. These came principally from south Wales, where previously the species had been extremely scarce (the only well-documented site being the WWT Llanelli Wetland Centre, Carmarthenshire). Reports were thus received from both Newport Wetlands RSPB Reserve (JWh *et al*.) and Ynysyfro Reservoir (DSp) in Gwent during early/mid July, with another record from near Magor in Monmouthshire (KJ) during the same period. At the edge of the species' range in England, sightings were also received from new sites in Yorkshire, with a record of 150+ at Sherburn in Elmet, North Yorkshire, on 15 August (CAb) being particularly interesting.

In addition to continuing range expansion, there were signs of ongoing immigration during the year. On the East Anglian coast, a 'small influx' was thus noted at Eccles-on-Sea, Norfolk, on 16 August (NBo), coincident with the appearance there of *Lestes barbarus* (see above), and one was also noted at Winterton Dunes, Norfolk, on 20 August (per PT).

Aeshna affinis (Vander Linden) – Southern Migrant Hawker

The species had a good year in its recently established breeding strongholds around the greater Thames Estuary. Records were received from new sites in the area, e.g. at Elmley Nature Reserve on the Isle of Sheppey, Kent (KF),

while at more traditional sites good numbers were seen, with a count of 30+ at Canvey Island, Essex, on 9 July (TCa) being of particular note. In addition to these records from Kent and southern Essex, individuals also reappeared in the St Osyth area of northeast Essex, where they had first been seen in 2016 (Parr, 2017). Up to four males were thus reported between 7 July and 20 August (CAt). These records may indicate that the British breeding population is now starting to expand.

In addition to our resident population in Kent and Essex, a few individuals were also noted elsewhere in southern England; it is presumed these represent immigrants, though it is perhaps conceivable that the species now breeds more widely than currently appreciated. A female was thus photographed at Ravensroost near Minety in Wiltshire on 5 August (DP), while a male was photographed at Pagham Harbour, West Sussex, on 23 August (ABo). Two further reports from southwest England are, in addition, still being assessed by the national Odonata Records Committee.

***Aeshna mixta* Latreille – Migrant Hawker**

There were few signs of any large-scale movements during the year, though a report of 150 at Covehithe, Suffolk, on 14 August (KK) is perhaps suggestive of a migratory event. Records of dragonflies attracted overnight to moth traps may potentially also refer to migrants (Parr, 2006), and individuals were recorded in such a manner at Sandwich Bay, Kent, on 22 August (IH) and Bawdsey, Suffolk, on 17 September (MD).

***Anax ephippiger* (Burmeister) – Vagrant Emperor**

This primarily Afro-tropical species continued its run of recent good showings in Britain, with numerous sightings throughout the year, primarily in southwest England though occasionally further afield. Between 12 March and 11 April no less than 17 confirmed or ‘probable’ individuals were noted from the Isles of Scilly, Cornwall, Devon and Dorset. Although only about a quarter of the records were conclusively referable to *Anax ephippiger*, it is likely that most, if not all, reported sightings in fact relate to this species since very few other dragonflies are flying in northern Europe at this time of year. Later in the season, single individuals were then photographed at Studland Bay, Dorset, on 7 May (DP), at Scaling Dam, North Yorkshire, on 9 July (GM) and at Minsmere, Suffolk, on 15 July (JA). The autumn was then to see another significant influx, with some 15 reports between 2 October and 11 November. Records were primarily from southwest England (Isles of Scilly, Cornwall, Devon, Dorset, Hampshire), but an individual was noted at Cosmeston, Glamorgan, on 3 November (per GDP) and a female was seen at Gorton, Greater Manchester, on 18 October (DB).

Anax imperator Leach – Emperor Dragonfly

One was attracted to a moth trap at Ipswich Golf Club, Suffolk, on the night of 23 July (NS), with another similarly attracted to a moth trap at Portland Bill, Dorset, on the following night (MC). Particularly as records of this species at light are relatively unusual, this is perhaps suggestive of some sort of movement.

Anax parthenope Sélys – Lesser Emperor

It was a good year for *Anax parthenope* during 2017, with reports from over 30 sites spread across 16 counties. Records were principally from southern England (including sightings in Devon, Somerset, Dorset, Hampshire, Kent, Essex, Suffolk, Norfolk, Berkshire, Worcestershire and Lincolnshire), but also included a few individuals noted in the Midlands and more northerly parts of England (Staffordshire, West Yorkshire, East Yorkshire). In addition, there was a record from Skokholm, Pembrokeshire, on 2 June (GE) and a male was seen on North Ronaldsay in the Orkney Islands on 15 June (SP). This is only the second Scottish record, the previous individual also having been seen on Orkney, back in June 2000 (Parr *et al.*, 2004).

The first record of the year was from Frampton Marsh, Lincolnshire, on 26 May (EM, TCo), and at least three waves of immigration were noted between late May and mid July, with a prominent spike around 17–21 June. Immigration waves frequently coincided with arrivals of *Sympetrum fonscolombii* (see below). A few further individuals were then noted later in the season, with the last record of the year being a male photographed at Trimingham, Norfolk, on 17 September (JG). Most records made during 2017 seemingly refer to primary immigrants, but a few locally-bred individuals were probably also involved. One such candidate was a long-staying male seen at Ormesby Little Broad, Norfolk, over 1–21 June (KS *et al.*). This site has produced regular sightings since at least 2014 (Parr, 2017).

Crocothemis erythraea (Brullé) – Scarlet Darter

The following records have been accepted by the Odonata Records Committee; in addition a further report from Norfolk on 14 June 2017 is still under consideration.

5 July 2016	Male photographed at Hickling Broad, Norfolk (P. Riordan)
8–9 July 2017	Male photographed at Longham Lakes, Dorset (M. Wood *et al.*)

The above accepted reports are only the eighth and ninth British records (all since 1995) and the first confirmed sightings since 2004 (Cham *et al*., 2014), though occasional reports of 'possibles' have been received during the intervening period. Over the past two–three decades the species has colonised both Belgium and The Netherlands, and continues to do well in these areas, with records from no less than 339 separate 5 km squares in The Netherlands during 2017 (Waarnemingen.nl, 2018). The recent British sightings serve as a reminder that the species also remains a potential colonist to the UK.

***Libellula fulva* Müller – Scarce Chaser**

This species has been expanding its range quite considerably in recent years (Cham *et al*., 2014). The first confirmed record for Wales was made on 7 June 2017, when a female was photographed at Porthkerry Country Park, Glamorgan (PB).

***Libellula quadrimaculata* L. – Four-spotted Chaser**

Libellula quadrimaculata has, in the past, sometimes been observed in enormous migratory swarms numbering into the millions (Lucas, 1900), though nowadays such numbers are no longer seen in western Europe and, in Britain, the species rarely attracts particular attention though migrations do still occur (e.g. Parr, 2014). During 2017, an individual was recorded from an oilrig in the North Sea some 160 miles east of Edinburgh, Midlothian, on 27 May (MG). In mainland Britain, a record from Scolt Head Island, Norfolk, on 23 May (NL) may conceivably be part of the same wider migratory event, since the species does not breed at this site. Later in the season an individual seen at Bouldnor on the Isle of Wight on 20 June (DD) is also of interest, being some 25 km from the only known breeding site on the island.

***Sympetrum danae* (Sulzer) – Black Darter**

Evidence for internal dispersal during the year took the form of sightings of an immature male near the coast at Birkdale, Lancashire, on 10 August (PK) and of two males and a female at Trowbarrow Local Nature Reserve, Lancashire, on 8 September (CAd). *Sympetrum danae* does not breed at either site, and indeed the habitat at Trowbarrow is atypical for the species. Further south, two males seen near the coast at Dunwich Heath, Suffolk, on 3 October (TG) are perhaps more likely to have been immigrants from the Continent.

***Sympetrum fonscolombii* (Sélys) – Red-veined Darter**

From once being a scarce and erratic visitor to our shores, *Sympetrum*

fonscolombii has now become a regular immigrant, and 2017 saw some of the largest influxes ever reported from Britain. During the spring and early summer months, records were received from roughly 90 sites in the UK, spread over 36 counties. Most sightings came from southern and eastern regions of England, but records extended as far north as the Orkney Islands. Here a male was photographed on Copinsay on 20 June (JS, SM), and a 'red darter' seen during mid June on the island of Sanday was almost certainly also this species. These are the first records for Orkney; indeed the species still remains quite unusual even further south in Scotland. During 2017, there were, however, records from Newmains Pond in Berwickshire on 19 May (DG) and from Millars Moss in the Scottish Borders during mid June (DG).

Early season sightings commenced on 16 May, at Ham Fen in Kent (RWC), and at least two major influxes were noted, peaking around 25–27 May and 19–21 June (Fig. 1). Signs of an additional smaller influx during early July were also seen. By the end of July, records of mature adults had largely tailed off, but around this time widespread emergences of locally-bred second generation individuals started. Presumed breeding was indeed even reported from a few sites where the arrival of adults had been missed during spring. The first report of second generation *S. fonscolombii* was from Hanningfield Reservoir, Essex, on the surprisingly early date of 10 July (JB), with subsequent records following around the country from 31 July onwards. A minimum developmental time from egg-laying by primary immigrants to emergence of second generation individuals could be deduced at a few well-watched sites in Hampshire and Suffolk; this period was in the range 68–72 days. Productivity in general appeared rather low, with only a handful of second generation individuals (often just low single figures) being noted at all but the best sites. It is, however, possible that some individuals went unnoticed, since autumn immatures soon disperse away from their natal area (Parr, 2007). Although most records of confirmed or presumed local breeding came from southern England and East Anglia (notably in Cornwall, Dorset, Hampshire, Essex, Suffolk and Norfolk), there were also a few reports further north, with Yorkshire in particular producing a number of important sightings. Daily counts of up to a dozen or more tenerals and/or immatures were thus reported from a site near Goole in East Yorkshire during September and the first days of October (PHi *et al*.), with several reports of immatures also coming from Kilnsea Wetlands, East Yorkshire (AH *et al*.), and from St Aidans RSPB Reserve, West Yorkshire (DJ *et al*.). The last record of *S. fonscolombii* for the year was an immature male seen at North Cave Wetlands, East Yorkshire, on 14 October (NBr), this perhaps being a dispersing individual from elsewhere in the county.

Sympetrum striolatum **(Charp.) – Common Darter**

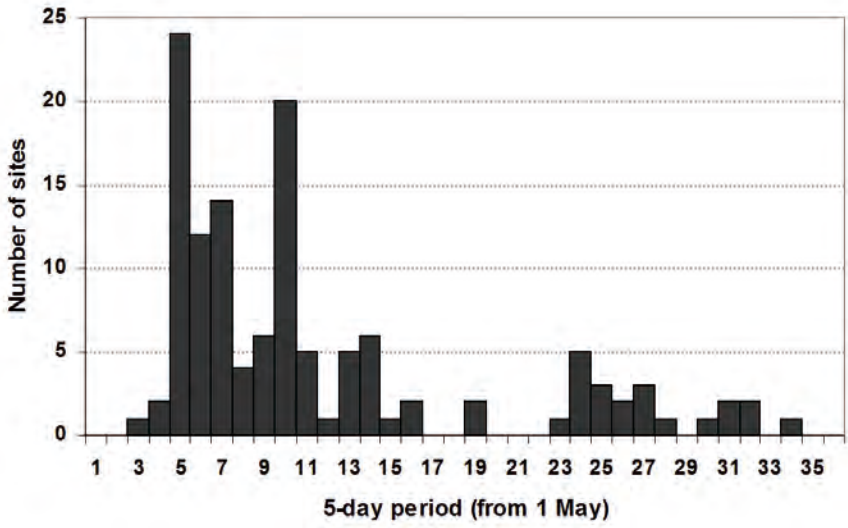

Figure 1. Sites reporting new appearances of *Sympetrum fonscolombii* in each five day period throughout the season (showing first and second generations).

There were few signs of any large-scale movements by *Sympetrum striolatum* during 2017, though smaller-scale migrations can be hard to detect due to the simultaneous presence of numerous resident individuals. Records of dragonflies caught overnight in UV moth traps may, however, often refer to migrants (Parr, 2006), and individuals were noted in such a manner at Bawdsey, Suffolk, on 18 July (MD), at Bradwell-on-Sea, Essex, on 20 & 26 August and 30 September (SD) and at Portland Bill, Dorset, on 16 & 29 August and 3 September (MC).

Conclusions

The 2017 reporting year was a highly eventful one for migrant and dispersive dragonflies. Several dispersive resident species showed notable range expansions, and many of our recent colonist species faired well. For a number of these, e.g. *Lestes barbarus* and *Aeshna affinis*, this included evidence for continuing immigration. The major highlights of the year referred to large-scale arrivals by a number of migrant species whose strongholds lie in southern Europe or even further south. Up until only about 20–30 years ago, most of these species were of only very sporadic and limited appearance in Britain, if indeed they had been recorded at all. Even by recent standards, the year's arrivals of *Anax ephippiger* and *Sympetrum fonscolombii* were however of considerable note. Clearly, shifts in the European dragonfly fauna thought to be linked to

climate change (Ott, 2010; Parr, 2010; Termaat *et al*., 2010) are still ongoing and are of major significance. Although not yet involving a large number of individuals, the recent upsurge in appearances of *Crocothemis erythraea* are no doubt part of the same phenomenon, and serve as a reminder that this species is indeed a potential colonist to Britain.

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Recapture rates and habitat associations of *Leucorrhinia dubia* (Vander Linden), (White-faced Darter), on Fenn's and Whixall Mosses, Shropshire

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Abstract

Land-use changes and habitat loss are important drivers of biodiversity decline at both global and local scales. To protect species from the impacts of land-use change it is important to understand the population dynamics and habitat associations across these scales. Here we present an investigation into the survival and habitat preferences of *Leucorrhinia dubia*, White-faced Darter, at the local scale at Fenn's and Whixall Mosses, Shropshire, UK. We used Mark-Release-Recapture (MRR) methods to investigate survival and used sightings of individual dragonflies along with habitat data to investigate habitat preference. We found that survival between capture-visits was very low and that *L. dubia* showed a clear preference for the open moss habitat on this site. We also found that the detectability, either through sightings or recaptures, was potentially very low and suggest that this should be taken into account in future analyses. We suggest that, by encouraging recorders to submit complete lists and to repeat visits to sites, detectability could be easily estimated for dragonfly species. Incorporating this into analyses would improve estimates of population trends and habitat associations.

Introduction

There has been a marked decline in global biodiversity in the last several decades, a decline which is expected to continue, and this has been largely attributed to changes in land-use activities (Sala, 2000). Land-use activities include agriculture, forestry, creation of urban areas, and use of natural resources (Foley *et al*., 2005). These activities have a huge impact on environmental characteristics and often cause habitat loss and fragmentation, contributing largely to the decline in global species diversity (Holloway *et al*., 2003). As such, management and protection of habitats and populations is vital at both local and

global scales (Foley *et al*., 2005; Holloway *et al*., 2003).

A bias exists in conservation research towards charismatic vertebrates (Di Marco *et al*., 2017). Although Odonata are charismatic invertebrates they are not immune to this bias (Clausnitzer *et al*., 2009). In addition, much research into Odonata focuses on physiology, evolution and behaviour (Córdoba-Aguilar, 2008) and they have rarely been the focus of conservation research (Clausnitzer *et al*., 2009). Basic ecological research into demography, survival and habitat use is essential for effective protection of species and habitats. For any taxa this requires detailed ecological and life history data collected in the field. These are often difficult to obtain, particularly on large scales. Integrating large scale data such as presence-only distribution datasets with more detailed local information is a current challenge in conservation ecology (Powney & Isaac, 2015).

Methods to analyse habitat preferences are varied depending on the data available. The current 'gold standard' is the use of site occupancy models which take into account detectability (the probability that a species is detected in a site if present) when estimating occupancy (the probability that a species is present in a site) (MacKenzie *et al*., 2003). Models using this framework help avoid the problem of 'imperfect detection', i.e. failing to spot a species during a survey on a site where it is actually present (MacKenzie *et al*., 2003). These models require repeated surveys where both detections and non-detections are recorded. However, these data are rarely available. On larger scales a number of methods exist which can use only presence records along with environmental covariates (Elith & Leathwick, 2009). These can tell us about habitat use but are constrained to estimate a measure of the relative importance of habitats rather than the true probability of presence (Elith *et al*., 2011) and are limited by the environmental data available. At very small scales, such as individual protected areas, detailed data on habitats and land cover can be difficult to obtain because datasets collected on global/continental scales lack the resolution required and bespoke methods of producing these data (e.g. drones) are currently expensive or require intensive fieldwork (e.g. ground-based methods). Datasets such as the UK land cover map (LCM2015) are too crude for local studies in some areas even though the resolution is 15m. Simpler methods which indicate preferred habitat, such as selection indices (Manly *et al*., 2007), have fewer assumptions and can be revealing even at small scales (Neu *et al*., 1974).

Investigating survival and movement requires recognition of individuals, and methods using Mark-Release-Recapture (MRR) are well established (McCrea & Morgan, 2014). Such analyses can give information about the age-sex specific survival probabilities of individuals, the use of different sites or habitats and how these change over time, and the likelihood of encountering individuals again in the future. High quality data of this type can provide accurate

estimates of population size. Mark-Release-Recapture methods have been used on Odonata populations in the past to monitor rare species (Foster & Soluk, 2004; Cordero-Rivera & Stoks, 2008) as well as to study the life history of more abundant species. The latter include studies by Finck (1982) and Banks & Thompson (1987) who investigated lifetime reproductive success in *Enallagnma hageni* (Hagen's Bluet) and *Coenagrion puella* (Azure Damselfly) respectively, Bennet & Mill (1995) who studied survival in *Pyrrhosoma nymphula* (Large Red Damselfly), and Anholt *et al*. (2001) who looked at daily survival rates in *Coenagrion puella* and *Ischnura elegans* (Blue-tailed Damselfly). Since odonates can be individually marked relatively easily, they have also been used as model species for methodological research on the development of MRR techniques (Manly & Parr, 1968).

Leucorrhinia dubia is a specialist of lowland peatbogs, where it breeds in bog pools containing sphagnum mosses (Smallshire & Swash, 2014). Its life cycle includes a 1-3-year larval period (Smallshire & Swash, 2014). Emergence is weather dependent and typically starts in either May or June. Tenerals are thought to disperse to low scrub following emergence, staying there whilst they mature. Following this, the adults return to breeding pools, with males returning sooner than females so they can hold breeding territories (Smallshire & Swash, 2014). The adult flight period typically ends in either late July or August. *Leucorrhinia dubia* has a scattered distribution and its populations have been declining in Britain over the past several decades. Despite being classified as a species of least concern on the IUCN Red Data List (Clausnitzer *et al*., 2009), this decline in Britain has resulted in a classification of Endangered on the Odonata Red Data List for Britain (Daguet *et al*., 2008). The decline is largely attributed to habitat loss and the resulting habitat fragmentation (Daguet *et al*., 2008). Thus, over 90% of England's peat bogs have been lost or substantially damaged by the beginning of this century (English Nature, 2002). There are currently only three stable historic populations of *L. dubia* in England, along with two recently reintroduced populations, one in Cumbria and one in Cheshire (Clarke, 2014; Meredith, 2017).

In the current study two methods were used to investigate important ecological characteristics of *L. dubia* on Fenn's and Whixall Mosses in Shropshire, UK. Mark-Release-Recapture was used to investigate survival and movements of adults during the flight period, and a selection index method to investigate habitat use.

Methods

Study area

Fenn's, Whixall and Bettisfield Mosses (FWB Mosses; Fig. 1) are located within Shropshire (52°55′N 2°46′W) and they support a large, long-established population of *Leucorrhinia dubia*. Fenn's, Whixall and Bettisfield Mosses are a lowland raised bog complex of almost 1000 hectares (Meredith, 2017). Historically, the Mosses were used for peat cutting and in the 19th century they were drained to allow larger-scale operations to take place (Meredith, 2017). Eventually, in 1990, the Mosses were taken over by English Nature (now Natural England) and long-term restoration began, benefitting a whole host of mossland species, including *L. dubia* (Meredith, 2017). Our study focused on Fenn's and Whixall Mosses (SJ489364) which are both North of the Llangollen canal.

Field methods

The site was surveyed twice per week between 22 May and 6 July 2017. This encompassed the peak flight period of *Leucorrhinia dubia* (Smallshire & Swash, 2014). Two separate breeding pools within Fenn's and Whixall Mosses Mosses were sampled simultaneously, along with a variety of scrub and other potentially suitable habitat. On each sampling occasion, the full sampling area was searched for any *L. dubia* individuals. Different routes were walked on each occasion to allow different sections within the sampling area to be searched at different times of the day. Sampling sessions lasted between 5-10 hours and were carried out between 10.00 and 16.00 BST, as this is the favoured flight period for adult dragonflies (Smallshire & Beynon, 2010). Sampling days were weather dependent (Chin & Taylor, 2009) and weather conditions were recorded on all sampling days. Mark-Release-Recapture sampling and selection index recording were carried out at the same time.

Mark-Release-Recapture (MRR) Mature adults were caught using a net and marked with a unique number on one wing (Fincke, 1982; Banks & Thompson, 1987; Bennet & Mill, 1995; Chin & Taylor, 2009), using an Edding 404 permanent marker pen (Plate 1). The insects were then released at point of capture and any behavioural observations recorded. Not all observed individuals were captured and tenerals were excluded from the MRR survey as during this life stage they are fragile and handling may cause wing damage (Allen & Thompson, 2010). Tenerals are easily identified by their pale green colouration, a lack of their full adult colouration and by their dull wings (Smallshire & Swash, 2014). Insects recaptured on the day of marking were not re-counted (Foster & Soluk, 2004). Following initial marking, recapture on successive days was only necessary

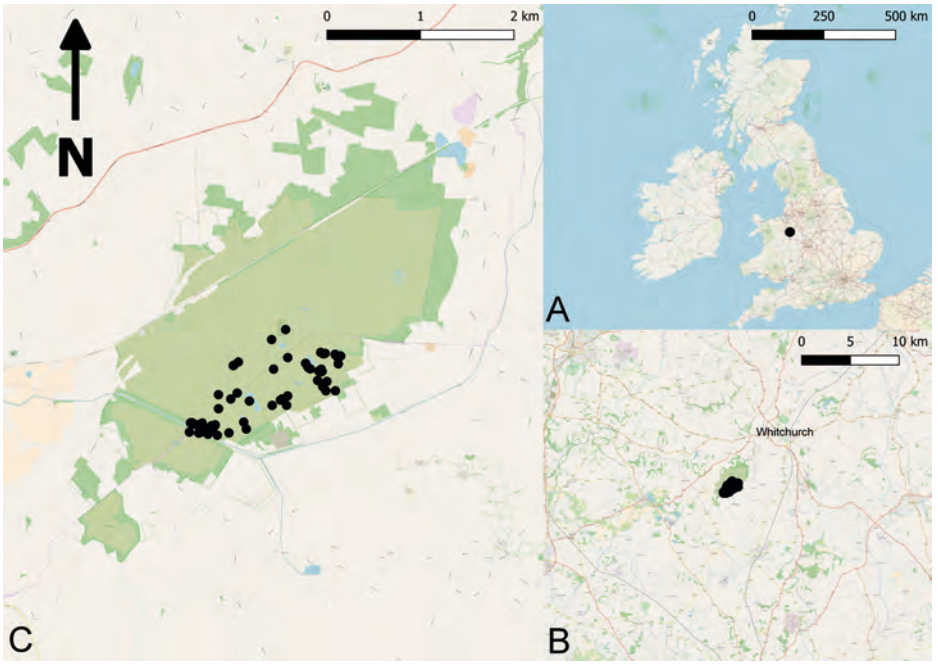

Figure 1. Location of the sampling location on Fenn's, Whixall and Bettisfield Mosses. (A) the location of the study area (black) in the United Kingdom, (B) the study area at Fenn's, Whixall and Bettisfield Mosses (black), in relation to the nearest town, Whitchurch, Shropshire – the area in green adjacent to the study area shows the extent of the Mosses, (C) the sites where *Leucorrhinia dubia* was present within the study area – the extent of the Mosses is shown in green. (background: © OpenStreetMap contributors, CC BY-SA).

when relevant information could not be collected from re-sighted individuals (Lettink & Armstrong, 2003).

Habitat selection index *Leucorrhinia dubia* presence was recorded while searching the site during the MRR study. This included captured individuals as well as those seen on survey routes but not captured. On each occasion the location of the individual was recorded with a hand-held GPS unit (Garmin GPSMAP 64). Additionally, a phase 1 habitat survey (Joint Nature Conservation Committee, 2010) was conducted across the study site to produce a habitat map using 100 x 100 m grid cells. The proportions of five habitat types were recorded in each square: moss (peat moss, rushes and sedges), scrub (low woody vegetation), scrub-moss (peat moss with low woody vegetation), water (open pools) and woodland (mature trees). From this the dominant habitat in each square was calculated. Of these, only water was not used in analyses as adult individuals tended to be sighted over terrestrial habitat.

Plate 1: A marked male *Leucorrhinia dubia* at Fenn's and Whixall Mosses in 2017.

Data analysis

Mark-Release-Recapture (MRR) Daily survival probability and the probability of recapture were estimated using a continuous-time open MRR model, as described in Fouchet *et al*., (2016). Classic MRR models require that time is divided into discrete units while in the Fouchet *et al*. (2016) model time can be measured on a continuous scale. This allows robust estimates in the case of lags between capture sessions of varying duration. The analysis was carried out using the *CMRT* package (Santin-Janin & Fouchet, 2015) in R version 3.5.0 (R Core Team, 2018).

Habitat selection index Selection indices calculate habitat use as a ratio between habitat where a species is recorded compared to the proportion of each habitat within the study area (Manly *et al*., 2007). Although relatively simple they can be effective in indicating habitat use (Manly *et al*., 2007). Selection indices can be sensitive to the scale used in calculating habitat use. However, Neu's index is relatively robust to changes in scale (Neu *et al.*, 1974) and hence was used in this study. Neu's index (Manley *et al., 2007)* calculates $Wi = Ui / \prod i$ where Ui is the proportion of squares of each dominant habitat type among all of the squares with *L. dubia* records and $\prod i$ is the proportion of each dominant habitat type among all of the squares in the study area. Values of the index >1

indicate use of a habitat type in a higher proportion than other habitats available in the study area. Selection index analysis was performed in R version 3.5.0 (R Core Team, 2018) using the *adehabitatHS* package (Calenge, 2006).

Results

Mark-Release-Recapture (MRR) model

A total of 13 sampling days were carried out at FWB Mosses from the 22nd May 2017 until the 7th July 2017. During these sampling days, a total of 50 adult *Leucorrhinia dubia* individuals were marked (41 males and 9 females), and a total of 6 recaptures were made. Probability of survival between sampling days was estimated at 0.06 (95% confidence intervals: 0.02-0.17). Probability of recapture on each sampling day was estimated at 0.05 (95% confidence intervals: 0.00-0.11).

Habitat selection index

During the field work a further 248 *Leucorrhinia dubia* individuals were observed from a distance but not captured (Fig. 2). *Leucorrhinia dubia* were shown to

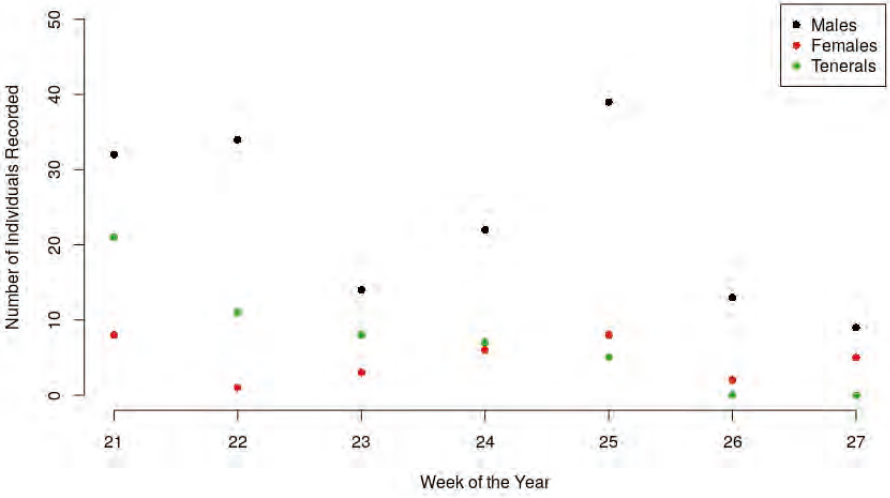

Figure 2: Number of *Leucorrhinia dubia* of different sex and age classes recorded in Fenn's and Whixall Mosses in May-July 2017.

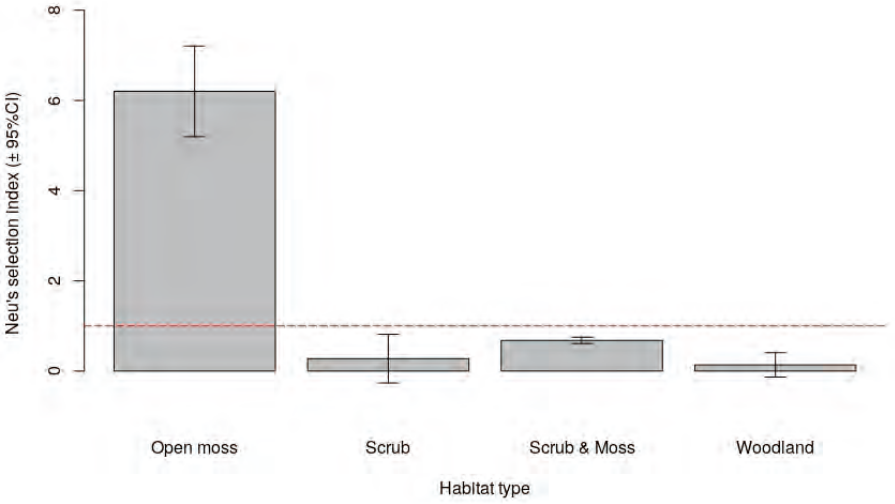

Figure 3: Neu's selection index for *Leucorrhinia dubia* records on Fenn's and Whixall Mosses. The red dashed line represents a selection index of 1 (i.e. no selection). If the 95% confidence limits (CI) are above the red line, the habitat is positively selected, whereas if the confidence limits are below the red line the habitat is negatively selected.

have a clear preference (Neu's index > 1) for 'moss' habitats, whereas 'scrub', 'scrub and moss' and 'woodland' appeared to be avoided (Neu's index < 1) (Fig. 3).

Discussion

The MRR model suggested that both adult survival and recapture rates were low. Although low capture rates might be expected in a large invertebrate population and have been noted before in Odonata (Cordero-Rivera & Stoks, 2008), this was lower than expected. Although male *Leucorrhinia dubia* hold territories they are less tied to these sites than species such as *Libellula quadrimaculata* (Four-spotted Chaser) and so are less predictable in their movements (Merritt *et al*., 1996). We suggest that future MRR approaches for this species, and other similarly cryptic species, need a greater number of capture days and more researchers in the field making captures. This increase in effort is likely to

increase the capture rate and increase the accuracy of estimates.

Many more *L. dubia* were seen than were captured and they showed a positive selection for the 'moss' habitat as opposed to the other habitats available across the site. The 'moss' habitat consists of peat with low heather vegetation and wet flushes and is the habitat most commonly found at pool edges. This is the habitat described in previous research on *L. dubia* (Dolný *et al*., 2018) and described in Boudot & Kalkman (2015) as including "peat moss, rushes and sedges". Locally on this site, *L. dubia* appear to avoid complex vegetation, including scrub and woodland. However, *L. dubia* sites, especially those in Scotland which represents the stronghold for this species in Britain, are often forested (Cham *et al*., 2014). Breeding pools within these sites are likely to be in open areas but the association with woodland, particularly ancient woodland (Cham *et al*., 2014), is suggestive of some associations between *L. dubia* and these habitats at larger scales.

The difference between habitats at Fenn's and Whixall Mosses and those in the Scottish Highlands is potentially due to the availability of suitable bog pools. At Fenn's and Whixall Mosses these are man-made and generally not close to woodland and scrub. In the Scottish Highlands these bog-pools are often within a woodland at low altitudes. The difference may also reflect the individuals that were seen in this study where adult males were sighted more often than females or tenerals, which might use complex habitat such as woodland more often as cover. Bias towards recaptures of adult males was also noted by Bick & Bick (1961) in their MRR study of *Lestes disjunctus australis* (Southern Spreadwing). Habitat use across the range of this species in Britain is an area that warrants further research, particularly at the local scale.

Leucorrhinia dubia is well camouflaged within its habitats and, as such, there is a good chance of missing individuals because of habitat complexity (i.e. low detectability) (Mazerolle *et al*., 2007). Unfortunately, our field methods did not allow us to estimate detectability in terms of sightings but the low capture probability suggests it is very low. In future we suggest that survey methods are designed so that detectability can be estimated explicitly, in order to get more accurate estimates of occupancy and thus of resource selection. At present we are unable to determine whether *L. dubia* are avoiding more complex vegetation or whether individuals are harder to see and therefore record in these habitats.

Data which allows the estimation of detectability can easily be collected with just a few minor changes to currently common survey methods. The majority of these changes are already being requested by the British Dragonfly Society to provide data for the upcoming State of the Nation's Dragonflies in 2020. We emphasise two of particular importance:

1. Complete lists. Records should be made of all the Odonata species detected on a single visit and thus allow non-detection to be inferred where species are not recorded (Isaac & Pocock, 2015). This requires recorders to note very common species as well as rarities. Unfortunately, there is a tendency in biological recordings to note only the rare or exciting species (e.g. first record of the year) and this can bias our inferences about population change amongst more common species (Isaac *et al*., 2014).

2. Repeated site visits. This helps to estimate the detectability of a species (MacKenzie *et al*., 2003) and consequently obtain unbiased estimates of occupancy, not affected by imperfect detection. We also suggest that, where possible, recorders include some measure of effort in their surveys (e.g. time spent surveying or distance walked). Ideally this would be standardized and included in official protocols such as those already commonly in use for bird surveys.

We present the results in this paper as an indication of what can be done in terms of conservation research in Odonata. Although we have been unable to make firm inferences regarding *L. dubia* survival and habitat preference, this study provides valuable information for the design of future studies. We suggest that research into the conservation ecology of *L. dubia*, along with other Odonata species threatened with declining ranges, declining populations or habitat loss, is essential to the long-term conservation of these species. Methods for such studies can be well informed by current practices used with other taxa. In particular, the analytical advances made in ornithology, research on Lepidoptera and work related to the use of data collected through citizen science provide a fantastic opportunity to advance our knowledge on the conservation ecology of Odonata.

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