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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.

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Cover illustration: : Male *Leucorrhinia dubia* at Scaleby Moss, Cumbria. Photograph by Nick Franklin.

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

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

Species list in accordance with Davies, D.A.L. & Tobin, P. (1984 & 1985) The Dragonflies of the World: A systematic list of the extant species of Odonata. Vols 1 & 2.

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The White-faced Darter (*Leucorrhinia dubia* Vander Linden) re-introduction project in Cumbria

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Summary

Leucorrhinia dubia (White-faced Darter) is a small dragonfly especially associated with bog-pools in peatlands. In England, there are only three areas (including one in Cumbria) where it has strong populations, most of its former sites having been lost due to habitat changes, mainly human-induced. A project in Cumbria aims to restore a population that once existed and was lost through afforestation in the mid 20th century. Approved by landowners and conservation bodies in 2008, an annual programme based on IUCN guidelines has been implemented from 2010 onwards to restore a colony at Cumbria Wildlife Trust's Foulshaw Moss Reserve near Morecambe Bay. The donor population, Scaleby Moss, is in north Cumbria. Translocation of larvae has been the main methodology, though experimentation with obtaining eggs began in 2013. Monitoring the populations at both sites, mainly by collecting exuviae at the breeding pools, has been the main measure for ensuring that the population at Scaleby Moss has not been adversely affected and for judging the efficacy of the translocations to Foulshaw Moss. Early years of the project were marred by poor summers but good numbers emerged at Foulshaw Moss in both 2013 and 2014, with clear evidence of on-site breeding. However, it is too soon to say whether a sustainable colony has been established. The genetic diversity of the new population has yet to be assessed and a current University-based research study on the genetics of the species in the UK may prove helpful in this regard. The long-term management of the donor site remains a concern and reinforces the need for the current project, which will continue for several more seasons. A parallel re-introduction project in Cheshire commenced translocations in 2013.

Introduction

Leucorrhinia dubia is considered to be 'Endangered' in the U.K. In Scotland it is found in at least 27 hectads but its populations are scattered. In England it is now extinct in the south of the country and there are only three areas with strong populations – in Staffordshire, Shropshire/Clwyd border and Cumbria (Cham *et al*., 2014). A decision was reached to increase the chances of the species'

survival in England by restoring a population in an area where it had previously existed in Cumbria, namely Foulshaw Moss (Fig. 1). The origins of this project derive from a casual conversation in about 2006 between John Dunbavin, Manager of Cumbria Wildlife Trust's Foulshaw Moss Reserve and myself. Informal discussions soon followed, with the 'team' consisting of John, Corrie Bruemmer of Natural England and myself. We worked through the guidelines on re-introductions published by the IUCN (IUCN, 1998) and much time was spent working on these, answering the questions posed and developing and costing an action plan. Since there was no precedent for such a project with this species, we had to rely on our own ideas. We consulted with people who knew the species well: these included Tim Beynon (President of the British Dragonfly Society (BDS) 2000-2004) and Betty Smith (then BDS Scotland Recorder). Useful published sources included Pajunen (1962), Sternberg & Buchwald (2000) and Beynon (2001). We also consulted the BDS Conservation Officer and the Dragonfly Conservation Group. The eventual proposal (Clarke, 2008) was finalised and circulated to the key individuals and official bodies, especially Natural England (regarding species issues and SSSI implications), Cumbria Wildlife Trust (CWT) (as landowner of Foulshaw Moss and as a conservation body) and the BDS as a source of Odonata expertise generally. There was general approval and no objections to our plans. The chosen donor site, Scaleby Moss, is also in Cumbria (Fig. 1). The main landowners at this site were involved from the outset and their co-operation has been a key factor in the project.

Changes in the Cumbria status of *Leucorrhinia dubia*

Just before the mid 20th century there were five extant sites for *Leucorrhinia dubia* in Cumbria - including the donor site, Scaleby Moss (Fig. 1). By about 1970 two of the three northern moss-land colonies (i.e. Cumwhitton, NY515520, and Oulton, NY250510) had lost their breeding pools, leaving only Scaleby Moss. By about 1990, the site at Claife Heights, Windermere (Green Tarn, SD369990), had also declined. However, a second small site, Brownstone Moss (SD381976), was found at Claife Heights in 1993; this still has *L. dubia*, though the numbers emerging there are so small as to suggest that it may be sustained by the existence of at least one more site nearby. Discussions between Forest Enterprise, CWT and myself have already resulted in habitat improvement plans for the species in that area. In the south of the county, Foulshaw Moss, the fifth of the above sites, and one of three adjacent mosses in the 'Witherslack complex', had been extensively afforested in the 1950s and 1960s, which is presumably when its colony was lost. My attempts to trace specimens collected pre-1950 from any of these mosses have so far been unsuccessful. Lucas (1900) simply refers to 'Witherslack'; museum specimens, if they exist at all, may only bear that location name. However, from available historic imagery, Foulshaw Moss seems always to have been the most probable.

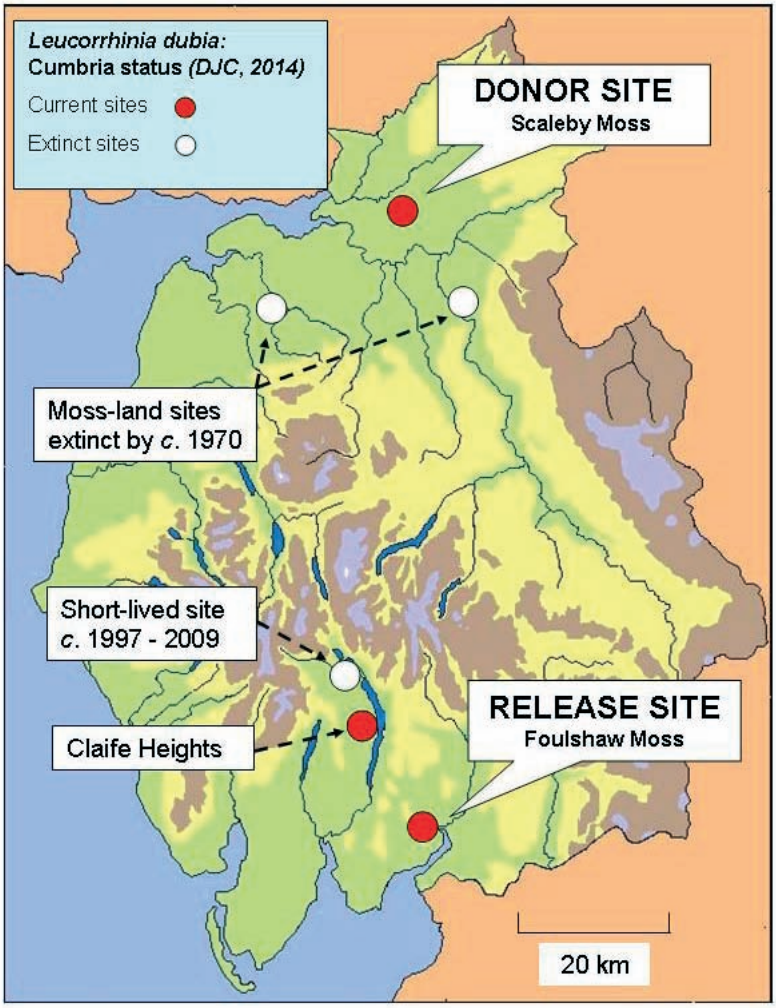

Figure 1. The Cumbria *Leucorrhinia dubia* (White-faced Darter) project sites, together with the past and present distribution of the species in Cumbria. The basemap contains Ordnance Survey data © Crown copyright and database rights.

There have been no confirmed records of *L. dubia* out-with the known sites in the county in the past fifty years or more - with one intriguing exception. In 1999, whilst surveying for Medicinal Leeches, Heather Marshall noticed a few *L. dubia* adults and seven exuviae (presumably resulting from oviposition in 1997) at the large woodland pool in Tongue Intake Plantation (NY327026). In the following year I collected 80 exuviae from this site. Hopes of a burgeoning

new colony were dashed by an unexplained rapid decline in the next few years; by 2010, there was no evidence of the species' presence there. It may be no coincidence that the summer of 1995 had been exceptionally fine and had led to range-expansion of other Odonata species. It is possible that a local 'dispersal' of *L.dubia* also occurred then, albeit over a distance of only about 8 km from the nearest known site. The future survival of the species in the county was therefore looking increasingly threatened (Clarke, 2003).

The Programme

As stated in the original proposal (Clarke, 2008), the aims and objectives of the project are as listed below:

a) Aims

- To improve the long-term prospects for survival of the White-faced Darter as a 'flagship' species in Cumbria's biodiversity.
- To support the maintenance of invertebrate biodiversity in England.
- To develop a process knowledge-base that would assist future projects of a similar nature. (The project could become the first planned re-introduction of a dragonfly species within the UK.)

b) Objectives

- To create suitable breeding habitat conditions at a protected site within the former range of the species in Cumbria.
- To effect a re-introduction sourced from another local population.
- To monitor and manage the re-introduction site, evolving an effective written Management Plan to sustain the re-introduction (photographic documentation would be included).
- To disseminate the knowledge gained through the process and to develop its educational potential through work of the British Dragonfly Society, Natural England and Cumbria Wildlife Trust.

The originally proposed timescale for the project was nine years, of which the first three were to be a monitoring phase, the second three a translocation phase, and the final three monitoring the outcome (Table 1).

All the main programme elements to date, i.e. monitoring, translocating, reporting and promoting, have been followed. Although not one of the original objectives, it was decided at an early date to consider a genetic analysis. However, this proved problematic. In 2012 I discussed this in some detail with Phill Watts of

the University of Liverpool and concluded that the level of work needed, and its costs and the timing implications, suggested that this aspect of the programme needed to be re-thought (see below).

Table 1. The *Leucorrhinia dubia* (White-faced Darter) re-introduction programme, as set out in Appendix 1 of the 2008 project programme (provisional) (Clarke, 2008).

Action	pre-intro phase			intro-phase			post-intro phase		
	2007	2008	2009	2010	2011	2012	2013	2014	2015
DC: final document, inc consultations/research		Jan							
DC: proposal update (if required)		March							
Press releases/articles (if success)									
Scaleby: exuvia counts (4 p.a.)	May/June	May/June	May/June	May/June	May/June	May/June	May/June	May/June	May/June
Translocations: Scaleby to Foulshaw				April	April	April			
Foulshaw Moss: monitor pool quality		May & Sept	May & Sept	May & Sept	May & Sept	May & Sept	May & Sept	May & Sept	May & Sept
Foulshaw Moss: exuiva counts (8 p.a.)				May/June	May/June	May/June	May/June	May/June	May/June
Scaleby: monitor pool quality	June	June	June	June	June	June	June	June	June
Genetic analysis; Scaleby 2008; Foulshaw 2012 & 2015		autumn				autumn			autumn
Annual team meeting	autumn	autumn	autumn	autumn	autumn	autumn	autumn	autumn	autumn
DC: Annual report-writing (with review report in 2013)		Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov

The donor site

Some 8 Km north-east of Carlisle, the donor site, Scaleby Moss (NY430635), is a small, lowland peat-moss, some 65 Ha in extent, with SSSI status. Originally a raised bog, it was extensively cut for peat until the mid 20th century and is now almost level. Old peat-cuttings formed a complex of pools towards the Moss centre, though these have progressively become occluded with *Sphagnum* and only one now has permanent open water. *Leucorrhinia dubia* was only discovered there in 1946. Most of the pools now occupied by the species were dug by English Nature in 1993 (Dalglish, 1996). They are rectangular, averaging some 40m^2 in area and about two metres deep, in solid peat, and hold water very well. Pools 25, 26, and 27 form one group ('Group A'), Pools 22, 23 and 24 forming a second group ('Group B'), the two groups being only about 100 metres apart. Pool 22 (Plate 1) is typical of these pools, all of which were utilised by *L. dubia* within about three years after their creation. Pool numbering relates to a survey of the old peat cuttings by English Nature in the 1980s; the 1993 pools were simply added on. Only one of the older cuttings (Pool 20) now has open water.

The site is ringed by woodland (pine and birch) and the open heathland is

Plate 1. Pool 22 at Scaleby Moss in August 2012. This is one of the six pools monitored for exuviae of *Leucorrhinia dubia* from 2007 to 2014. Note the developing pine and birch in the background.

subject to regeneration of both tree species from wind-blown seed (Plate 1). At present, Scaleby Moss has much other invertebrate interest but would clearly become woodland if unchecked. The site is in private ownership and has no public access routes.

The receiving site

In contrast to the donor site, Foulshaw Moss (SD455833) is vast - some 350 Ha in extent. It is on the northern fringes of Morecambe Bay and, being more coastal, is probably warmer than the donor site. It has deep peat and was extensively afforested in the mid twentieth century, which damaged much of its natural history interest. It has SSSI and SAC status and was acquired by Cumbria Wildlife Trust in 1998. Since then it has been subject to a major tree-removal and re-wetting programme, which has only just been completed. New public access routes have been developed. An area of high quality mire vegetation (NVC: M18 *Erica tetralix* - *Sphagnum papillosum* raised bog and blanket mire) at the northern end of the site was never afforested. The pools designated for

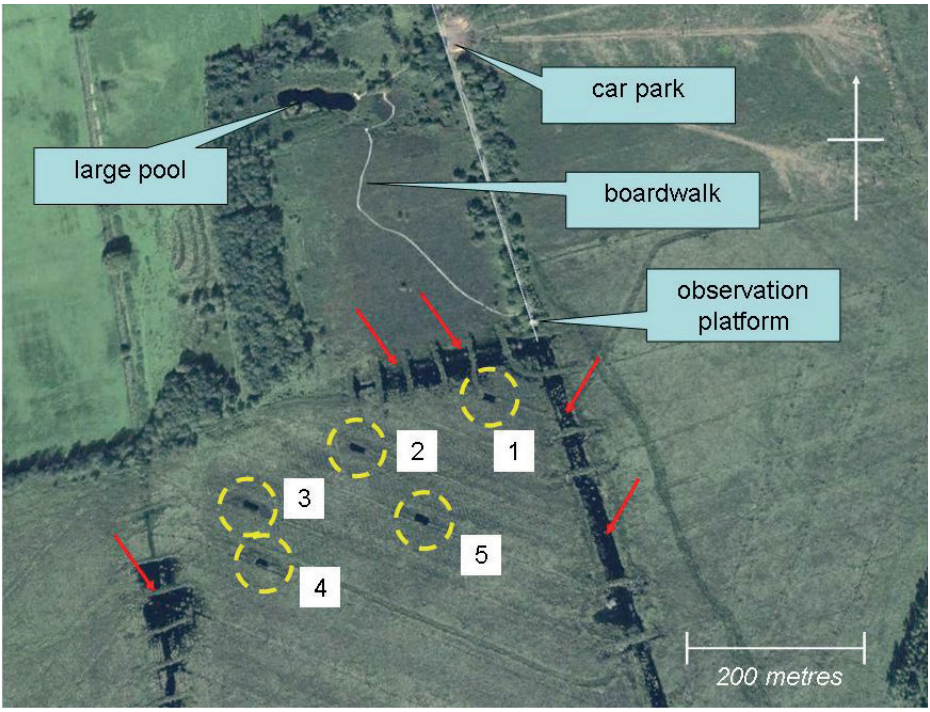

Plate 2. Foulshaw Moss, northern end, showing the locations of the re-introduction pools (circled yellow) and associated ditches and pools (arrowed red). British National Grid Reference at the observation platform: SD459835. Bunding work in winter 2013/2014 created many pools in addition to those shown on the map area. Map data © 2014 Google, Infoterra & Bluesky.

the re-introduction pools of *Leucorrhinia dubia* are located close to this. They are five in number, have dimensions similar to the Scaleby pools, and were created in 2005-6 as part of the ditch-blocking and water management work (Plate 2). In contrast to the donor site, *Sphagnum cuspidatum* growth seems quite prolific. The site holds other significant heath-land invertebrates such as *Coenonympha tullia* (Large Heath Butterfly) and *Metrioptera brachyptera* (Bog Bush-cricket). As at Scaleby Moss, a range of heath-land Odonata and other invertebrates and vertebrates already use these pools. *Sympetrum danae* (Black Darter) is the only abundant odonate of equivalent size to *L. dubia*, though with different seasonal timing and ecology from the latter species.

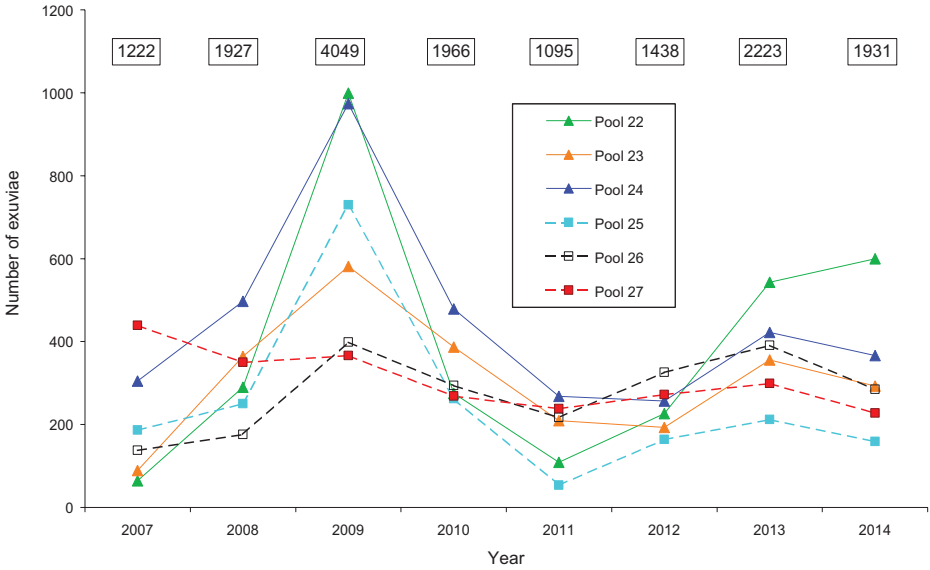

Figure 2. Trends in numbers of *Leucorrhinia dubia* emerging from each of the six pools at the donor site, Scaleby Moss, from 2007 to 2014, as determined by collecting exuviae. Solid lines = 'Group A' (Pools 22-24); dashed lines = 'Group B' (Pools 25-27). Year totals are given across the top. Note that, in 2007, only 62% of the normal survey was achieved, giving a significant under-count for that year.

Monitoring at the donor site

Exuviae

Monitoring exuviae was carried out by carefully working round the margins of six pools (Pools 22-27), finding and removing exuviae and counting them, thus providing the best possible evidence of the numbers of *Leucorrhinia dubia* emerging. This procedure has so far been carried out by the monitoring teams each year from 2007 to 2014. Since data were kept separately for each of the six pools, the trends in their individual productivity can be seen (Fig. 2). Counting and identification checking was carried out by me.

Collecting exuviae involved different groups of people on almost every occasion but always with John Dunbavin (JD) and/or myself present. There has always been a minimum of four visits each year at approximately fortnightly intervals, commencing in early May, usually with a final 'mop-up' in early July when emergence has ceased. CWT volunteers were brought from Kendal by JD on each occasion and the team of 3 or 4 would spend approximately 2.5 hrs each time, working around the pool margins. Since many of the volunteers had no

Plate 3. Exuviae of *Leuchorrhinia dubia* at Scaleby Moss: a typical emergence situation, on stems of *Eriophorum angustifolium* at a pool edge.

previous experience, searching efficiency will have been variable.

The figures demonstrate the minimum number emerging at each of these pools (Fig. 2). Clearly, an unknown proportion of exuviae will have been overlooked and/or removed by weather in between successive monitoring visits. However, this technique does provide a relatively standardised indication of the population strength at the site, as well as any changes that may be occurring. Breeding also occurs at the only other pool (Pool 20) but no account has been taken of that.

The mean annual exuvia count for the 8-year period (2007 – 2014) is 1,981. This indicates that the numbers emerging annually at Scaleby Moss (including the large, un-monitored Pool 20) are unlikely to have been less than about 2,000 and have ranged to at least twice this number. The figures confirm that, thus far at least, our minor 'depredations' resulting from the removal of eggs and larvae, have had no evident negative effect on the donor population as a whole. Stock removal has so far always been mainly from Pool 24 and, to a lesser extent, from Pool 23, which are at the heart of the site. Emergence counts and

Plate 4. A recently emerged male *Leucorrhinia dubia* on *Eriophorum angustifolium* at Scaleby Moss.

the extent of *Sphagnum* development here has indicated that these pools are especially productive, and we accordingly judged that least harm would be done to the population as a whole by focussing on them.

Exuviae were often found on emergent *Eriophorum* stems (Plate 3), not infrequently in tiers, especially in the corners of the pools. In good weather they could also be found high on surrounding heather. Occurrences on the surrounding 'lawns' of *Sphagnum*, up to 0.5 m away from the pools, may have been a result of temporary high water levels due to heavy rainfall.

Apart from the high peak in 2009, numbers seem to have remained relatively stable. The 2009 outcome is somewhat enigmatic. The weather during the emergence period was much better than in most of the other years. There could have been more emergence than usual but it is doubtful if weather alone would have affected this. Exuviae may just have been easier to find, especially if many were higher on surrounding heather, and perhaps far fewer were removed by poor weather. The fact that two years later, in 2011, this season of abundance was not followed by another peak is surprising, given the evident two-year life

cycle. Indeed, 2011 produced the lowest figures of the whole period. Interpreting the figures remains problematic.

During some of the exuvia monitoring visits we encountered active emergence and took due care not to disturb this vulnerable stage. The presence of emergers (Plate 4) was recorded but it was considered that counting either these, or adults, during our short visits would have given little or no additional information regarding the population strength.

Habitat

The regular visits to collect exuviae provided ample opportunities for visual inspection and photography of the pools. There is now a visual record extending annually over the past 6 years (2009 – 2014) and more intermittently since about 1985. The most significant changes observed have been to the 'Group A' pools. There has been an unexplained decline of floating *Sphagnum* at each of these pools and there has also been some evident decline of emergent *Eriophorum* on one side of Pool 25. Godwin *et al*. (1957) proved a peat depth of about five metres at the centre of the Moss. Presumably it is shallower below the pools, possibly allowing some of the deposits underlying the peat to affect the water chemistry. Pools 22-24 ('Group B') have shown less decline of *Sphagnum*, though they are more affected by the growth of marginal heather and regeneration of birch and pine. Whilst there are no signs of eutrophication at any of the pools, or their margins or surrounding areas, indications that they are increasingly visited by wildfowl in small numbers give some cause for concern. This apparently relates to the development of duck-shooting pools close to the Moss. Thus there is a potential source of nutrient input and possibly increased predation of larvae and emergers. Scattered *Sphagnum* has been noted around some of the pools in recent years and the possibility that some 'undeclared' removal is occurring in the interests of wildfowl encouragement cannot be dismissed. Pool 24 usually has the best developed *Sphagnum* cover each year (up to about 75%), though the cover has been noticeably slow to reach this level following cold or wet springs. In 2014, cover by mid July was less than 20%, in contrast to the adjacent pools, at which it was 80% or more.

Ongoing, larger scale changes to the habitat are the re-growth of both pine and birch, the scrub and many larger trees having been removed under the auspices of English Nature between 1998 and 2005. This re-growth is now of increasing concern because there are no active plans to manage these subsequent changes which, if allowed to go unchecked, could eventually make the site unsuitable for many scarce invertebrates, including *Leucorrhinia dubia*.

Monitoring at the Receiving Site

Pools and habitat

Monitoring the condition of the pools has been carried out annually by John Dunbavin and myself by visual inspection and photography. At the group of five pools selected for use, *Sphagnum* growth has been good and rapid. Indeed, the pools look in as good or better condition for the species than those at Scaleby Moss. Unlike Scaleby Moss, there is no major issue with tree re-growth; current management work at Foulshaw Moss will ensure that the site becomes even wetter in the near future than it is now.

There are many water bodies (both pools and ditches) near to the re-introduction pools (Plate 2). Many have at least some *Sphagnum* development and there are no obvious reasons why *Leucorrhinia dubia* should not colonise them as well as, or instead of, the pools we have chosen to place larvae in. The potentially available number of water-bodies was increased considerably by bunding work in the winter of 2013/14 and the maturation of these over the next few years will be of great interest. Fortunately, a good number of them are publicly accessible.

Two aerial predators occur at Foulshaw Moss that are rarely present at Scaleby Moss - *Anax imperator* (Emperor Dragonfly) and *Falco subbuteo* (Hobby). In June, before the huge emergence of *Sympetrum danae* (Black Darter) late in the month, both could target *L. dubia*. It may possibly be an easier prey item (for *A. imperator* in particular) than *Libellula quadrimaculata* (Four-spotted Chaser), the only other anisopteran on the wing in that period at Foulshaw Moss. Already there is anecdotal evidence from Foulshaw Moss that *A. imperator* will take *L. dubia*. Until numbers of the latter have built sufficiently, this could impact on its breeding success. *F. subbuteo* is probably less of a threat at present, though is likely to become more so if its numbers increase.

Stock

Selection

In the original proposal (Table 1), translocations were to have been based solely on mature larvae, collected and moved just before they were due to emerge, i.e. in Spring. We made an early decision (in 2010) to supplement this each year with a mix of hatchling larvae/eggs, on the grounds that this would enable larger numbers to be moved without threatening the emergence at the donor site, and that it would test the suitability of the Foulshaw Moss pools more effectively by

Plate 5. Obtaining eggs from the female of a pair of *Leucorrhinia dubia* caught 'in cop.'

exposing the full range of stages to that environment.

Eggs/hatchlings stock was collected simply by removing floating *Sphagnum* in summer. As June through to early July is normally the main oviposition period, and with the eggs being expected to hatch within about 3-4 weeks of laying (depending on temperature), the most suitable 'window' within which to collect larva-rich *Sphagnum* was judged to extend from July until mid August.

We had initially hoped to be able to quantify all of the stock translocated but with eggs and hatchlings this was clearly impossible and was an unavoidable weakness of the methodology. Close visual inspection of netted *Sphagnum* readily reveals the presence of (well-camouflaged) hatchlings, though many would not be found without time-consuming and very intensive scrutiny. For the same reason, even larger, 1st year, larvae were likely to have been collected unseen and un-quantified. The 40 litres of dense *Sphagnum*/water mix removed on each occasion represented the quantity we judged to contain adequate numbers of hatchlings and/or eggs, and was also the greatest amount that two of us could readily carry at one time from the donor pools across the mossland

to the waiting vehicle.

Developments in BDS thinking on best practice for bio-security in translocations led them to recommend (for 2013) that obtaining eggs was a better alternative to moving egg-rich *Sphagnum*. The process involved catching mating pairs, separating the female and inducing her to oviposit by dipping her abdomen into water (Plate 5). This proved labour-intensive, rather uncertain of outcome, and weather-dependent. Not all females produced eggs, and when they did it was impossible to know immediately whether they were fertile. Eggs kept to observe their development were often subject to fungal infections, especially when infertile. In the end, three batches, amounting to at most a couple of hundred eggs, were transferred to Foulshaw Moss in 2013 – though without knowing whether they would develop. This third element of 'stock' remains the most difficult and time-consuming to deal with in practice.

Translocation

Translocations have taken place from 2010 to 2013 (Table 2). Only Pools 1, 3 and 4 have been used for reintroductions. No introductions of any type have been made into Pools 2 and 5, leaving these as convenient 'controls' to help demonstrate any on-site breeding. Move dates for mature larvae have varied a little from year to year – dependent upon the seasonal timing. Cool Springs have made the originally planned late April period rather unproductive, early-mid May being more typical.. Exceptionally, in 2011 emergence at Scaleby Moss had already started by late April. Releases were always made within about two hours of capture.

2010. Pool 4 at Foulshaw Moss (Plate 6) was selected to receive the first translocation and was chosen on the basis of having the best *Sphagnum* development at the time. This translocation was just of eggs/hatchlings and was carried out towards the end of June (Table 2)

2011. Introductions of mature larvae commenced in 2011 and it was decided to place these into a different pool (Pool 3) in order that their emergence could be distinguished from any possible emergence from Pool 4 (though none was expected in 2011). One hundred final instar larvae were introduced in early May, followed by a *Sphagnum* stock of eggs/hatchlings, also into Pool 3, towards the end of July (Table 2).

2012. As in 2011, both mature larvae and a mixture of eggs and hatchlings were translocated. Fifty final instar larvae were added to Pool 3, while the eggs/hatchlings mixture was introduced into Pool 1 (Table 2).

Plate 6. Pool 4 at Foulshaw Moss in June 2013. One of the group of five similar-sized pools used to introduce translocated stock of *Leucorrhinia dubia*. Note the extent of Sphagnum rafting.

2013. As noted in the previous section, it was decided to translocate eggs only in 2013, again using Pool 3 as the receiving site.

2014. Attempts to find sufficient mature larvae to move in 2014 (on 2nd June) were surprisingly unsuccessful despite ongoing emergence, which continued until well after that date. As a result, no mature larvae were moved in this year. In order to give a further boost to the population emerging at Foulshaw Moss in even-numbered years, an eggs/hatchlings mix was translocated on 14 August and divided between Pools 3 and 4.

Results at Foulshaw Moss 2011-2014

Emergence

As at the donor site, emergence was monitored by collecting exuviae. Exuviae were monitored at the five pools (Plates 2, 3). Additionally, monitoring of the numbers and activities of adult insects was carried out at these, as well as

Table 2. The re-introductions of *Leucorrhinia dubia* to the pools at Foulshaw Moss (Plates 2, 6).

	2010	2011	2012	2013	2014
Pool 1	-	-	**8Aug:** Eggs/hatchlings	-	-
Pool 2	-	-	-	-	-
Pool 3	-	**4 May:** 100 Final instars **20 July:** Eggs/hatchlings	**24 May:** 50 Final instars	**25 June:** Eggs only	**14 Aug:** Eggs/Hatchlings
Pool 4	**22 June**: Eggs/hatchlings	-	-	-	-
Pool 5	-	-	-	-	**14 Aug:** Eggs/Hatchlings

at adjacent pools/ditches where possible. Counting the exuviae that could be clearly shown to have resulted from a known translocation event was the only effective measure of performance but we were well aware that this could only continue to apply until 'contamination' of pools by on-site oviposition at the receiving site began to become a factor.

In 2011 and 2012, CWT volunteers (especially Ian Brodie), John Dunbavin (Foulshaw Moss Manager) and I searched for exuviae and adults. For 2013 and 2014 we decided that employing professionals was essential to ensure more intensive coverage. We were fortunate that Tony and Heather Marshall ('Marshall Ecology') were able to do this and indeed they exceeded their initial brief. Exuviae were searched for by working carefully on hands and knees around the pool margins, removing all those found and noting which pools they were recovered from. A special monitoring sheet was devised for this purpose. As at Scaleby Moss, the number of exuviae recorded indicates the minimum number of emergers, it being most unlikely that all exuviae would have been found.

2011 The main emergence was, as expected, at Pool 3, into which 100 final instar larvae had been introduced in April of the same year. 43 exuviae were found, though it is possible that many more of the 100 actually emerged.

Interestingly, 12 exuviae were also found at Pool 4, which must have been from first-year larvae introduced by chance in 2010 at the same time as the eggs/hatchlings stock. This was useful proof that this pool could support the species for at least a year.

2012 The main emergence was at Pool 4, again as expected, since the hatchlings introduced in 2010 should have completed their growth in two years. A total of 135 exuviae was found. This gives indirect evidence that the 40 litres of Sphagnum used for translocation into this pool in 2010 contained a minimum of 135 eggs/hatchlings. Indeed, it probably contained at least several hundred, as considerable mortality would have taken place during hatching and the early stages of larval development. An emergence of at least 34 at Pool 3 was the outcome of the introduction of 50 final instars there in April. Allowing for exuviae missed, the total emergence in 2012 is likely to have been in excess of 150. This was a clear indication that larvae can successfully complete their growth and development at Foulshaw Moss and that a 2-year cycle is indicated.

2013 Not only did this season prove to be much improved weather-wise on previous years throughout the flight period, it also yielded some encouraging results. There was significant emergence at unexpected pools (i.e. pools that could not, on the reasonable assumption of a 2-year life cycle, have been expected to produce emergers from translocated eggs/larvae) (Fig. 3). In total, about 62% of the 2013 emergence was therefore concluded to have been the result of on-site breeding. 483 exuviae were collected, so emergence is likely to have exceeded 500 individuals. This result perhaps tends to suggest that the 'double-dose' approach in 2011 – i.e. introducing mature larvae in Spring followed later in the same year by eggs/hatchlings may have been beneficial.

2014 With the summer of 2012 having been exceptionally wet, with presumed poor survival and breeding success, numbers emerging were expected to be low. However, 256 exuviae were found, of which at least 77% are considered to be the outcome of on-site breeding (Fig. 4). Presumably, on-site breeding may also have increased the potential for emergence at unmonitored (and often un-monitorable) pools and ditches – adding to the challenges of assessing progress.

Adults

2011 The first free-flying adult *Leucorrhinia dubia* was found and photographed on 11th May. Several individuals of both sexes were found between Pool 3 and the tree/bracken shelter at the edge of the Moss. There were no observations of mating or egg-laying.

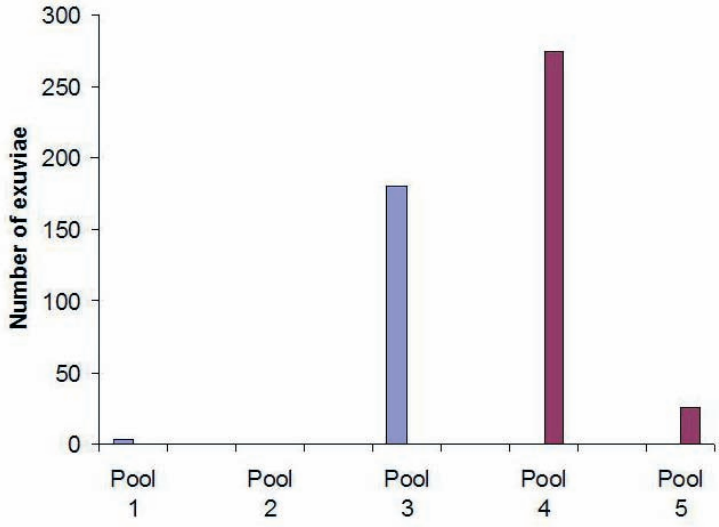

Figure 3. Numbers of exuviae collected from Pools 1-5 at Foulshaw Moss in 2013. Columns in blue include emergence expected from introductions in 2011; columns in red indicate probable on-site breeding.

2012 Adults were seen on at least five dates from 31st May to 9th July, although never more that two at once. A male or males were seen at Pool 3 on 19th June and a female was photographed on the boardwalk on 9th July. Again, neither mating nor oviposition were observed.

The paucity of observations of maturing individuals and adults in both 2011 and 2012 was a disappointment. However, given the size of Foulshaw Moss, adults may have dispersed widely. More critically, the weather throughout the normal flight period (i.e. late May- late July) in both of these years was extremely poor – very windy in 2011 and exceptionally wet in 2012. This must have had considerable impact on the survival of emergers. Frustratingly, whether it had affected numbers sufficiently to prevent breeding altogether could not be determined.

2013 The use of the contract ecologists mentioned above ensured that the chances of observations of adults were also much increased. This coincided with more favourable weather than in the two previous years and with significantly increased emergence. The contractors observed adults (mainly mature males) at pools on at least 30 occasions between 21 May and 9 July, with no emergence noted after 7 June. They also observed copulation and oviposition,

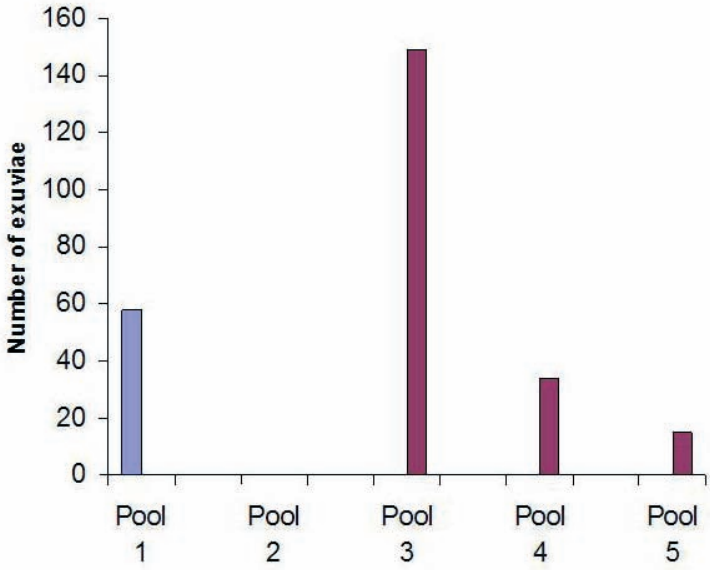

Figure 4. Numbers of exuviae collected from Pools 1-5 at Foulshaw Moss in 2014. Columns in blue include emergence expected from introductions in 2012; columns in red indicate probable on-site breeding.

though both of these only once. Another observer also noted and photographed both processes at a pool adjacent to the re-introduction pools and there was at least one other record of copulaton, along with photographic evidence (Plate 7). Adults were also seen by quite a number of casual visitors, some of whom were clearly the vanguard of a developing 'Odonata tourism' interest in the site. Other sightings of adult *L. dubia* included the large pool located about 500 m north of the re-introduction pools (Plate 2).

2014 The weather at the start of the emergence season was mainly unsettled, often cool and wet, though there were also some good sunny days. It was much improved in June until quite late in that month. Sightings of adults started from 15th May and continued until early July. Our contractors again monitored adults after completing exuvia collecting. Posters placed on site encouraged several visitors to send us records. These were mainly in the form of photographs, some very useful, further expanding the growing resource of observers. As in 2013, they included evidence of mating (Plate 8). The last record of an adult was on 7th July, and a group of us visiting the site on 12th failed to find any – suggesting an early end to this year's predominantly fine season. Interestingly, a small and very obvious white-faced dragonfly was seen (head-on) through binoculars on

Plate 7. Female *Leucorrhinia dubia* ovipositing at a pool adjacent to the re-introduction pools at Foulshaw Moss in 2013. Photograph by Susan Brookes.

Plate 8. Mating *Leucorrhinia dubia* at Foulshaw Moss. Photograph by Norman Fieldhouse

14 June, basking on the boardwalk at Roudsea Moss NNR, (SD335826) - about 12 km west of Foulshaw Moss (P. Hornby, pers. comm.). It promptly flew off and the observer, an experienced and cautious naturalist, felt some reluctance about confirming its identification. However, an alternative to *L. dubia*, at that date especially is difficult to suggest. This is thus an alert to the possibility that the species might tend to disperse from the re-introduction site, locally at least.

Publicity

The Project has received significant coverage, both locally and nationally – all of it positive. A Press Release by CWT to mark the first emergence at Foulshaw Moss in 2011 resulted in inclusion in *The Guardian* (13 June 2011) and on the BBC News website (10 & 12 July 2011). Interest from the BBC also extended to the commissioning of a 4-minute slot for their *One Show*, which was made by *Tigress Productions*, and duly broadcast on BBC1 in the 7pm programme on 20th June 2011. This included some very good footage of the sites and of the emergence process. Reaching a large, non-specialist audience, it gave the project some excellent coverage.

The British Dragonfly Society was, of course, among the more important consultees at the outset of the project and progress has subsequently been fed back to the membership through the Society's Newsletter (Clarke & Dunbavin, 2012, 2013). I have made presentations to the annual BDS Members' Days, at Edinburgh 2010 and Oxford 2013; the latter occasion also included a presentation by Vicky Nall on the Delamere project (see below). The Cumbria project has also featured in several other presentations made by me to natural history group meetings and events within the county, and is also referred to in the new Dragonfly Atlas (Cham *et al*., 2014).

Project funding and management

We have been fortunate that habitat creation for *Leucorrhinia dubia* at Foulshaw Moss has been a natural spin-off from CWT's major peat-land restoration work there. It has also helped enormously that the needs of the project have, very willingly, become part of the Reserve Manager's 'day job'. Natural England High Level Stewardship (HLS) Special Projects funding has helped the Trust to cover some of the administrative costs of the re-introduction project, especially travel, writing reports and employment of survey contractors. The huge input of volunteer time in monitoring the donor site (itself having a significant travel element) has also been a key to keeping costs low: at least 80 hours have been contributed to this annually over the past eight years. A substantial part of my

contribution has also been voluntary. A valuable and unplanned benefit of using so many volunteers over the years is that a large number of people have been trained to monitor exuviae and have become knowledgeable and enthusiastic about dragonflies.

Conclusions

Project duration

Even without the weather disruptions, a three-year translocation phase for the project may have been, with the benefit of hindsight, overly optimistic. Even five years for a species with a two-year life cycle would have been relatively short, and indeed has proved to be so. It has been proposed in my report to CWT (Clarke, 2012) that the situation will be reviewed again at the end of 2014. Happily, things now seem to be moving in the right direction and we have had the benefit of the two successive good-weather seasons in 2013 and 2014. However, much still depends on obtaining the hard evidence that will enable us to judge whether, and when, the new population has become genuinely self-sustaining. The 2014 review will be a key decision-making document for the project and will be circulated to the usual consultees.

Genetic screening

It was part of the original programme (Table 1) to carry out an assessment of whether the new population was sufficiently genetically diverse. The size of stock translocations should of itself have guaranteed adequate variability. However, it is the number of adults breeding at Foulshaw Moss, in the initial years especially, that will determine whether any genetic 'bottle-neck' exists. There is little point in screening until there is clear evidence of sustainability at Foulshaw Moss and it will be at least another year before this can be considered. In the meantime, a study at Manchester Metropolitan University that will look at different *Leucorrhinia dubia* populations in the UK has just started. This is based on a project design developed by Watts (2012) and should establish some useful baseline data. When completed, this could make testing the Foulshaw Moss population much simpler and less costly. Exuviae from Scaleby and Foulshaw Mosses and Delamere Forest (see below) are being included in this study.

Gathering habitat and environmental data

It was always intended to capitalise on opportunities to study the habitat conditions at the project sites when these arose. We know nothing about water

chemistry, *Sphagnum* growth cycles and other factors, and yet changes to these and other parameters may be ongoing and critical to the future. One such opportunity has arisen in 2014, when a University of Cumbria final year student will be assessing a range of factors at the two sites, as well as at other sites that might be suitable for future projects in the county.

Other projects

Interest in the Cumbria project has already encouraged the development of a second English project for the re-introduction of *L. dubia*. Delamere Forest Cheshire had been lost as a breeding area for the species (V. Nall, pers. comm.). Translocations to the Doolittle basin began in 2013, using stock from Fenns/Whixall and Chartley Mosses (Nall, 2013). The scheme is being managed through Cheshire Wildlife Trust and a local Steering Group.

The longer term

Whether or not the project succeeds, the viability of the donor site remains a key issue. The apparent reductions in abundance of pool *Sphagnum* are beginning to look significant; tree regeneration is a further issue. Meanwhile, liaison with Natural England, the BDS and the landowners will continue, and hopefully lead to proactive management of the site for the benefit of *Leucorrhinia dubia* and other heathland invertebrates such as *Coenonympha tullia*, *Callophrys rubi* (Green Hairstreak Butterfly), *Dicallomera fascelina* (Dark Tussock Moth) and several scarce arachnids. If the habitat's suitability for *L. dubia* declines dramatically, a possible 'rescue' project in which larger stock translocations (to sites to be determined) are used must be a consideration. Without strong populations, either here or at Foulshaw Moss, no further projects in the county will be possible. In Cumbria, I have had discussions with Natural England and Cumbria Wildlife Trust about possible future introduction/re-introduction projects – all for the longer term and much dependent on the outcome of the current project. If other projects do become a possibility, we will bear in mind Tim Beynon's useful advice (Beynon, pers. comm.) that White-faced Darters can successfully breed in pools much smaller than those at either of this project's sites. Where pool creation becomes an option, a 'more but smaller' approach may help to resolve issues of 'rotational management' of breeding pools and other aspects, such as monitoring.

Acknowledgements

It is a pleasure to thank those now too-numerous-to-list Cumbria Wildlife Trust volunteers who have spent hours on their hand and knees in all weather

conditions gathering exuviae. Ian Brodie gave much help at Foulshaw Moss in 2010-2012, work that was carried forward most effectively thereafter by Tony and Heather Marshall ('Marshall Ecology'). John Dunbavin has efficiently organised this help over the years, as well as offering enthusiastic support for the project as a whole. Tim Beynon has been a valued 'critical friend' and given the benefit of his work with this species. Dave Thompson through his student Heidi Feuchtmayr at the University of Liverpool facilitated translation from German. The British Dragonfly Society's Conservation Officer (successively, Caroline Daguet, Katherine Parkes and Claire Install) and the Dragonfly Conservation Group, and staff of the Cumbria offices of Natural England, have always been supportive. Mo Richards and Colin Adams monitored the minor sites in Cumbria. The Hughes family have been most helpful with access to the donor site. Vicky Nall kept me up to speed with the Cheshire project. Phill Watts (University of Liverpool) and Charles Baillie (Manchester Metropolitan University) advised on genetic issues; Nick Franklin (cover image), Susan Brookes and Norman Fieldhouse provided some important photographs. I thank them all.

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A Review of the Odonata of the Maltese Islands

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Summary

This paper is the result of five years of detailed observations of Odonata at several sites in the Maltese Islands. It updates the status and relative abundance of the various species. There is currently only one zygopteran *Ischnura genei* (Island Bluetail) established on the Islands. *Calopteryx virgo* (Beautiful Demoiselle) is considered a vagrant, while the occurrence of *Calopteryx haemorroidalis* (Copper Demoiselle), is considered to be highly doubtful. There are nine species of anisopterans which are established in the Islands, these being *Anax imperator* (Emperor Dragonfly), *Anax parthenope* (Lesser Emperor), *Orthetrum cancellatum* (Black-tailed Skimmer), *Orthetrum coerulescens* (Keeled Skimmer), *Orthetrum trinacria* (Long Skimmer), *Sympetrum fonscolombii* (Red-veined Darter), *Crocothemis erythraea* (Broad Scarlet), *Trithemis annulata* (Violet Dropwing) and *Selysiothemis nigra* (Black Pennant). Three more: *Orthetrum nitidinerve* (Yellow-veined Skimmer), *Orthetrum chrysostigma* (Epaulet Skimmer) and *Pantala flavescens* (Wandering Glider), have recently been added to the Islands' list, while two – *Orthetrum brunneum* (Southern Skimmer) and *Sympetrum striolatum* (Common Darter) – which were formerly considered common, are now very rare. *Anax ephipigger* (Vagrant Emperor) is a fairly regular migrant, appearing in considerable numbers in some years. *Aeshna mixta* (Migrant Hawker) is rare but might be on the verge of establishing itself on the Islands, following a recent spate of records, including ovipositing females. Various inaccuracies and conflicting statements appearing in previous contributions are corrected. Observations on behaviour are included where these are of special interest as well as where they are in contradiction of what has been stated in the literature.

Introduction

The Maltese Islands are a small archipelago situated near the centre of the Mediterranean, about 90 km south of Sicily and 335 km north of the Libyan coast, at approximately 36^{o} N; 14^{o} E. The archipelago consists of three principal islands: Malta (249 km^{2}), Gozo (70 km^{2}) and Comino (2.6 km^{2}) (Fig. 1). There are also a number of islets which, however, hold no fresh-water. As

in other Mediterranean countries, the climate consists of hot, dry summers and mild, rather moist, winters. June to September is the hottest period, with an average temperature of 30°C and with extremes of up to 40°C Average rainfall is about 500 mm annually but it is very unevenly distributed. Rain falls mainly in autumn and winter, with heavy cloudbursts causing flash-floods which are not uncommon in September and October. Most rainwater is lost to the sea but, in most valleys, a series of dams has been built over the years, creating shallow reservoirs. The water retained in these reservoirs is used for irrigation purposes and, in years with poor rainfall, some of them are dry by the end of May, or even earlier. However, water is present in some all year round and these constitute the most important habitats that support dragonfly populations. Unfortunately, several of the watercourses have their banks overgrown with the invasive alien *Arundo donax* (Giant Reed), with the result that they are in the shade for a substantial part of the day. Many parts of these watercourses are polluted by agricultural waste, including fertilizer, pesticide and herbicide containers and plastic bags, as well as indiscriminately dumped rubbish, which might include bags of household waste and dead animals. Some water surfaces in the reservoirs along these watercourses become choked with *Lemna minor* (Common Duckweed). These are generally avoided by odonates, with the only exceptions appearing to be *Crocothemis erythraea* (Broad Scarlet) and *Ischnura genei* (Island Bluetail). Other important artificial habitats are several small reservoirs (often cisterns) scattered around agricultural land. The water is generally pumped up from underground sources and used for irrigation. These reservoirs are generally small and lack any emergent vegetation and several of them are stocked with predatory alien fish, principally *Gambusia* sp. (Mosquito fish). However, odonates still manage to complete their life cycle in them, as evidenced by the exuviae of various species regularly present on the retaining walls, e.g. as at Ghajn Tuffieha and at Bahrija. Ponds and fountains in public gardens, such as at San Anton in Balzan and The Garden of Serenity at Sta. Lucia, also provide an additional important habitat and are the main stronghold of *Trithemis annulata* (Violet Dropwing). Again, this is despite the presence of *Carassius auratus* (goldfish), *Gambusia* sp., and *Trachemys scripta elegans* (Red-eared Terrapin).

The Odonata of the Maltese Islands has been rather poorly studied until recently. Literature prior to 2008 is very scant, the most important earlier contributions being those of Valletta (1949, 1957). The most extensive works are those of Sciberras (2008) and Debagriele (2013).

Methods

This study covers the five-year period 2009–2013. In 2009, daily observations

were carried out at the Ghadira Nature Reserve where I worked as managing warden. Sporadic visits were also made to San Anton Gardens and to Fiddien. In 2010, Fiddien was only visited once as the water had dried up in late June. The series of reservoirs in the valley at Imselliet were visited on a regular basis during the same year. Several other sites were added to the observation list in 2011 and others were added in 2012. Most sites were visited at least once a week between the middle of February and the middle of December, usually for about an hour but sometimes for a bit longer. Certain sites, particularly the valleys of Imselliet and the upper regions of Ghajn Rihana, were usually only visited between June and August due to the danger posed by the hunter poachers present at these sites during the open hunting season. Cumulative numbers of visits to the different sites through the season were recorded (Table 1). There were 14 main observation sites and seven others that were visited less frequently (Fig. 1). In valley systems with a series of dammed reservoirs, such as at Imselliet and Ghajn Rihana, 20-30 minutes were spent at each reservoir, recording the presence of adult odonates. Counts were also made in the stretches between reservoirs, where most immatures and females were found. At other sites, e.g. Ta' Qali reservoir, one hour was spent counting adults as well as observing behaviour. Binoculars used were Pentax Papilio 8.5x21, while photos were taken using Fuji FinePix S200EXR and HS30EXR cameras. Field visits during this five-year period amounted to 1,102 involving >1,500 hours of observation. The order in which the species are listed follows Dijkstra & Lewington (2006).

Main Observation Sites

Ghadira Nature Reserve (35°58'N 14°21'E). A reclaimed saline marshland of *c*. 6 hectares engineered in the early 1980s, situated in the northern part of Malta. Two small, freshwater artificial ponds which I built in the early 1990s attract the most dragonflies. Various species of dragonfly have also been observed ovipositing in the heavily brackish and saline waters but no exuviae have been found, other than at the freshwater ponds.

Fiddien (35°54'N 14°21'E). A section of a watercourse originating at Dingli and going on to Chadwick Lakes (see below). The watercourse holds running water depending on the amount of rainfall. Along the path adjacent to the watercourse, water used to seep in a small patch and was a main attraction for *Orthetrum coerulescens* (Keeled Skimmer). Originally the source of this water was not known but, after a flash-flood in early September 2012 swept away many sections of the path, it was discovered that an 18" water pipe with a small leak was running underneath the path. Further down the path is a small reservoir used for irrigation. Occasionally in summer it fills with water, thought

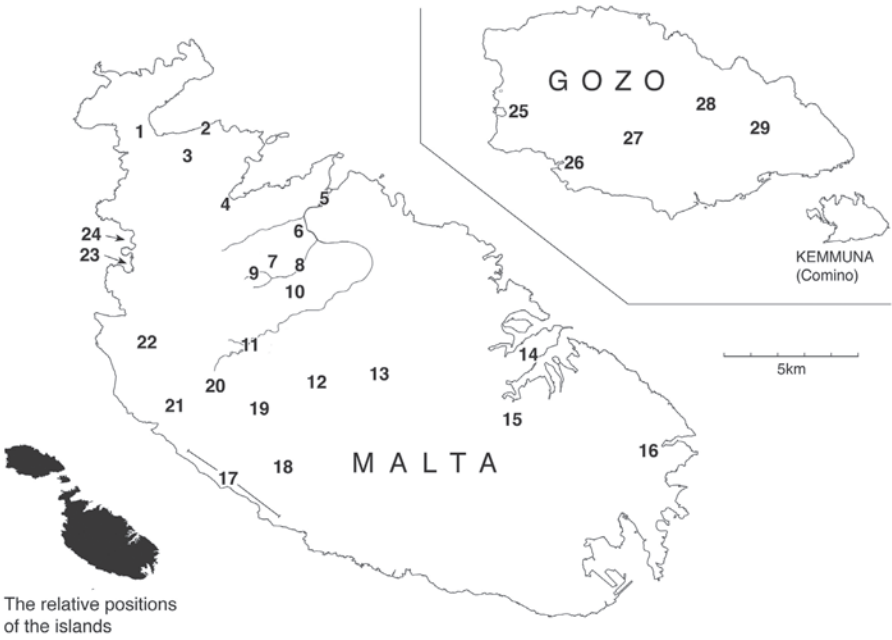

Fig. 1. Map of the Maltese Islands indicating sites where my observations were carried out as well as other places mentioned in the text: 1, Ghadira; 2, Near Ghajn Zejtuna; 3, Mellieha; 4, Is-Simar; 5, Salina; 6, Burmarrad; 7, Bidnija; 8, Ghajn Rihana; 9, Imselliet Valley; 10, Gnien l-Gharusa tal-Mosta; 11, Chadwick Lakes; 12, Ta' Qali; 13, San Anton Gardens; 14, Argotti Gardens; 15, Gnien is-Serenita; 16, Marsascala; 17, Dingli Cliffs; 18, Buskett; 19, Rabat; 20, Fiddien; 21, Mtahleb; 22, Bahrija; 23, Gnejna Bay; 24, Ghajn Tuffieha; 25, Dwejra; 26, Xlendi Bay; 27, Villa Rundle Gardens, Victoria; 28, Xaghra; 29, Nadur.

to originate from a large covered reservoir providing potable water to large parts of Malta. In other years, with low autumn and winter rainfall, it dries up in late spring. In summer 2013 the upper section was re-excavated and the trees growing along the sides (mainly *Populus alba* and *Salix pedicillata*) were heavily pruned, creating another section of habitat ideal for odonates.

Imselliet Valley (35°55'N 14°23'E) (Plate 1A, B). A watercourse running alongside a dirt road with terraced fields on both sides. The watercourse is divided into sections by a series of low dams. The sides of most of these are steep and overgrown with *Arundo donax* (Giant Reed). Although the water is heavily used for irrigation, three of the reservoirs hold water all year round. One of these reservoirs is much wider than the others, with less steep banks (Plate 1A), and holds the largest diversity and number of odonates. According to my observations, Imselliet Valley is one of the most important sites for odonates in the Maltese Islands.

Table 1. Sites showing frequency of observation and time of season during the period 2009-2013.

Site	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ghadira Nature Reserve	0	28	47	61	60	78	78	69	66	50	0
Fiddien	0	0	5	10	15	12	17	13	13	0	0
Imselliet Valley	0	0	0	7	28	27	15	1	0	0	0
Ghajn Rihana	0	1	4	4	2	0	0	0	2	0	0
Chadwick Lakes	1	4	13	11	8	16	15	19	17	14	0
Chadwick Lakes – Mosta side	0	1	10	6	9	15	13	9	3	1	0
San Anton Gardens, Balzan	0	0	1	4	7	16	12	10	2	2	1
Garden of Serenity, Sta. Lucia	0	0	0	0	3	1	1	0	0	0	0
Gnejna Bay	0	0	0	2	1	3	2	0	0	0	0
near Ghajn Zejtuna	0	0	0	2	6	3	0	0	0	0	0
Salina	0	6	2	8	4	1	1	4	3	3	0
Ta' Qali reservoir	0	0	0	0	0	3	5	4	6	2	0
Ghajn Tuffieha	0	0	0	0	1	7	4	0	0	0	0
Gnien l-Gharusa tal-Mosta	0	4	10	7	4	0	0	8	9	11	1
Other sites*	0	0	0	1	1	2	0	4	3	1	1

*Argotti Gardens, Floriana; Bahrija (valley and agricultural reservoir); Mtahleb; Rabat; Simar Nature Reserve; Rundle Gardens, Gozo; and Xlendi Bay, Gozo.

Ghajn Rihana (35°55'N 14°24'E). Another watercourse, which is actually a continuation of that at Imselliet. Two roads (over narrow bridges) cut across this watercourse which runs down to Burmarrad. Again the water is used for irrigation. In the upper part (below Bidnija) two of the reservoirs usually hold water until late June, in low rainfall years, and to mid-August when rain is more plentiful. The lower part, further down from the Mosta-Burmarrad road, dries up much earlier. This part of the watercourse, which is without *Arundo donax* but with trees lining one side, is a stronghold for *Orthetrum cancellatum* (Black-tailed Skimmer).

Chadwick Lakes (35°54'N 14°22'E) (Plate 2A, B). Despite its name this is another dammed watercourse that runs from below Mtarfa to the Mosta-Rabat

A

B

Plate 1. Two of the series of dammed reservoirs at Imselliet Valley, holding some water all through summer. (A) the widest and most important reservoir, (B) one of the narrower reservoirs with thick stands of *Arundo donax* (Giant Reed) along the steep sides and the entire surface covered with duckweed.

A

B

Plate 2. The main (largest) reservoir at Chadwick Lakes. (A) filled to capacity on 20 April 2012, (B) dried out on 8 May 2012, showing how quickly water is extracted for irrigation.

road. The main upper reservoir holds the largest water body (Fig. 2A). However, from early spring, water is pumped for irrigation and, in some years, it is dry by mid-May (Fig. 2B) except for a very small patch. Further down, a small shallow stretch holds water all year round thanks to water from an unknown source flowing irregularly into it. The reservoir at the lower end (Mosta side) usually holds some water all year round due to water overflowing from an underground source from which water is pumped to fill water bowsers. However, the water in this reservoir is sometimes polluted with sewage. In recent years one of the reservoirs has become heavily overgrown with *Arundo donax*; the others are free from this invasive alien.

San Anton Gardens, Balzan (35°53'N 14°26'E) (Plate 3A). Six pools with fountains are found in these gardens. Two of these have swans and ducks while all of them hold *Carassius auratus* (goldfish). Three of them also have terrapins, while in one of them *Pelophylax bedriagae* (frogs) were present in 2012 and were seen on three occasions to prey upon ovipositing female *Anax imperator* (Emperor Dragonfly). These pools are periodically emptied and cleaned. This garden holds one of the largest local populations of *Trithemis annulata* (Violet Dropwing).

Garden of Serenity, Sta. Lucia (35°51'N 14°29'E) (Plate 3B). Two large ponds are found in this garden. Terrapins were introduced in the larger one, while both of them teem with *Gambusia* sp.(Mosquito fish). The main odonate species found here is again *Trithemis annulata*.

Gnejna Bay (35°55'N 14°20'E) (Fig. 4A) and near **Ghajn Zejtuna** (35°58'N;14°22'E) (Plate 4B). The habitat at these two sites is very similar, with water seeping and trickling down clay slopes and forming small puddles. These two sites, together with Fiddien, are the strongholds of *Orthetrum coerulescens* in Malta.

Salina (35°56'N 14°25'E). Disused salt-pans, which are now being rehabilitated. A canal surrounding them used to be blocked with seaweed in some years, as a result of which the water was rendered brackish by fresh water flowing into it from Burmarrad. As a result, a reed-bed ran alongside it in some places but this no longer exists. Small sections of the adjacent ground flood with rainwater and may be wet until late spring. A park was recently built on one side and an artificial small watercourse has become an attraction for odonates.

Ta' Qali reservoir (35°53'N 14°25'E) (Plate 5A). A very large and deep concrete reservoir which supplies irrigation water to the National football stadium. No emergent vegetation exists and the water surface is polluted by plastics and other alien material.

A

B

Plate 3. Examples of ponds and fountains found in public gardens – heavily patronized by *Trithemis annulata* (Violet Dropwing). (A) San Anton Gardens, Balzan, (B) Garden of Serenity, Sta. Lucia.

A

B

Plate 4. Typical Keeled Skimmer habitat in the Maltese Islands. (A) at Gnejna Bay, (B) near Ghajn Zejtuna.

A

B

Plate 5. Agricultural and other reservoirs. (A) Ta' Qali – a large reservoir used to irrigate the national football stadium, (B) typical small agricultural reservoir at Ghajn Tuffieha.

Ghajn Tuffieha (35°55'N 14°21'E) (Plate 5B). The area visited consists of three small agricultural reservoirs. They are stocked with *Gambusia sp.* but frequented by several odonates; exuviae of different species are regularly present on the retaining walls.

Gnien l-Gharusa tal-Mosta (35°54'N 14°25'E). A small, agricultural reservoir which fills up after the autumn and winter rains. The water is not apparently used for irrigation. The main species utilizing this reservoir is *Sympetrum fonscolombii*. It is the only species that has been seen emerging so far, although *Anax imperator, Anax parthenope and Orthetrum cancellatum* have all been seen ovipositing.

Species Accounts

Zygoptera - Calopterygidae

***Calopteryx virgo* (Linnaeus, 1758) - Beautiful Demoiselle.** The flight period of this species in Europe is given as May to late September (Dijkstra & Lewington, 2006). Sciberras & Sammut (2008) recorded a single dead specimen of *C. virgo meridionalis* found in a shore rock pool at Marsascala between 1987-88. They also mentioned coming across two unconfirmed records – a forewing found in a water reservoir at Zebbug, Gozo in 1985 and a dead specimen found at Nadur, Gozo in 1997. In addition, the same authors (Sciberras & Sammut, 2013) reported finding fragments of a specimen in Valletta's collection which, when assembled by one of the authors, were identified as belonging to this species and carried a label reading 'Malta, Dwejra (Gozo) 11.iii.1973.' They also reported seeing a specimen in a Tunisian collection. Dr. L.F. Cassar (pers. comm.) had passed on to Valletta three specimens of *Calopteryx* sp. collected outside the Maltese Islands. It is highly probable that the assembled specimen was one of these three and that the label referring to the specimen collected on 11 March belonged to some other odonate. I have not recorded this species in the Maltese Islands and there are no suitable habitats for this species.

***Calopteryx haemorrhoidalis* (Vander Linden, 1825) - Copper Demoiselle.** A severely damaged specimen found in a paper envelope in Valletta's collection was identified by Bernd Kunz as belonging to this species (Sciberras & Sammut, 2013). A data label found with this specimen indicated that it was found at Marsascala on 28 July 1986. As with *C. virgo*, it is also likely that, despite the data label found accompanying the specimen, this specimen also belonged to one of the three which Cassar had passed on to Valletta and thus the addition of this species to the Maltese list is highly doubtful. As with the previous species,

no suitable habitat exists for this species in the Maltese islands.

Zygoptera - Coenagrionidae

***Ischnura genei* (Rambur, 1842) - Island Bluetail.** This damselfly is very common in areas with still or gently flowing water overgrown with vegetation. It is on the wing from late March to early November with peaks from early April to mid-May and from mid-September to mid-October (Fig. 2). Two generations are produced annually.

Both Ebejer *et al*. (2008) and Sciberras (2008) list this species as widespread with records from March-April and June to October. Degabriele (2013) also stated that ovipositing females are often guarded by the male. However, during hundreds of observations I have not seen a male guarding an ovipositing female. Balzan (2012) stated that this species reaches a higher population count early in spring with a progressive population decline as the flight season progresses.

Anisoptera - Aeshnidae

***Aeshna mixta* (Latreille, 1805) - Migrant Hawker.** This species is a very rare visitor to the Maltese Islands but is a species which may be on the point of establishing itself on the Islands. It was first recorded in 1976 when a female was collected at Balzan, Malta on 26 June (Ebejer *et al*., 2008), although Sciberras & Sammut (2013) erroneously cite this date as 26 April 1976. Sciberras & Sammut (2013) also report a specimen found in Valletta's collection dated 12 June 1948, San Anton Gardens, which was collected by Valletta himself but had apparently been misidentified as *Anax imperator*. Sciberras & Sammut (2013) also added other records: a male seen by Sciberras at Sarraflu, Gozo on 28 August 2009, one sighted by Degabriele in 2011 (but Debagriele (2013) did not mention this sighting), a female photographed on Comino on 25 May, 2012 and another (probably male) seen on the same small island on 27 May 2012, as well as a male photographed by myself at Ghadira Nature Reserve on 1 November 2012. Degabriele (2013), citing Ruf *et al. (*2011), stated that a small number of ovipositing females had been recorded recently and photographed at a pond to the south of Xaghra, Gozo and also noted that the same authors had seen a male at the same locality. No dates were provided by Degabriele and I have been unable to obtain a copy of Ruf, T. et al. (2011).

***Anax imperator* (Leach, 1815) - Emperor Dragonfly.** A common dragonfly which is often seen hunting away from water. I have also, on occasion, seen it hunting over the open sea in bays. It is on the wing from the end of February to early December with the highest numbers from June to mid-September (Fig. 3).

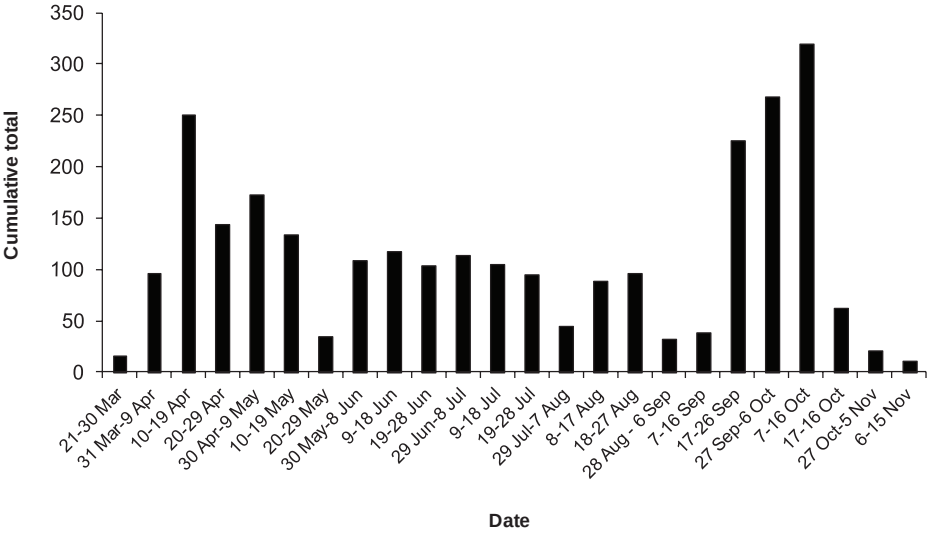

Fig. 2. *Ischnura genei* (Island Bluetail) cumulative totals observed in the period 2009-2013, showing relative abundance and flight period.

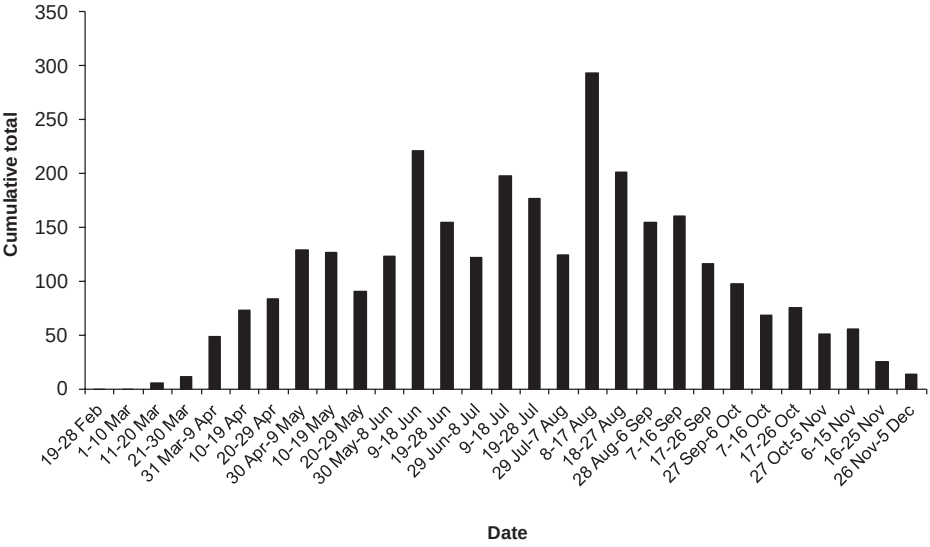

Fig. 3. *Anax imperator* (Emperor Dragonfly) cumulative totals observed in the period 2009-2013, showing relative abundance and flight period.

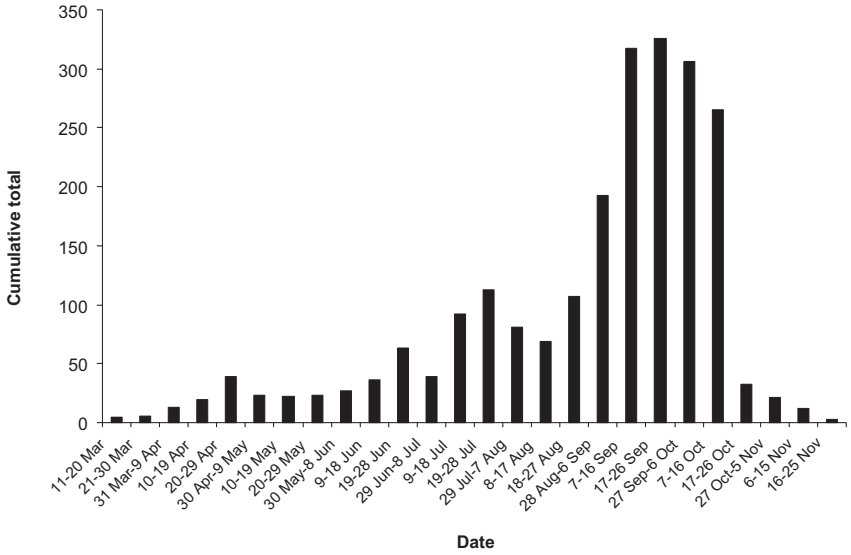

Fig. 4. *Anax parthenope* (Lesser Emperor) cumulative totals observed in the period 2009-2013, showing relative abundance and flight period.

Females oviposit unattended on floating vegetation or other debris. In 2013, over 200 exuviae were counted at the largest reservoir of Chadwick Lakes in early April, suggesting mass emergence at this time, although few were seen on the wing there at that time. However, smaller numbers of exuviae were also seen at other sites later in spring and again in August – September.

Ebejer *et al*. (2008) listed it as common and widespread from April to October but also recorded it in January. Sciberras (2008) and Corso *et al.* (2012) suggested that this species is being displaced by *Anax parthenope* (Lesser Emperor). I found no such evidence. During the present study, *Anax parthenope* occurred in greatest numbers from September to mid-October, i.e. after the peak for *A. imperator* (see below & Fig. 4.) Balzan (2012) also noted that populations of *A. imperator* reached a high population level in early spring, numbers decreasing as the flight season progressed. Degabriele (2013) gave a flight period from January to October and found the species most common in spring.

***Anax parthenope* (Selys, 1839) - Lesser Emperor.** Commonly seen from about the middle of March to late November, with a marked peak from the end of August to mid-October, when numbers are presumably greatly augmented by migrants (Fig. 4). Valletta (1951), Sciberras (2008) and Corso *et al.* (2012) all reported large migrations. Large numbers appeared in the days following a flash-flood in early September 2012. Ebejer *et al*. (2008), who also described it

as common, reported it on the wing in February, April-May, July, September and November. Degabriele (2013) gave the flight period as February to November, occurring in greater numbers in summer and autumn. He also stated that oviposition can either occur in tandem or by the unaccompanied female. While this is true, unaccompanied ovipositing females are very rarely encountered.

During my five-year observation period, breeding activity seemed to be more concentrated in the afternoons, while feeding activity was more pronounced in the mornings. This could perhaps be associated with the fact that *A. parthenope* habitually hunts other smaller dragonflies and *Sympetrum fonscolombii* (Red-veined Darter), one of its favourite prey species, is much more numerous ovipositing in tandem at water bodies in the mornings. On 11 April 2013, two tandem pairs were seen seeking floating vegetation over the open sea at Xlendi Bay in Gozo.

***Anax ephipigger* (Burmeister, 1839) - Vagrant Emperor.** This species occurs primarily as a migrant, sometimes arriving in considerable numbers, mostly in spring. It was first recorded for the Maltese Islands by Valletta (1949). From 2000 to 2008 it occurred annually, except in 2006 (Sciberras, 2008). During the current five-year study period it was recorded in 2009 (2 single specimens), 2011 when a huge migration occurred on 18 March and over 4,000 individuals were seen in the north-eastern part of Gozo (Sciberras, 2011) and in smaller numbers in 2012 and 2013 (Fig.5A, B). Ebejer *et al* (2008) recorded it in February to April and in July to August. In the same paper it was also stated that one of the authors had observed several individuals mating and ovipositing at three localities in Malta but with no further details. Sciberras (2011) observed ovipositing tandems in April, May and October, all in small rock pools, and found a teneral male in August 2010, claiming that this confirmed breeding in the Maltese Islands, although no exuvia was found. During the past five years I have seen this species from the end of February to mid-April, once in mid-May and once in mid-September, and from mid-October to late November. The late autumn sightings were all at Chadwick Lakes and involved several tandems ovipositing both in 2012 and 2013, which might suggest the presence of a permanent breeding population, this site not having been visited so late in the season before.

Degabriele (2013) gave a flight season of February to October. He also mentioned that Ebejer *et al.* (2008) "had observed the species to roost locally in strategically chosen places during the evening". However, Ebejer had been referring to large numbers having been seen by him congregating on trees at dusk before a migration from Abu Dhabi in September 1984.

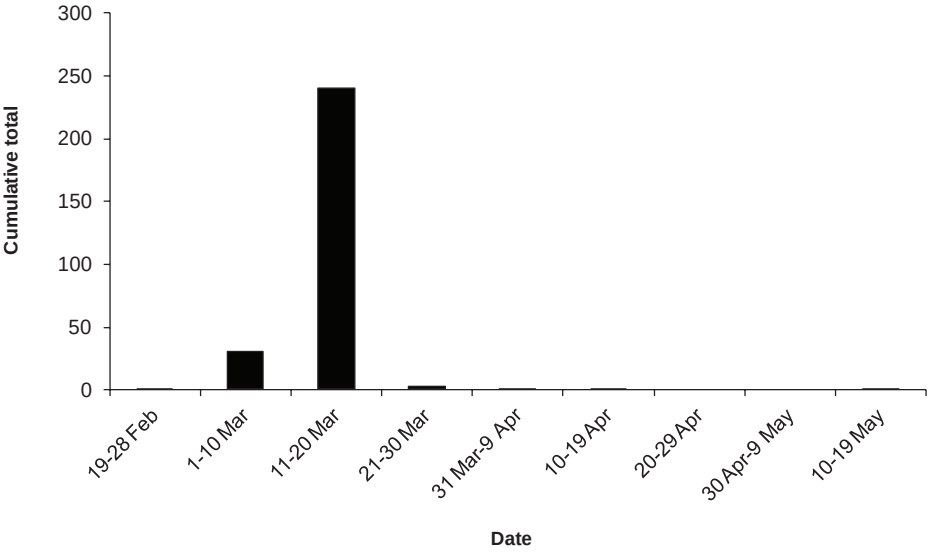

Fig. 5A. *Anax ephipigger* (Vagrant Emperor) cumulative totals observed in spring 2009-2013, showing relative abundance and flight period (the 4,000 specimens recorded by Sciberras (2011) on 18 March 2011 are not included).

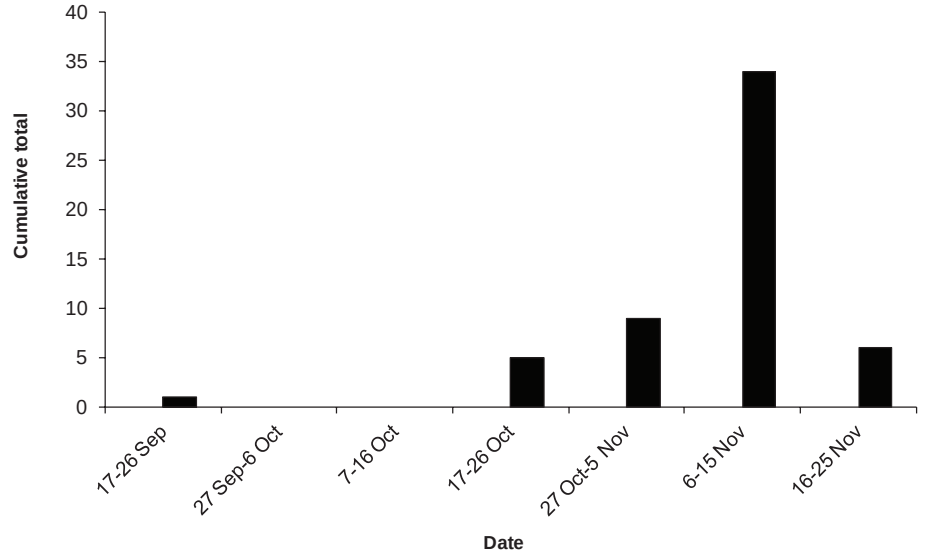

Fig. 5B. *Anax ephipigger* cumulative totals observed in autumn 2009-2013, showing relative abundance and flight period. October and November sightings were all at the main reservoir at Chadwick Lakes in 2012 and 2013. This site had not been visited at this time of year in previous years.

Anisoptera - Libellulidae

***Orthetrum cancellatum* (Linnaeus, 1758) - Black-tailed Skimmer.** Found on the wing from early April to mid-September (Fig.6), this species only occurs in fairly large numbers at a few sites. One of its strongholds seems to be Ghajn Rihana Valley, where a sizeable population was discovered in April 2012. Only a few were seen at this site in 2013 as the water had dried up by mid-April. The high numbers recorded in the latter part of April (Fig. 6) resulted from this 2012 population discovery. A smaller population is found at the Ghadira Nature Reserve, where several emerge every year from a small fresh-water pond which was constructed in the early 1990s. Emergence at this site is protracted and takes place from mid-April until the third week of August. During the five years under study I have also seen the species at several other sites but always in single figures.

Ebejer *et al*. (2008) described it as common, frequenting all types of water bodies, including garden ponds. However, one of the authors of this paper stated that the species had greatly decreased, recording only an average of five sightings annually between 2000 and 2008 (Sciberras, 2008) and suggested that the decline he observed might have been due to the increasing population of *Orthetrum trinacria* (Long Skimmer). The same statement is repeated in Corso *et al*. (2012). However, during my study I found no evidence for this. Balzan (2012) stated that the lack of records for this species, which had previously been considered as common, may suggest that populations of Odonata in the Maltese Islands are on the decline. Debagriele (2013) also noted that numbers of this species had declined since the 1990s. He gave the flight period as being May to October, the same as Ebejer *et al.* (2008).

***Orthetrum coerulescens* (Fabricius, 1798) - Keeled Skimmer.** This species is common but localized and is on the wing from early May to late October, peaking in the second half of July (Fig.7). The preferred habitat in the Maltese Islands appears to consist of small pools originating from water seeping from clay slopes, such as are found at Gnejna, and Ghajn Zejtuna (the last site also noted by Sciberras (2008)). Ebejer *et al*. (2008), Sciberras (2008), Balzan (2012) and Degabriele (2013) ascribed the local population to the ssp. *anceps.* However, Boudot *et al.* (2009) list the populations of the Maltese Islands, Sicily, Sardinia, Corsica, some parts of southern Spain, Cyprus and some of the Greek Islands as being intermediate phenotypes between *O*. *coerulescens coerulescens* and *O*. *coerulescens anceps*.

Sciberras (2008) stated that, although past literature gave the impression of this species being rare, during 2000-2008 (the years of his study period), he noted a range expansion and an increase in local abundance. Ebejer *et al.* (2008)

listed it as common near flowing water and recorded it on the wing in March, presumably on the strength of a male specimen collected on 14 March 1990. Balzan (2012) stated that this species is related to diverse landscapes and the presence of associated flowing (lotic) water bodies. Degabriele (2013) stated that he and Balzan (2012) found it to exclusively frequent flowing waters and slow moving streams which are shaded by trees and tall vegetation. He also stated that the species is becoming rather widespread. While Balzan (2012) noted that the species peaks in summer (near to the yearly temperature peak), Degabriele stated that it is more abundant in spring. Sciberras & Sammut (2013) stated that this is one of the species showing a fast decline in population numbers.

***Orthetrum brunneum* (Fonscolombe, 1837) - Southern Skimmer.** First recorded by Valletta (1949), this species was not seen by me during this five-year study period, despite searching diligently for it in all the places where it had been recorded. Ebejer *et al.* (2008) listed six specimens found in private collections and stated that the species is confined to freshwater streams near Rabat, Buskett, Mtahleb and Bahrija with a flight period from June to August and in October. Sciberras (2008) listed a sighting on 20 July 2008. Degabriele (2008) mentioned three males in a private collection but bearing no data label, so they may have been collected elsewhere. Boudot *et al.* (2009) surprisingly list it as present and of Least Concern status in the Maltese Islands.

***Orthetrum nitidinerve* (Selys, 1841) - Yellow-veined Skimmer.** This species is a recent addition to the list of Odonata of the Maltese Islands. In 2008 eight (six males – 1 of which was collected – and two females) were sighted at Mellieha (Sciberras *et al.,* 2010). Sciberras & Sammut (2013) also mention four sightings at wied Rihan since a first sighting in 2010 but give no dates. None were seen by me during the five years of this study.

***Orthetrum chrysostigma* (Burmeister, 1839) - Epaulet Skimmer.** A very recent addition to the Maltese Odonata list. On 12 June 2010 I photographed a freshly-emerged teneral female near one of the ponds at Ghadira Nature Reserve (Gauci & Sciberras, 2010). In the same paper another three sightings, all female, were reported from the Mellieha area by Sciberras. These were on 19 June 2008, 10 July 2009 and 13 July 2010. Corso *et al.* (2012) mentioned identifying a male from photographs of specimens of *O. coerulescens* sent to them by Sciberras and went on to suggest that the species may be overlooked, although in 300 images of *O. coerulescens* examined I have not found a single *O. chrysostigma*.

***Orthetrum trinacria* (Selys, 1841) - Long Skimmer.** This species was first identified in the Maltese Islands in 2003 (Ebejer *et al*., 2008). The authors

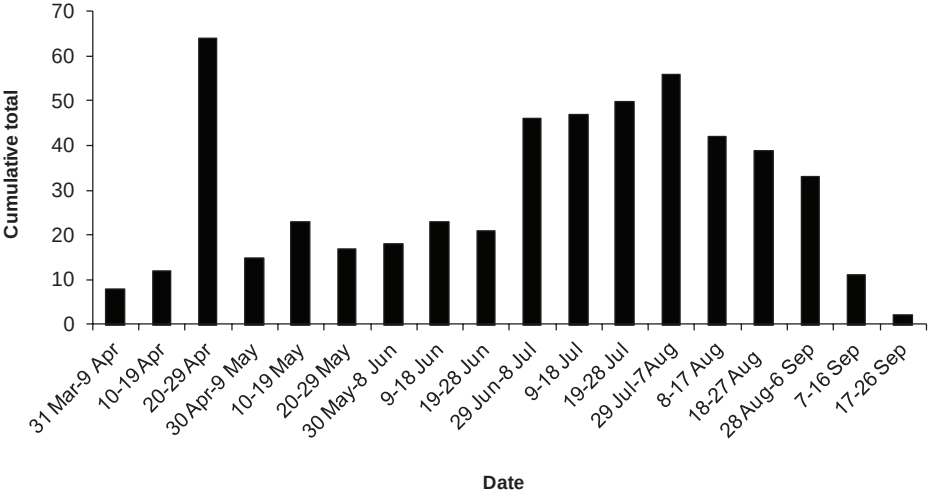

Fig. 6. *Orthetrum cancellatum* (Black-tailed Skimmer) cumulative totals observed in the period 2009-2013, showing relative abundance and flight period. The abnormally high numbers recorded in the ultimate 10-day period in April, result from a large population discovered at Ghajn Rihana in 2012 when this site was first visited. In 2013, following a winter of very low rainfall, the site was already dry at the end of April.

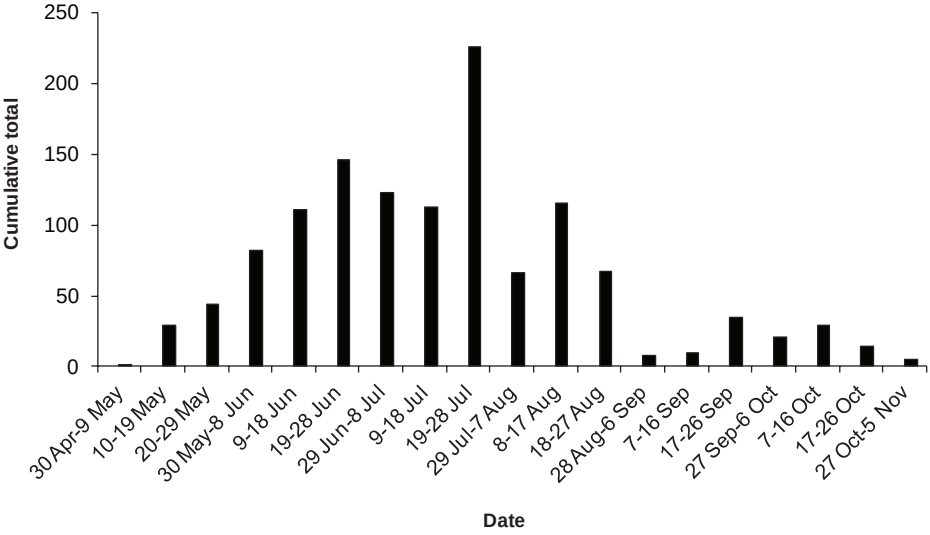

Fig. 7 *Orthetrum coerulescens* (Keeled Skimmer) cumulative totals observed in the period 2009-2013, showing relative abundance and flight period.

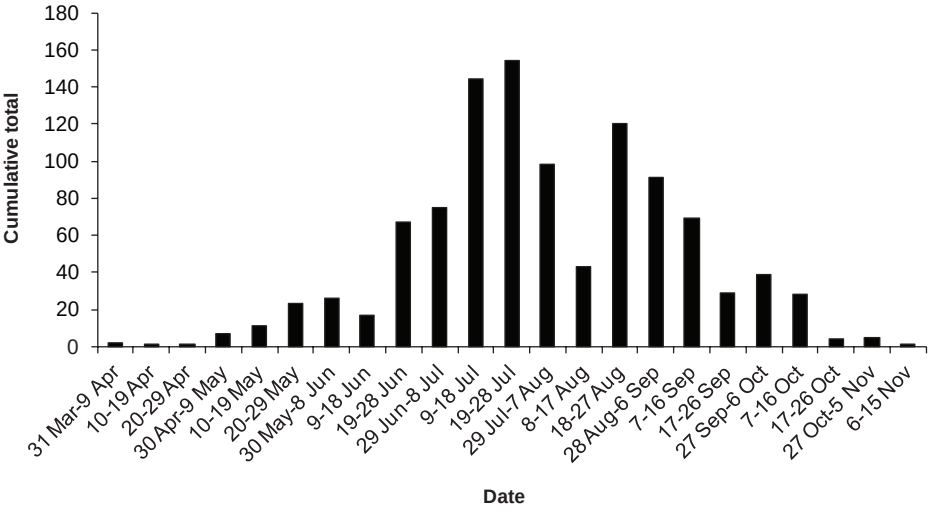

Fig. 8. *Orthetrum trinacria* (Long Skimmer) cumulative totals observed in the period 2009-2013, showing relative abundance and flight period.

recorded six specimens in private collections; these had been collected in June, August and October between 2003 and 2007. They also stated that more individuals had been sighted or captured in different localities and that larvae and exuviae had been observed. Balzan (2008) observed small numbers in several areas, mainly in Gozo, between late May and late July 2008. Sciberras (2008) noted an increase in this species' population and went on to state that this was accompanied by a reduction of formerly common species, which included *Sympetrum fonscolombii* and *Crocothemis erythraea*. He also stated that it occasionally chases *Anax imperator* and *Anax parthenope* and that only rarely was *Trithemis annulata* - another recent colonizer – found in ponds where *O. trinacria* holds territory. However, although he stated that *C. erythraea* had decreased as a result of the presence of *O. trinacria* he also stated that this species seems to be the only one able to co-exist with it.

Today, the species is common and widespread, appearing to prefer larger bodies of water, with or without vegetation. At sites with no emergent vegetation, as at Ta' Qali reservoir, males tend to perch on grass or low shrubs but sometimes also on the ground, close to the water body. They make regular sorties, flying low over the water and returning to perch on dry land. It is on the wing from early April to mid-November but with most from mid-May to early October (Fig.8). Although this species does at times prey on *S. fonscolombii* I found that none of the statements of Sciberras (2008) and later repeated in Corso *et. al.* (2012)

and Sciberras & Sammut (2013), that *S. fonscolombii* has all but disappeared due to predation by *O. trinacria*, are correct.

S. fonscolombii is still found in large numbers in the same areas holding strong *O. trinacria* populations (e.g. at Chadwick Lakes and Ta' Qali reservoir). I have seen the latter habitually being chased by *A. parthenope* rather than the other way round, as claimed by Sciberras (2008). Although Sciberras & Sammut (2013) stated that this species had taken over most ponds on the Islands they also noted that the species had "established a more permanent residence in the island of Gozo while being spotted occasionally both on the island of Malta and on Comino". Degabriele (2013) stated that "*Orthetrum trinacria* has been observed by the author to oviposit in tandem." I have witnessed several tens of ovipositing females and have never seen this species ovipositing in tandem. After copulation, which usually lasts from several seconds to a few minutes, the male closely guards the female during oviposition. Very often the process is disrupted by another male or males, in which case the female flies away and continues to oviposit unattended in some secluded area of the water body. Degabriele (2013) also stated that the species had established itself well locally and gave the flight season as May to October.

***Sympetrum fonscolombii* (Selys, 1840) - Red-veined Darter.** First recorded by Valletta (1949), this species was described by Ebejer *et al.* (2008) as one of the most common species across the Maltese Islands, recording it on the wing from March to May and again from July to November. Conversely, Sciberras (2008) stated that population numbers had decreased drastically, attributing the decline to a parallel increase in *Orthetrum trinacria* populations (see above). This was repeated in Corso *et al.* (2012), where it was also stated that the species is still quite common in areas, mostly coastal, not suitable to support breeding populations of *O. trinacria.* This was not found to be so at Ghadira Nature Reserve, a coastal area supporting a population of *O. trinacria* and where *S. fonscolombii* is very common in autumn. Balzan (2012) found that, in spring (he did not record it in autumn as his field work was from mid-April to mid-July), the population subsequently declined to nil.

Sciberras & Sammut (2013) also noted that numbers of this species had decreased drastically, especially during the past eight years. I have found no evidence of this and today the species is present in relatively small numbers from about mid-March to mid-June and again in much larger numbers from early July to early December, with the highest numbers between mid-August and mid-November (Fig. 9), when it is the most numerous odonate on the Islands. Most of those emerging in spring seem to move on, either migrating or dispersing locally away from water bodies. Few mature adults are seen, usually ovipositing, especially in April. The large numbers seen in autumn

generally appear soon after the first rains replenish habitats which had dried out in spring.

Corso *et al.* (2012) noted that, in nearly all specimens examined from the Pelagie Islands (lying between Malta and Tunisia south of Sicily and about 150 km from the Maltese Islands), the yellow area at the base of the hind wings was highly reduced and that on the forewing almost absent. They also noted that specimens had a diminutive size. In contrast they stated that, in Maltese specimens examined (photos), the yellow on the hind wings often reached the base of the triangle. Although this species is a known migrant, it is unclear whether the local autumn population consists of migrants, resident populations or both. In 2013 one of the reservoirs at Chadwick Lakes, which had been dry since the beginning of April, was filled to capacity in early July, probably as a result of the malfunction of a pump that brings up underground water for irrigation. This reservoir was immediately colonized by several species of dragonfly, including *S. fonscolombii*. However, while all other species present at this site had been present at other water bodies in the vicinity, no *S. fonscolombii* had been present there. So where did the strong population which established itself on the reservoir originate from? Was it the result of migrants or individuals present locally away from water bodies? The yellow posterior wing patch on the Red-veined Darters in this population was large, suggesting they were of local origin rather than African migrants. Also of interest is that, while this population established itself on this reservoir filled with fresh underground water, none were seen at Ta' Qali reservoir until after the first rains at the end of August, even though it is only about 1 km away, or at the largest water body at Imselliet Valley, which is no more than 1.5 km away. It might be plausible to postulate that this species has a strategy similar to that of tropical species mentioned in Corbet (1999), where larval development is completed in as little as 1.5 months and where adults are long-lived, surviving the dry season and postponing reproduction until the first autumn rains. The flooded reservoir dried up in mid-August and over 40 exuviae and a similar number of tenerals appeared at this time. It is presumed that larval development was completed in just over four weeks. This reservoir was again found to be half full a few days later and this species was again present in large numbers. It was noted that breeding activity (pairs in copula and tandems in oviposition) occurred in the mornings but that there was hardly any activity in the afternoons. Indeed, over a hundred specimens were counted on most morning visits, but only a handful (almost invariably males) were seen on afternoon visits. Ovipositing females which broke away from the male (this species oviposits in tandem) were often seen rising high until being lost out of binocular sight. These observations seem to suggest that autumn populations are indeed of local origin, although massive migrations do sometimes take place. I recall one such migration in the mid-1990s, witnessed in the afternoon at Dingli Cliffs, when several hundred, mostly

males, were seen flying in a north-westerly direction along the cliff edge.

The decrease in population numbers noted by Sciberras (2008) and Corso *et al.* (2012) is in contrast to my observations (above) and those of Degabriele (2013), who gave the flight season as March to November.

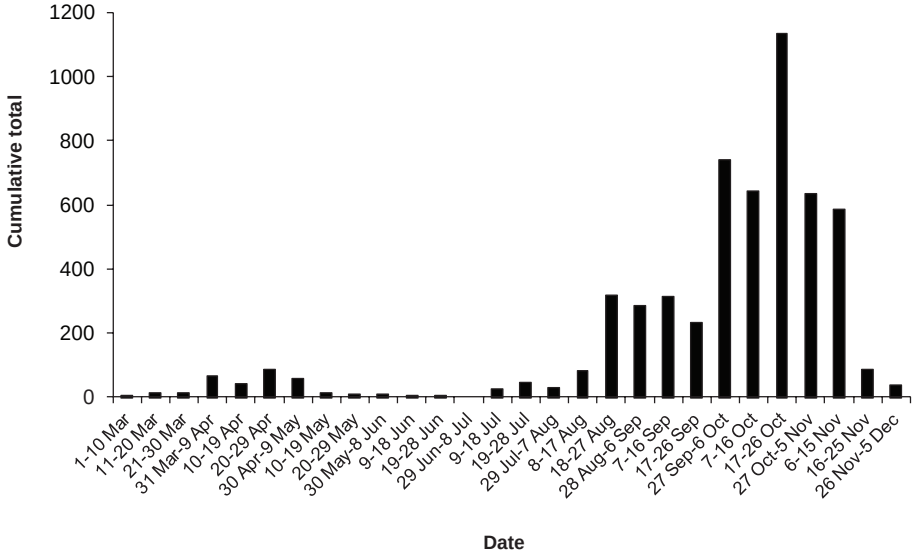

Fig. 9. *Sympetrum fonscolombii* (Red-veined Darter) cumulative totals observed in the period 2009-2013, showing relative abundance and flight period.

***Sympetrum striolatum* (Charpentier, 1840) - Common Darter.** This species was first mentioned as being present in the Maltese Islands in 1899 (McLachlan in Sciberras, 2008). Sciberras (2008) stated that the species had decreased drastically since the 1990s and that he had only observed it on a handful of occasions, although he recorded 34 at Cirkewwa on 12 August 2007. Ebejer *et al.* (2008) stated that local records suggested that the species was previously more common. Specimens they had examined in various collections had been caught between May and August and in October. Corso *et al.* (2012) also noted that its numbers had declined strongly, with the last observation being of one on 18 June 2009. They also quoted Sciberras (2008) as having said that the disappearance of the species could be attributed to the fact that its breeding sites were progressively being taken over by *Orthetrum trinacria*, although I could find no reference to this in Sciberras (2008). However, Sciberras & Sammut (2013) did state that this species (together with others) was showing a fast decline in population numbers and attributed this to the increase in the

numbers of *O. trinacria*. There is uncertainty as to the last recorded specimen - 18 June 2009 (Corso *et al.,* 2012) or 18 August 2008 (Sciberras & Sammut, 2013). Balzan (2012) stated that this species had been formerly considered a common species. Degabriele (2013) stated that, in autumn 2012, he found it in a wider variety of habitats than *O. trinacria*, without giving any indication of the relative abundances of the two species. He stated that the species had been recorded between May and October.

Today the species is certainly very rare. I have only seen and photographed it twice during my five-year observation period: single males at Fiddien on 7 October 2011 and at Chadwick Lakes on 25 October 2011. Given the fact that, prior to the year 2000, odonates received little attention in the Maltese Islands, it is difficult to say whether this species has actually disappeared or has been confused with *S. fonscolombii.*

***Crocothemis erythraea* (Brauer, 1868) - Broad Scarlet.** Already recorded for the Maltese Islands in 1899 (McLachlan in Sciberras, 2008), this species has been described by all authors (Ebejer *et al*., 2008; Sciberras 2008; Corso *et al*., 2012; Debagriele, 2013) as the commonest and most widespread dragonfly species occurring in the Maltese Islands. Its status has not changed and it is found on the wing from the end of March to late November, with a peak from June to October (Fig.10). With a few exceptions, it is generally the most numerous odonate on any type of water body. The species is so numerous that males continually interact intraspecifically as well as with other species. I have often seen them harassing ovipositing tandems of *Sympetrum fonscolombii*, *Selysiothemis nigra* and even *Anax parthenope*, as well as ovipositing females of *Orthetrum trinacria*, despite the fact that, in the last species, the female is closely guarded by the male. Degabriele (2013) stated that females repeatedly copulate before ovipositing and that they oviposit alone, unaccompanied by males. I have observed a few hundred females copulating and ovipositing and can say that females are normally guarded by the male. However, due to the very high concentration of males, once a female starts to oviposit other males try to copulate with her. The guarding male usually chases away other males and the now unguarded female is forced to copulate again with another male. This can repeat itself a number of times until the female decides to leave the water body, although sometimes she may sneak to a secluded area to continue ovipositing alone.

Degabriele (2013) stated that two generations are produced annually. This is not apparent in Fig. 10 but emergence at the two ponds present at Ghadira Nature Reserve also suggests the production of two generations, with peaks in emergence from the end of March to the beginning of July and from early August to the end of September, although emergence took place throughout

the whole period.

***Trithemis annulata* (Palisot de Beauvois, 1807) - Violet Dropwing.** This species was first recorded for the Maltese Islands in 2007 (Ebejer *et a*l., 2008). However, Sciberras (2008) stated that sightings dated back to 2005. It was noted that, by 2008, it had become the second most common species occurring in the Maltese Islands (Sciberras, 2008; Corso *et al*., 2012). Balzan (2008) recorded it in small numbers at various sites in Gozo.

Today the species is very common at some sites, notably at San Anton Gardens, The Garden of Serenity at Sta. Lucia, and at Ta' Qali reservoir, where it is by far the most dominant species. At other sites it is far less common and is mostly in evidence in the latter part of the flight season. It is on the wing from early May to early December, with most seen from June to October (Fig.11). Strangely, while I have found a relatively large number of exuviae at The Garden of Serenity in Sta. Lucia, I have not managed to find any at San Anton Gardens, where the species is even more numerous and where on several occasions I have watched females ovipositing.

Degabriele (2013) gave the flight season as May to October and stated that he had observed that this species oviposits in tandem. During my observations I never found this to be so. Copulation lasts only a few seconds and is always exclusively on the wing. The female then proceeds to oviposit on her own with the male guarding closely.

***Selysiothemis nigra* (Vander Linden, 1825} - Black Pennant.** The Black Pennant was first recorded in the Maltese Islands in 1952 (Valletta, 1957). Ebejer *et al.* (2008) listed seven specimens in collections and stated that the species prefers standing shallow waters, including brackish. They recorded it on the wing from June to August but no exuviae had been found at that time. Sciberras (2008) recorded one specimen collected in July and five females seen in August 2007, all in Gozo, as well as two permanent populations at reservoirs in the north of Malta in the same year. I recorded the species present, mostly at Ghadira Nature Reserve, daily from 19 July to 22 August 2008, as reported by Sciberras (2008). Corso *et al*. stated that, since 2009, it has been observed regularly in other areas, even away from water, especially in August to September, and noted a maximum of 13 in one area on 17 July 2011. Sciberras & Sammut (2013) added a further sighting of 15 specimens in the south of Malta on 12 August 2009 and stated that, from 2010-2012, over 112 had been observed by one of the authors and several other observers. They postulated that the species might have been overlooked in the past due to its small size and habit of flying very low. Degabriele (2013) recorded a number of male, female, tandem and ovipositing specimens at Imselliet, Qlejgha (Chadwick Lakes) and

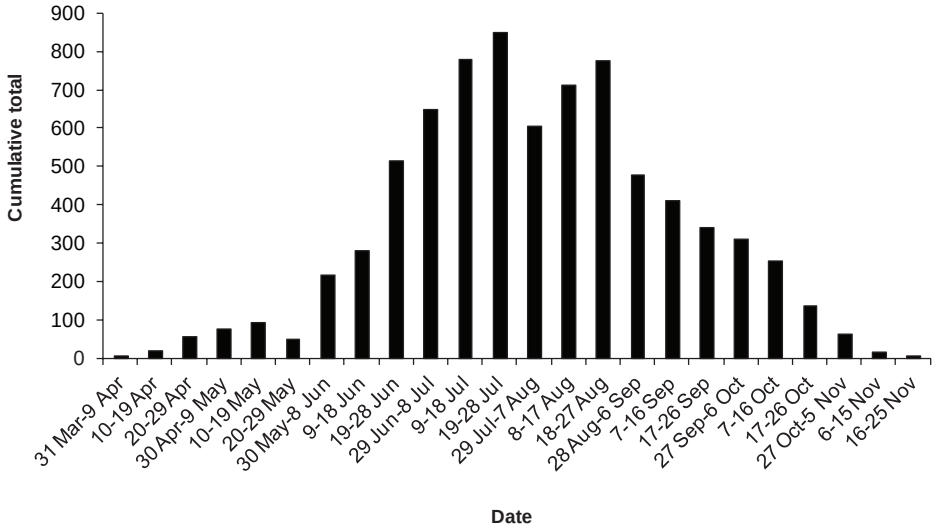

Fig. 10. *Crocothemis erythraea* (Broad Scarlet) cumulative totals observed in the period 2009-2013, showing relative abundance and flight period.

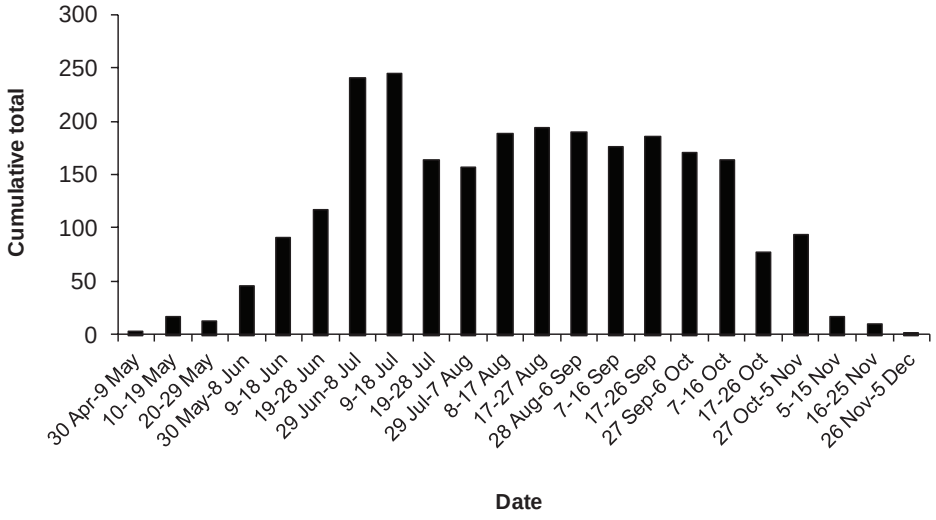

Fig. 11. *Trithemis annulata* (Violet Dropwing) cumulative totals observed in the period 2009-2013, showing relative abundance and flight period.

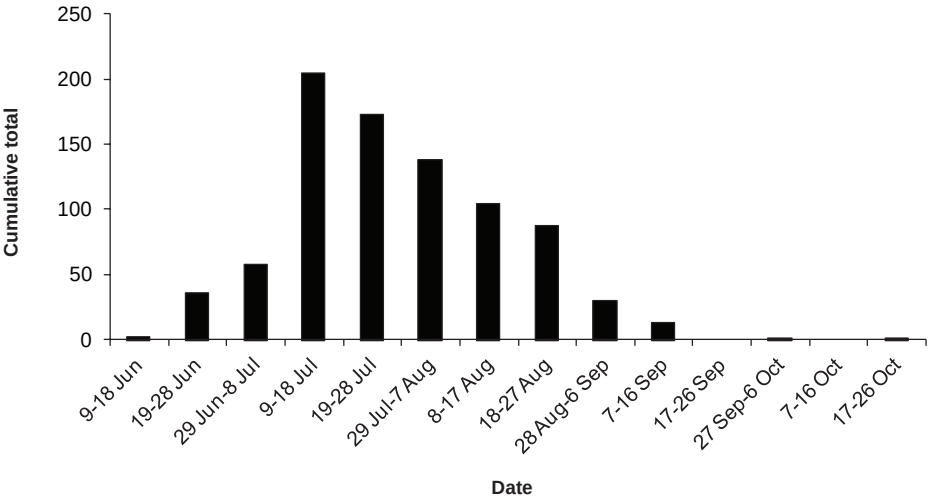

Fig. 12. *Selysiothemis nigra* (Black Pennant) cumulative totals observed in 2009-2013, showing relative abundance and flight period.

Hesri valley.

Today the species is quite common in some areas and is seen on the wing from mid-June to mid-September, with occasional sightings well into October (Fig.12). Late September and October sightings are usually away from water in the Buskett and Dingli Cliffs area and refer to both sexes. It could well be that these sightings refer to migrants. More than 25 were present in the morning of 19 July 2013 at Chadwick Lakes. This species is continually harassed, especially when ovipositing in tandem, by other odonates, especially *Anax parthenope, Orthetrum trinacria and Crocothemis erythraea.* Copulation usually lasts less than one minute and often takes place on the wing. The species oviposits in tandem but sometimes, when the tandem is disrupted by harassment from other odonates, the female continues to oviposit on her own.

***Pantala flavescens* (Fabricius, 1798) - Wandering Glider.** This species is the latest addition to the list of the Odonata of the Maltese Islands. Three specimens were recorded in 2013: one at Qlejgha valley (Chadwick Lakes) in August, a male at Fiddien on 25 September and one at Hesri valley on 31 October (Degabriele, 2013). Interestingly the species was recorded for the first time on the Pelagie Islands of Lampedusa and Linosa in October 2012 (Corso *et al*., 2012).

Discussion

While prior to 2008 hardly any studies relating to the Odonata of the Maltese Islands were published, the trend has been somewhat reversed in recent years, with the most recent contributions being those of Balzan (2012), Sciberras & Sammut (2013) and Debagriele (2013). Since the first of a series of papers published in 2008 (Ebejer *et al.,* 2008) no fewer than seven new species have been added to the Maltese Islands list, raising the total to nineteen. Two of these, *Orthetrum trinacria* and *Trithemis annulata*, have since become established and are now common, with several large populations in various parts of the Islands. The presence of one other species, *Calopteryx haemorrhoidalis*, is doubtful. Some authors, (Sciberras (2008), Corso *et al.* (2012) and Sciberras & Sammut (2013)) have argued that, due to the spread and establishment of *O. trinacria*, other species, e.g. *Sympetrum striolatum,* have all but disappeared since the early 1990s. However, it seems highly likely that this species may have been confused with *Sympetrum fonscolombii*. Sciberras (2008), Corso *et al.* (2012) and Sciberras & Sammut (2013) also suggested that the presence of *O. trinacria* was responsible for the perceived decline of *S. fonscolombii*. However, as this study and that of Degabriele (2013) have shown, the *O. trinacria* population does not appear to impact on that of *S. fonscolombii*, which is still a very numerous species. Sciberras (2008) also stated that *Anax parthenope* was out-competing *Anax imperator* and had become the commoner of the two. This study has shown that this is not so. The two species peak at different times of the season and, while *A. parthenope* is more numerous in autumn, *A. imperator* peaks in spring. This has been confirmed by Degabriele (2013).

Despite the dearth of freshwater bodies in the Maltese Islands, the resident odonate populations do not appear threatened. Also, despite the fact that water bodies in some years dry up before the odonate larvae have completed growth, populations seem to remain relatively stable. With a few exceptions, most of them are adapted to man-made environments, mainly consisting of concrete reservoirs without any emergent vegetation. The main threats seem to stem from pollution, mainly from pesticides and fertilizers, including empty containers haphazardly disposed of along valley water systems, and all sorts of rubbish – from domestic appliances to dead animals – dumped by irresponsible individuals in the same systems.

Several species of dragonfly are expanding their range, attributable mostly to global warming. Degabriele (2013) predicted the appearance of a further twenty-five species of damselflies and dragonflies in the Maltese Islands in the near future.

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Migrant and dispersive dragonflies in Britain during 2012 and 2013

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Summary

The years 2012 and 2013 were quite eventful for migrant and dispersive species in Britain. *Sympetrum fonscolombii* (Red-veined Darter) in particular appeared in good numbers during both years, though local breeding was more noticeable during 2012. After record-breaking appearances of *Anax ephippiger* (Vagrant Emperor) during 2011, another major influx was also noted during autumn 2013. *Anax parthenope* (Lesser Emperor), by contrast, had a poor year in 2013, though appearances in the preceding year had been at above-average levels. Species such as *Sympetrum danae* (Black Darter) and *Ischnura pumilio* (Scarce Blue-tailed Damselfly) showed some notable migratory movements during the period, and rarer migrants similarly produced a number of highlights. The second and third British records of *Leucorrhinia pectoralis* (Large White-faced Darter) were, for instance, made in coastal Suffolk during late spring 2012, whilst a single *Sympetrum vulgatum* (Vagrant Darter) was noted in Kent during autumn 2013.

Recent colonist species also fared well during the reporting period, with *Lestes barbarus* (Southern Emerald Damselfly), *Coenagrion scitulum* (Dainty Damselfly) and *Aeshna affinis* (Southern Migrant Hawker) all holding their own. Populations of *Chalcolestes viridis* (Willow Emerald Damselfly) continued to strengthen, and some range expansion was noted, particularly in East Anglia. In addition to these newcomers, regular records of *Anaciaeshna isoceles* (Norfolk Hawker) from the Westbere region of East Kent hint at the presence of a newly-established population of the species that might well be of immigrant origin (another, confirmed, new population at Paxton Pits, Cambridgeshire, is more likely to be of local derivation).

Account of species

Notable sightings reported to the BDS Migrant Dragonfly Project during 2012 or 2013 are detailed below; background meteorological information is from the Met Office (2014). For details of events during 2011, see Parr (2012).

Chalcolestes viridis (Vander Linden) – Willow Emerald Damselfly

A recent colonist since 2007 (Cham *et al*., 2014), *Chalcolestes viridis* continued its range expansion in south-east England during the recording period, with several new sites reported from Essex, Suffolk and Norfolk. Such expansion was in general relatively unspectacular, though there were hints of something less expected during August 2012. An anonymous report of an individual at Sutton Gault in Cambridgeshire on 8 August was thus potentially the first record for the county, though unfortunately further searches failed to re-locate the species and confirm the original sighting. The habitat in the area is, however, suitable. On 27 August 2012 a further individual, seen only briefly and thus perhaps best treated as a 'probable', was noted by an experienced observer near Biggleswade, Bedfordshire (RR). This again is a potential first for the county. Unfortunately, no further sightings were made from either Cambridgeshire or Bedfordshire during 2013, so the precise status of the species in these two counties remains unclear. The absence of further sightings cannot, however, be taken as showing that the original records were erroneous. A female was, for instance, photographed at Culford in West Suffolk on 20 August 2012 (AP), setting the then western boundary for the species in the county. This individual was never seen again, nor any offspring noted in 2013, despite this being a well-watched site. The discovery of another individual only a kilometre away at Lackford Lakes on 14 August 2013 (JRi), does, however, suggest that the species has genuinely become established in the area. It will be interesting to follow developments in the next few years to see whether more substantial range expansion does now start to take place.

Lestes barbarus (Fab.) – Southern Emerald Damselfly

The following records have been accepted by the Odonata Records Committee:

15 July–13 Sept. 2012	Small numbers at Cliffe Marshes, Kent (J. Hunter, T. Hanson *et al*.)
1–27 Sept. 2012	Up to ten at Winterton Dunes, Norfolk (T. Needham *et al*.); oviposition noted
6 Sept. 2012	Male at Horsey, Norfolk (P. Heath)
24 July–1 Aug. 2013	Small numbers at Cliffe Marshes, Kent (P. Saunders *et al*.)
26 July–7 Sept. 2013	Up to ten at Winterton Dunes, Norfolk (S. Chidwick; P. Heath *et al*.); oviposition noted

Records from Cliffe refer to the putative breeding colony that has become established here over the last few years (Parr, 2012). Although only small numbers were seen at any one time, the damselflies often proved elusive, and with much suitable habitat present it is likely that the colony is larger than first apparent and that it will continue to do well. Away from this site, all other documented records came from the Norfolk coast. Individuals have been seen at Winterton on several occasions since the species was first noted as new to Britain from this site in 2002 (Nobes, 2003). The late observation dates during 2012, and the unexpected simultaneous presence of *Ischnura pumilio* (Scarce Blue-tailed Damselfly) (see below), rather suggest that the 2012 records at Winterton refer to fresh immigrants. The sighting of an individual some 2 km away at Horsey during the same period would also be in line with this. Oviposition was noted on 3 September 2012 (SCh) and over the weekend of 7–9 September 2012 (RF) and it seems likely that these breeding attempts at Winterton were successful, with further sightings being made in 2013. Once again, oviposition was observed (PHe, RC) and it is to be hoped that the sites at Cliffe and Winterton are both now well established.

In addition to the above records, photographic evidence (Anon., 2014) has recently come to light of individuals at a further British site; no precise details were however released. With the species being somewhat cryptically-coloured, the possibility that yet other, overlooked, sites also exist should similarly be borne in mind.

Coenagrion scitulum (Rambur) – Dainty Damselfly

Despite searches by several observers, no individuals of *Coenagrion scitulum* were recorded from the publicly-accessible site on the Isle of Sheppey, Kent (Brook & Brook, 2011) during the present reporting period. With frequently indifferent weather during the springs of (particularly) 2012 and of 2013 (Met Office, 2014) it is, however, not totally clear whether the species has genuinely been lost from this site. The species does certainly remain in the area. Some 7–8 individuals, including two ovipositing pairs, were noted at one of the nearby private sites on 20 June 2012 (JGB), whilst during 2013 nine ovipositing pairs were seen on 19 July, with a new site holding at least two males and a female also being found nearby (JGB). This is the fourth known modern site for the species, all in the Isle of Sheppey area.

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

Erythromma viridulum spread rapidly throughout southern and eastern England in the years immediately following its first appearances in Essex during 1999 and the Isle of Wight during 2000. This process was seemingly aided by, but was

not solely dependent upon, further waves of immigration. Around 2007/2008 the rate of range expansion then slowed considerably (Cham *et al*., 2014). The discovery of 50+ at the Penclacwydd WWT Reserve, Carmarthenshire, on 19 August 2012 (RT) was thus a significant event, in being the first record for Wales and also the first sign of major range expansion for several years.

In addition to range expansion, there was also some evidence for limited further immigration along the East Anglian coast during the reporting period, with fluctuating numbers suggestive of small influxes being noted at Eccles-on-Sea, Norfolk, during late July–mid September 2012 and during August 2013 (NB). One was also attracted to a moth-trap at Minsmere, Suffolk, on the night of 9 August 2013 (RH), while two were noted on *Artemisia vulgaris* (Mugwort) along the coastal sea defences at Walberswick, Suffolk, at the start of September 2013.

Ischnura pumilio (Charp.) – Scarce Blue-tailed Damselfly

Although this species is known to show dispersive tendencies under appropriate conditions, few signs of any major movements had been noted from the UK over recent years. Late summer 2012 was, however, to see this situation change. On 31 August a single female was noted at Tor Woods, Devon (per DSm), this being some distance away from previously known sites in the county. Small numbers seen at Badminston Gravel Pits, Hampshire, during early September (PW) were also new for that site. Finally, and more dramatically, an arrival was noted on the Norfolk coast during early September, a significant observation given that the species does not normally occur in East Anglia. Up to three (and possibly more) were observed at Winterton Dunes over 3–8 September (SCh *et al*.), with a pair in tandem photographed on 3 September (SCh). Up to four were also seen at Eccles-on-Sea, some 15 km away, during the period 6–17 September, with a pair in tandem noted on 9 September (NB). Given the simultaneous appearance of *Lestes barbarus* at Winterton, it is likely that records from Norfolk refer to immigrants from the Continent, though the origin of the individuals seen elsewhere is less clear.

During 2013, up to six were reported from Eccles-on-Sea over the period 1 July–1 August (NB), suggesting that the species had bred successfully at this new Norfolk site. However, the long-term future of the colony remains uncertain.

Aeshna affinis (Vander Linden) – Southern Migrant Hawker

During the present reporting period, numerous records were received from the greater Thames Estuary area, clearly relating to the recently-established breeding population in this region. During 2012, the only report from Hadleigh

Country Park, Essex – where breeding had been rigorously proven during the previous season (Chelmick, 2011) – was of two immatures, probably of this species, seen on 15 July (TC). Being a venue for the 2012 London Olympic Games, this site was however avoided by most observers during the summer. Nearby, confirmed records of mature adults were to be made during mid–late August at Wat Tyler County Park (NP *et al*.), West Canvey Marsh RSPB Reserve (MO *et al*.) and at Vange Marshes (per NP). Up to five or more individuals were present at many of these sites and mating was observed at West Canvey Marsh on 18 August (KP), with additional unconfirmed reports from elsewhere. Slightly further afield in Essex a male was seen and photographed at Rainham Marshes over 4–12 September (JHo) and there was a report from Blue House Farm NR, North Fambridge on 3 September (GS). On the Kent side of the Thames Estuary there were records from the Isle of Sheppey on 22 July (TC) and at Cliffe during mid August (THa, JY *et al*.). Mating was observed at the latter site on 10 August (THa), on which date up to four individuals were present there.

During 2013, records were again received from several sites in south Essex/ north Kent, though they were slightly less numerous than during 2012. In Essex, four adults, including an ovipositing pair, were noted at Hadleigh Country Park on 24 July (DC), small numbers were seen at Wat Tyler Country Park over 2–9 August (NP *et al*.) and two were present at Canvey Wick on 8 August (JWr, TB), with one at West Canvey Marshes on 19 August (NCh). In north Kent, a male and a female were noted at Cliffe Marshes over 3–4 August (MB, GH), with a male seen on 4 September (TL).

Aeshna affinis is clearly continuing to do well in the greater Thames Estuary area, though 2012 was a more eventful year than 2013. Following the large immigration into the area during 2010, it should be remembered that the following year was also relatively low-key. Taken together, these two facts may suggest that the life-cycle in our region is predominantly two years in length, so that currently the largest numbers of dragonflies are noted at two yearly intervals, in ‘even’ years, with only smaller numbers of individuals appearing during the intervening ‘odd’ years.

Away from the Thames Estuary breeding colonies, one record from Norfolk was accepted by the Odonata Records Committee.

8 Sept. 2012 Male at Strumpshaw, Norfolk (P. Philp).

The origin of this individual remains uncertain; it may well have been a fresh immigrant but there are other recent Norfolk sightings, so that a locally-bred individual cannot be totally excluded.

Aeshna mixta Latreille – Migrant Hawker

Evidence of significant migration was noted on the east coast of England during 2012, particularly during late August–early September. A male was seen on Inner Farne, Northumberland, on 18 August (GD) – this being one of the few records of the species from the Farne Islands – while an "influx" of 50+ was observed at Sandwich Bay, Kent, on 28 August (SBBOT) during a period of southerly winds. Some 150 were noted at Blue House Farm NR, Essex, on 3 September (GS) and records peaked at 60+ at Orfordness, Suffolk, on 8 September (MM). A "good influx" was also noted at Beachy Head, Sussex, during the first week of September (JC). In addition to these daytime sightings, several *Aeshna mixta* were also caught in UV moth traps during high summer, these records potentially also referring to migrants (Parr, 2006). A male was trapped at Lade, Kent, on the night of 30 July (PTr), whilst in East Suffolk, individuals were trapped on 20 August both at Ipswich (NS) and nearby Bawdsey (MD); a single *A. mixta* was also caught at Bawdsey on the night of 23 August (MD).

In contrast to the events of 2012, few signs of large-scale movement were noted during 2013. One individual was, however, attracted to a moth-trap at Bawdsey on the Suffolk coast on the night of 1 October (MD).

Anaciaeshna isoceles (Müller) – Norfolk Hawker

During 2012, single individuals of *Anaciaeshna isoceles* were reported from Paxton Pits, Cambridgeshire, on 10 June (ID) and from Chislet, Kent, on 13 June (MH). The preceding year had seen records at both Paxton Pits and from just a few kilometres away from Chislet, at Stodmarsh, Kent (Parr, 2012). This coincidence of unusual sightings immediately raised the possibility that newly-established breeding colonies might now be present in both Cambridgeshire and Kent. Confirmation of a new colony at Paxton Pits was indeed obtained during 2013, when exuviae were discovered on 7 June and in the days thereafter, with adults being seen from 19 June (ID). In Kent, up to five individuals were noted at Westbere from 14 July 2013 (DSa), with ovipositing being reported on 15 July (MH). Since this site is again in the Chislet/Stodmarsh area, the evidence for local breeding in this region, whilst not as strong as at Paxton Pits, is now also starting to become compelling.

It would appear that *A. isoceles* is currently starting to establish itself in areas away from the well-known strongholds in Norfolk and Suffolk. In addition to the records from Cambridgeshire and Kent, unusual sightings were also made during 2013 at Potton Wood, Bedfordshire, on 3 June (IW) and at Thompson Water, West Norfolk, on 16 July (per PTa). It seems plausible that the west Norfolk sighting and the new Cambridgeshire population have originated from

individuals dispersing away from the Norfolk Broads area (with the Potton Wood individual, in turn, perhaps having come from Paxton Pits?), whilst the new Kent population might ultimately be of immigrant origin.

Anax ephippiger (Burmeister) – Vagrant Emperor

Following the major immigrations of *Anax ephippiger* into Britain that took place during both spring and autumn 2011 (Parr, 2011), there were to be no sightings of the species during 2012. Another major influx was, however, noted during 2013. A female was photographed at Godolphin Woods, Cornwall, on 12 August 2013 (CM) but it was not until the autumn that most dragonflies arrived. On 25 September a female was noted near Zennor, Cornwall (SCm), whilst a day later there was a record from Geosetter in the Shetland Isles (RM). On 6 October, individuals were seen at Hilfield Park Reservoir, Hertfordshire (SM), and at Gunton, Suffolk (AE), while on 9 October another, probably different, individual was seen in Suffolk at Lowestoft (PTh). Around the same time in October, a male and a female turned up at Bovey Heathfield in Devon (JWa). Unlike previous sightings during autumn 2013, which had referred to individuals present for just a single day, the dragonflies at Bovey stayed around for some considerable time, with the last record being a brief sighting of a/the female on 12 November (JWa); ovipositing was noted on at least two occasions (KP, JPS). Yet further *A. ephippiger* started appearing in Britain towards the end of October. A male was seen at Hanham, near Bristol, on 25 October (RL), with another male at Newport, Monmouthshire, on the same day (KC) and one at Shoreham Harbour, Sussex, on 30 October (DSa). Further Welsh records came on 12 November, when a male was photographed near Nantyffyllon, Glamorganshire (CF), and on 13 November when a female was noted at Aberystwyth, Ceredigion (DMK). The final record for the year was an individual found freshly dead at Muxton Marsh, Shropshire, on 23 November (GSH). In addition to all the British records of *A. ephippiger* during 2013, there were also unprecedented numbers observed in Ireland. These records are described by O'Sullivan (2013).

Anax ephippiger was first recorded in Britain during 1903 (Cham *et al*., 2014), then, after a few further sporadic occurrences, the species went through a period in the 1980s and 1990s when it was recorded nearly annually. However, such records generally involved only small numbers of individuals. There then followed a quieter phase but immigration now seems to be increasing once more. The growth of interest in dragonflies over recent decades complicates interpretation, but the occurrence of three very substantial migratory influxes over the period 2011-2013 rather suggests that the numbers arriving in Britain may now be greater than at any time in the recent past. This could involve heightened population levels in source areas – likely to ultimately be sub-Saharan Africa (Cham *et al*., 2014) – and perhaps also climatic effects closer

to home.

Anax parthenope Sélys – Lesser Emperor

During 2012, there were to be records of *Anax parthenope* from some twenty sites during the year – a slightly above average showing and not a bad number given the often indifferent summer weather. Records mostly occurred during the period 5 July–24 August, though an individual was noted at Tennyson Down on the Isle of Wight on 6 October (MH). The bulk of sightings were to come from southern or south-eastern coastal counties, i.e. Cornwall, Devon, Dorset, Hampshire, the Isle of Wight, East Sussex, Kent, Suffolk and Norfolk. Some inland records were, however, made (notably in Cambridgeshire and Rutland), and there was also a more northerly sighting in Cheshire (PHi). Most individuals observed seem likely to have been primary immigrants, though a few locally-bred individuals were probable also involved. Records were thus received from New Hythe Lakes in Kent, where successful breeding had been noted during 2011 (Parr, 2012), and also from Dungeness, Kent, where the species is now annual and breeding is strongly suspected. Several records of tandem or ovipositing pairs were made during 2012, notably at a private site in Surrey on 11 August (MG), at Blashford Lakes, Hampshire, on 19 August (GP) and at West Langney Level, East Sussex, on 23 August (DSa). This raises the potential for further local breeding in years to come.

Despite the good showing during 2012, rather few records were to be received during 2013. No sightings were apparently made at New Hythe Lakes, Kent, perhaps indicating that the colony there might no longer be extant. Further records were, however, made from Dungeness in Kent and from West Langney in East Sussex, where two males were seen on 22 August (KG). This suggests that some successful local breeding may still have taken place, though records at Dungeness could also include a proportion of fresh migrants. Away from these potential breeding sites, new sightings, mostly referring to single males, were reported from Drift Reservoir, Cornwall (an ovipositing female) on 14 July (CM), Lower Moor Farm NR, Wiltshire, on 24 July (SCo), Morton Bagot, Warwickshire, on 6–7 August (MI) and near Reculver, Kent, on 8 August (MH). In all, records of *A. parthenope* were thus received from six sites during 2013; this is one of the lowest annual totals since the species first appeared in Britain almost two decades ago, though as the species is no longer considered highly unexpected it is possible that some individuals now go unreported.

Given the need for appropriate weather conditions (Parr *et al*., 2004) it is not surprising that the number of migrants reaching Britain each year does fluctuate somewhat. What perhaps is more surprising is the fact that despite regular breeding attempts, some of which have clearly been successful, *A. parthenope*

has not as yet developed anything more than a 'toehold' as a British resident. Perhaps the species is largely an obligate migrant; some populations of the allied North American species, *Anax junius* (the Green Darner), do indeed behave in a somewhat similar manner (Cham *et al*., 2014)

[***Crocothemis erythraea* (Brullé) – Scarlet Darter**

Crocothemis erythraea has been expanding its range northwards in Europe over recent decades, apparently in response to climate change (Ott, 2007). Despite continuing to do well on the near Continent, no confirmed records were made from Britain during the reporting period, the last positive sighting having been in 2004. There was however a record of a 'possible/probable' from the Seasalter Levels, Kent, on 28 June 2012 (SW).

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

This species is noted for sporadic irruptions that have, in the past, occasionally been of enormous magnitude, though now-a-days events seem to be much smaller (Cham *et al*., 2014). During the current reporting period, small numbers were seen at Landguard on the Suffolk coast over 26–28 May 2012, with a peak of 6+ on 27 May (GB). The species does not breed at this site and is normally recorded there less than annually. The present sightings coincided with the arrival at the site of a male *Leucorrhinia pectoralis* (Large White-faced Darter) (see below), and co-migrations of the two species have indeed been reported before (Haritonov & Popova, 2011).

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

A female was photographed at Marazion Marsh, Cornwall, on 17 July 2013 (CM); this is the first confirmed record for the county. *Libellula fulva* is currently expanding its range within Britain quite dramatically (Cham *et al*., 2014), though the Cornish individual might potentially be of continental rather than local origin.

***Orthetrum coerulescens* (Fab.) – Keeled Skimmer**

In recent years, this species has been noted from unexpected localities on a number of occasions, records probably referring to individuals dispersing away from their natal areas as a result of periods of warm, dry weather making the local habitat less favourable. Although little of note was reported during 2012, the summer of 2013 saw a number of such unusual sightings. A male was seen at Spurn Point, East Yorkshire, on 16 July, whilst inland in Yorkshire there were to be two further records of singletons seen during July at sites (Timble Ings

and Skipwith Common) well away from known strongholds for the species (per THu). In addition to these unexpected records from Yorkshire, two males were seen at Winterton Dunes, Norfolk, during early August (PHe) and the first record for modern-day Lancashire was made when a male was seen at Grindleton Pool, near Clitheroe, on 8 August (AHo). It seems likely that both wanderers from within Britain and, at least on the east coast, immigrants from the near Continent, may have been involved in the various sightings.

Leucorrhinia pectoralis (Charp.) – Large White-faced Darter

The following records have been accepted by the Odonata Records Committee; they represent only the second- and third-ever confirmed British sightings of the species, though occasional atypical records of immigrant '*Leucorrhinia dubia* (White-faced Darter)' from the east coast of England (e.g. Imms, 1900; Mendel, 1992) might just conceivably relate either to this species or to the related *L. rubicunda* (Northern White-faced Darter).

27 May 2012	Male at Landguard, Suffolk (G. Bennett)
16–19 June 2012	Male at Docwra's Dyke, Dunwich Heath, Suffolk (E. Beaumont, C. Ireland *et al*.)

The arrivals in the UK formed part of a large movement of *Leucorrhinia* species that took place in northwest Europe during late May/early June 2012; further details can be found in Parr (2013). The movement was dominated by *L. pectoralis* but *L. rubicunda*, and possibly small numbers of other *Leucorrhinia* species in addition to *Libellula quadrimaculata* (Four-spotted Chaser), were also involved.

Sympetrum danae – Black Darter

This species frequently shows a degree of internal dispersal within Britain and a male seen at Middleton Lakes RSPB Reserve, Warwickshire, on 11 September 2012 (MP, JRe) was the first county record since 2009, while a male seen at Birkdale Frontal Dunes, Lancashire, on 28 September 2013 (PS) was the first record from the site since 2010.

In addition to these records, a significant immigration, presumably from the near/mid Continent, was also noted on parts of the east coast of England during autumn 2013. Two males were reported from Gibraltar Point NNR, Lincolnshire, on 22 September (per NL). A major arrival was then noted on the coast of north-east Suffolk (a county where the species is not resident) during subsequent weeks. A male was, for instance, discovered at a site near Corton

on 26 September (AE), on a day that saw major arrivals of migrant birds of easterly origin on Britain's east coast. More thorough searches in subsequent days eventually revealed over 20 males to be present on 7 October (NM); this is more than all other Suffolk records for the past 50 years put together. In all, the influx was noted from some 5 sites along a 40km stretch of coast in the Lowestoft–Minsmere region but, apart from the site near Corton, other records referred just to singletons. The last Suffolk records of the year away from Corton were from Kessingland (LBC) and from Minsmere (PF) on 7 October, but at Corton itself individuals lingered on until 27 October. Interestingly, all reports during the influx referred to males, no females at all being recorded.

Sympetrum fonscolombii (Sélys) – Red-veined Darter

As has now become the norm, the reporting period was to see numerous records of *Sympetrum fonscolombii*, a species that was once only an occasional and erratic visitor to our shores (Cham *et al*., 2014). The 2012 season in particular was to produce a number of highlights.

During the spring and summer of 2012, records of mature adults were made from some 40 sites in Britain, with several waves of immigration clearly being involved (Fig. 1). Records were well scattered in southern and central England, ranging as far north as Spurn in East Yorkshire (SBO) and Middleton (per PM) and Seaforth (per PS) in Lancashire. There were four reports from Wales (from Glamorgan, Gwynedd, and two sites in Pembrokeshire) and, in addition, one from Scotland (a male on the cliffs near Dunbar, East Lothian, on 8 June (NCl), this being one of only a handful of all-time Scottish records). Counts at individual sites were generally in the region of 1–10 individuals, and there were several reports of breeding behaviour with other instances likely to have been missed/over-looked.

Sympetrum fonscolombii is known to have at least two generations per year in warmer parts of Europe and, on 11 August, a fresh immature female briefly landed on a fishing boat about 20km north-east of the Scilly Isles (RD). This individual was probably a migrant from more southerly regions of Europe but a successful second generation was soon also noted in Britain. During mid August–mid September, exuviae, emergents or fresh tenerals were thus discovered at Windmill Farm in Cornwall (CM *et al*.), Crookham Common in Berkshire (AHi), Badminston in Hampshire (PW), Plaitford Common in Wiltshire (SCo), a brownfield site near Severn Beach in South Gloucestershire (VS), and at Felbrigg in Norfolk (SCh). Counts at some sites were particularly high, with 250+ exuvia being found at Crookham Common, 120 exuviae at Badminston and with three-figure counts of tenerals/immatures at the site near Severn Beach. As expected (Cham *et al*., 2014), such emerging individuals did not

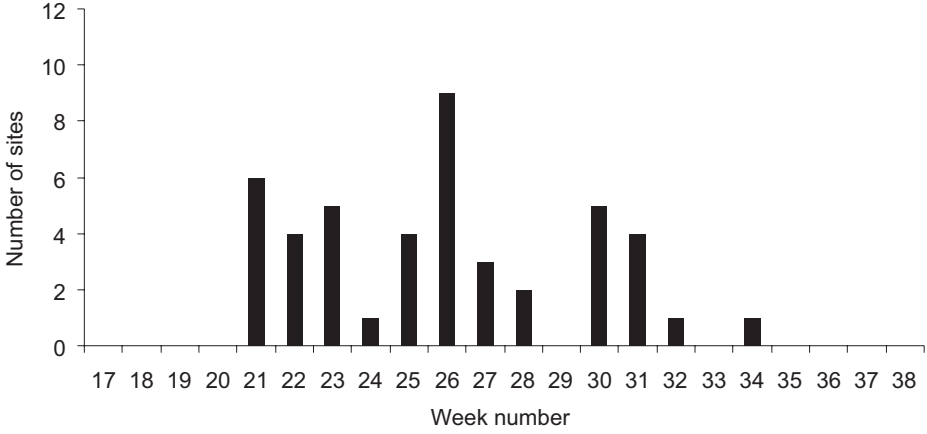

Figure 1. Temporal spread, by week, of new site records for adult *Sympetrum fonscolombii* (Red-veined Darter) during 2012. Week number 20 refers to the period 14–20 May, week number 30 to the period 23–29 July.

stay around to breed but, instead, clearly dispersed away from their natal sites. Such dispersing individuals presumably helped account for the several autumn records also made away from known breeding sites, though fresh immigrants from the Continent were probably also involved. The last record of the year was an immature female noted at Lower Pennington, Hampshire, on 7 October (PW).

During 2013, the season started with the discovery of a single teneral male at Victoria Park, Greater London, on 1 June (SH). This presumably was derived from a local breeding attempt made during the summer of 2012 but one where a one-year developmental period was involved, rather than the more rapid development seen at some other sites that year. Mid June–late July then saw a sizeable immigration into Britain, with records from Cornwall (four sites), Somerset, Dorset, Hampshire, the Isle of Wight, Kent (three sites), Norfolk, Lincolnshire, East Yorkshire (two sites), Warwickshire, Worcestershire, Gloucestershire (two sites), Staffordshire, Lancashire and Glamorganshire. The peak count was of 25+, including three ovipositing pairs, seen at Sandwich Bay, Kent, on 30 June (SBBOT). In contrast to the events of 2012, after the significant spring influx records in the subsequent autumn were then considerably patchier, with generally only isolated individuals putting in an appearance. The period early–mid October did, however, produce a more concerted run of sightings, with records from Cornwall, Dorset, West Sussex, East Sussex and two sites in Glamorganshire. At Llanilid, Glamorgan, around a dozen immatures were present on 11 October (AHu), with at least three immatures also present on 20

October (PR); this strongly suggests a locally-bred population. Breeding may also have taken place at Windmill Farm in west Cornwall. The last record of the year was a mature female seen in the northern New Forest, Hampshire, on 4 November (PW).

***Sympetrum vulgatum* L. – Vagrant Darter**

The first British record since a female was seen at Dawlish Warren, Devon, on 6 September 2007 (Parr, 2008) was made when a male was attracted to a moth-trap on the east Kent coast in early September 2013.

4-5 Sept. 2013	Male to UV light overnight at Kingsdown, Kent. (N. Jarman)

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

Several observations rather suggestive of immigration were made in East Anglia during 2012. On 24 July, high numbers were noted along the cliff edge, on the beach and in coastal *Ammophila arenaria* (Marram Grass) in the Kessingland area of Suffolk, at a time when many dead hoverflies were also found along the strandline (CJ). Later in the season, many hundreds were present at Swanton Novers, Norfolk, on 15 September and 200+ were noted at Orfordness, Suffolk, during early October (MM). In addition to these daytime sightings, there were several records of individuals attracted to UV moth traps overnight, which may potentially also be related to migration (Parr, 2006). A male was thus caught at Bradwell-on-Sea, Essex, on the night of 17 September (SD), whilst at Bawdsey, Suffolk, individuals were caught in UV moth traps on the nights of 8 September and 2, 18 and 23 October (MD). Outside of East Anglia, one was also attracted to light at Portland Bill, Dorset, on the night of 23 August (MC).

During 2013, few large aggregations or obvious signs of directional movement were noted. An even greater number of individuals was, however, attracted to UV moth traps in southern England than during 2012. Records included one at Little Treleaver, Cornwall, on 19 September (JF), three singletons at Portland Bill, Dorset, between 6 & 11 August (MC), two at Bradwell-on-Sea, Essex, on 24 August with singles on 4, 25 & 29 September and 1, 8 & 19 October (SD), plus individuals at Bawdsey, Suffolk, on 8, 12 (three) & 18 October (MD).

Conclusions

The period 2012–2013 saw generally high levels of immigration, most often involving species of southerly origin. *Sympetrum fonscolombii* in particular produced major influxes during both years and a substantial arrival of *Anax*

ephippiger also took place in autumn 2013. Some rarities of more easterly origin, such as *Leucorrhinia pectoralis* and *Sympetrum vulgatum*, also appeared during the reporting period. By contrast, *Sympetrum flaveolum* was not recorded, and it is now some seven years since the last major influx of this well-known migrant species. In addition to immigration from the continent, several instances of significant local dispersal within Britain were also noted during 2012–13, most likely in response to weather conditions affecting habitat suitability.

As with many of the migrant species, our new colonists also did well during the reporting period, though, apart from *Chalcolestes viridis*, many still remain highly localised in distribution. Records clearly show that Britain's dragonfly fauna remains in a state of considerable flux, most likely due, at least in part, to ongoing climatic change. It is highly likely that further major immigrations and/or the appearance of yet more new colonist species will occur in the very near future.

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The effect of temperature, solar radiation and latitude on the emergence patterns of 'spring' species in the south and midlands of Britain.

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Summary

Climate data for Devon, Dorset and Northamptonshire were obtained and compared to evaluate any differences that could explain why first emergence in the south of England is regularly 10-14 days ahead of that in the midlands (A. Parr, 2010, 2011, 2012, 2013). It was found that the average monthly temperatures for all three counties were no different in 2011, a year in which the spring was defined as 'warm' in a previous study (Tyrrell, 2012), implying that temperature alone cannot explain why emergence is earlier in the south. Solar radiation levels (kWh/m^2/day) were compared and were found to be higher in the southern counties than in Northamptonshire. Thus the conclusion is drawn that, although temperature plays a significant role in determining the timing of emergence for a particular species in a given locality, solar radiation may be the primary factor in determining why emergence in any one year occurs earlier in the south of the country.

Introduction

Tyrrell (2012) considered the impact of day length and temperature as possible primary factors governing the first emergence of 'spring' species. It was established that, while warm springs were shown to lead to earlier emergence, in cold springs emergence occurred at the same time as in average springs. Thus spring air temperature is only an important factor if it is high, under which conditions day length (which increases with increase in latitude after the Spring Equinox) appears not to be important. Thus higher temperatures were suggested as perhaps the reason why southern counties of England regularly see first emergence some weeks earlier than the Midlands. However, in cooler springs, day length may become a critical factor for determining emergence (Tyrrell, 2012). Tyrrell (2012) also suggested that sun intensity may play a role.

M. Parr (2013) argued, that of the species chosen by Tyrrell (2012), *Ischnura elegans* and *Enallagma cyathigerum* do not meet the criteria for 'spring' species

as defined by Corbet (1954, 1962, 1999), in Lancashire. However, Tyrrell (2013) considered that, although these two species cannot be described as 'spring' species using Corbet's criteria (e.g. Corbet, 1954), the synchronised emergence in the spring in Northamptonshire suggests that the larvae are behaving like 'spring' species in that they appear to be responding to the same emergence cues as those 'spring' species listed by Corbet & Brooks (2008) (Table 1), all of which show highly synchronised emergence in spring.

Table 1. 'Spring' Species, as listed by Corbet & Brooks (2008)

Anisoptera	Zygoptera
Anax imperator	*Calopteryx virgo*
Brachytron pratense	*Erythromma najas*
Cordulegaster boltonii	*Pyrrhosoma nymphula*
Cordulia aenea	
Somatochlora arctica	
Somatochlora metallica	
Gomphus vulgatissimus	
Leucorrhinia dubia	
Libellula depressa	
Libellula fulva	
Libellula quadrimaculata	
Orthetrum cancellatum	
Orthetrum coerulescens	

Recording first emergence dates is very dependent on observer effort and reliable data are difficult to obtain. While there is regular competition to record the first sighting of each species, as illustrated in A. Parr's regular article in Dragonfly News (A. Parr, 2010, 2011, 2012, 2013), to compare species and counties directly is not possible, since accurate first emergence dates require specific and regular searches for emergence over an extended period of time and, even then, there is no clear evidence that the actual first emergence date has been obtained. While the three chosen counties are well recorded with enthusiastic and active Vice County Recorders, recorded first dates will vary through factors other than climate variables. However, from reviewing published records (Parr, 2010, 2011, 2012, 2013) and the BDS Hot News pages (British Dragonfly Society, 2014), it is apparent that there is a clear trend, with emergence of 'spring' species generally occurring first in southern counties of England.

Material and Methods

In order to study further the impact of climate and latitude on emergence, data were obtained for the English midlands county of Northamptonshire and the southern English counties of Devon and Dorset. These last two counties were chosen to be representative of southern counties that regularly show earlier emergence than Northamptonshire. Since warm springs were the least likely for latitude to be an important factor, based on information in Tyrrell (2012), the data for one year in which there was a warm, spring, i.e., 2011 (Tyrrell, 2012) were used. The published first emergence dates for 2011 were compared for eleven species that are either 'spring' species (as noted in Corbet & Brooks (2008)) or that show behaviour similar to such 'spring' species (Table 2). The number of days before first emergence in Northamptonshire was also noted for each species.

Temperature data were obtained (Dawlish Weather, 2014; Pitsford Hall Weather Station, 2014 and Poole Weather, 2014) and analysed to see if there was any significant differences between the counties.

The earth receives a reasonably constant 1370 Wm^2 of solar energy (termed the Solar Constant) which is modulated by absorption, scattering by dust particles, cloud cover and latitude, among other factors (Burgess, 2009). Data for regional solar radiation levels are not frequently recorded by the vast array of weather stations across the UK and, when it is, there are disparities between the methods used. Averaged regional radiation levels are quoted in connection with the solar panel industry (Greenstream Publishing, 2014) and these were compared for the three counties, to determine any differences in the sun's intensity between them which may contribute to an explanation of differences in emergence times. However, data from these sources are not rigorous enough for statistical analysis.

Results

Of the eleven county records (other than from Northamptonshire), nine are from southern counties, the other two are from midland counties (i.e. *Brachytron pratense* in Bedfordshire and *Calopteryx splendens* in Warwickshire, these two counties being at a similar latitude to Northamptonshire). In the case of *B. pratense* the date of first emergence in Northamptonshire is quite noticeably later than in Bedfordshire (11 days) but for *C. splendens* the difference was only two days after being recorded in Warwickshire.

In all cases, emergence in Northamptonshire is later than in the southern

Table 2: First emergence dates for 'spring' species in 2011. Data from Parr (2011). *, 'Spring' species listed in Corbet & Brooks (2008)

Species	County	Date	Days before Northamptonshire
**Pyrrhosoma nymphula*	Cornwall	27/03/2011	21
**Libellula quadrimaculata*	Devon	09/04/2011	12
**Brachytron pratense*	Bedfordshire	10/04/2011	11
Coenagrion puella	Carmarthen	15/04/2011	11
Ischnura elegans	Dorset	16/04/2011	7
Enallagma cyathigerum	Dorset	16/04/2011	6
**Libellula depressa*	Devon	16/04/2011	12
**Cordulia aenea*	Dorset	17/04/2011	13
Calopteryx splendens	Warwickshire	20/04/2011	2
**Erythromma najas*	Somerset	22/04/2011	5
**Libellula fulva*	Sussex	26/04/2011	11

counties; from between five days for *Erythomma najas* to as much as 21 days for *Pyrrhosoma nymphula*. This trend is also observable for other years (e.g. A. Parr, 2010). However, it is recognised that these published dates cannot be treated as absolute first dates, as noted above.

Yearly temperature data for 2011 for the southern counties studied and for Northamptonshire were compared (Fig. 1) and an ANOVA carried out on the data to determine whether there is any statistical evidence of differences in temperature. For April 2011, the differences between Northamptonshire and Dorset and Devon were not significant ($P = 0.220$ and $P = 0.586$ respectively). In other words the spring temperatures were no different between the study counties. Thus temperature differences in spring cannot explain the earlier emergence dates in southern counties compared to Northamptonshire. However, some differences were apparent, with Dorset being noticeably warmer during the summer months (Fig. 1).

From the available solar radiation data for Britain it can be seen that the U.K. can be separated into approximate bands of solar intensity that show a clear decline with increase in latitude (Fig. 2) (SolarGIS, 2014). The bands run approximately south-west to north-east and are particularly well marked in the southern half of Britain. However, the pattern is disrupted, with western coastal areas receiving higher levels than further inland and areas of higher elevation generally receiving lower levels.

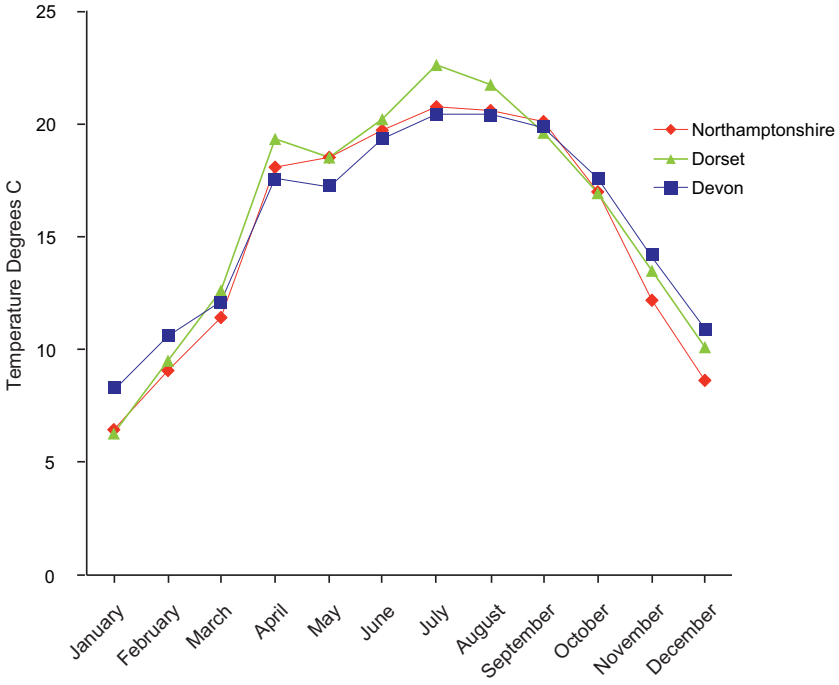

Figure 1: Average monthly temperatures for Northamptonshire, Devon and Dorset in 2011.

Comparing the solar radiation levels for the two southern counties with Northamptonshire it is apparent that Northamptonshire receives the lowest light intensity, with an average of 950kWh/m^2, whereas Dorset and Devon receive 1050kWh/m^2.

This difference is shown in more detail by the county data published by Greenstream Publishing (2014) (Fig. 3). Winter radiation levels appear very similar between the counties but differences are particularly noticeable in spring and summer (from March to September), when Northamptonshire receives significantly reduced solar radiation compared to Dorset and Devon.

Discussion

The factors that stimulate first emergence in odonates are clearly complex. Tyrrell (2012) established that, for a given site, higher temperatures cause earlier emergence. There is also evidence to show that emergence occurs earlier in southern UK counties than in midland or northern

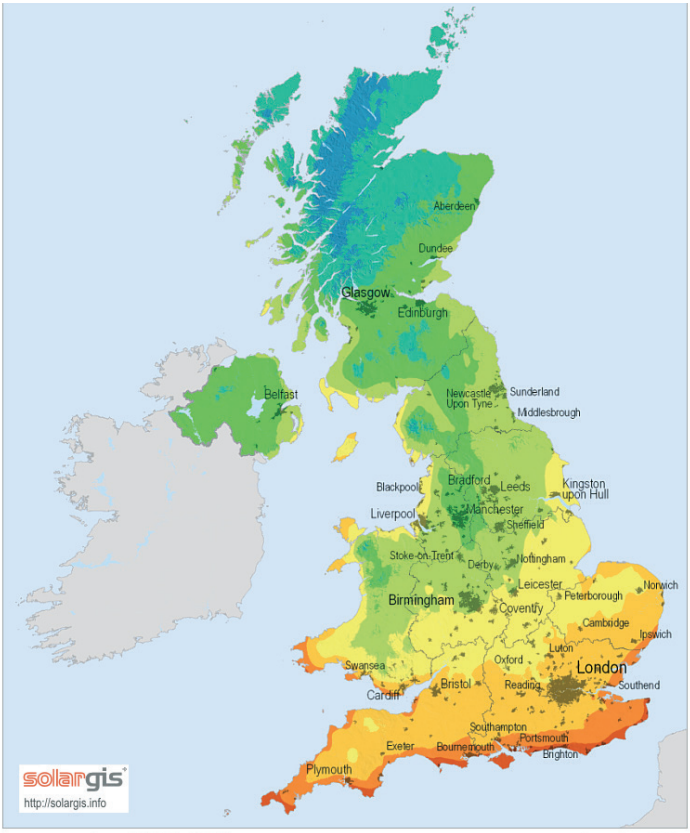

Fig 2: Solar radiation bands across the UK. SolarGIS © 2014 GeoModel Solar

counties (e.g. Parr, 2011) and it has been considered that this is because these counties are generally warmer. However, analysis of the temperature data obtained for this study has shown that, for a given year, there is no evidence to suggest that average spring temperatures were any different between the two southern counties (Devon and Dorset) and a midlands county (Northamptonshire). Hence, for a given year, temperature alone cannot explain why emergence is earlier in the southern counties. However, there is a correlation between higher solar radiation levels in the south and earlier emergence.

Corbet (1999) considered that regulation of growth is controlled by responses to environmental factors such as photoperiod (i.e. day length) and temperature, perhaps working together, although there is some discussion that Odonata in tropical climates are not regulated by photoperiod in the same way because the temperature is sufficiently high for emergence to occur (Corbet, 1999).

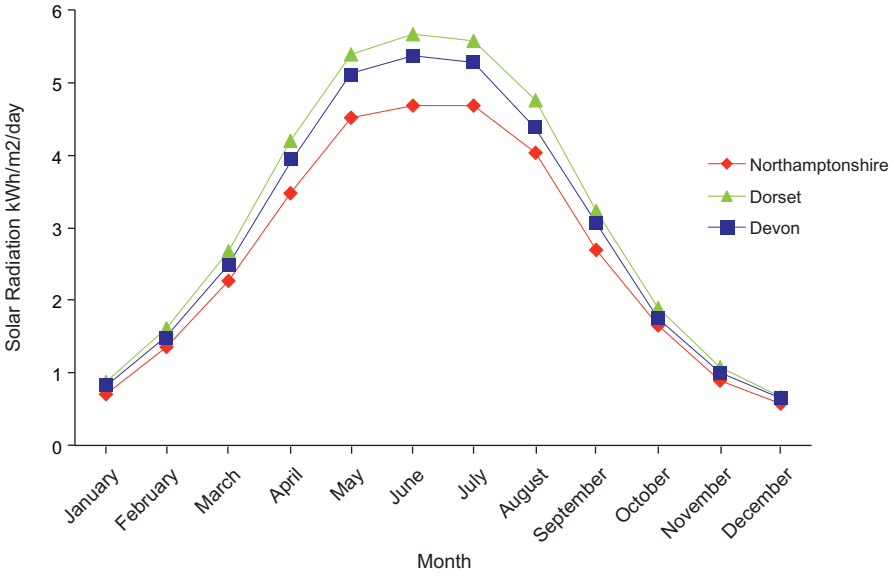

Fig 3: Average yearly solar radiation levels for Northamptonshire, Devon and Dorset.

In temperate regions, Odonata appear to vary their response to photoperiod depending on latitude. Indeed, Norling (1984) showed a compensation for difference in latitude in Sweden for *Leucorrhinia dubia*, a greater day length being required for emergence at higher latitudes. As the day length at a specific time of the year will be the same from year to year, it might be expected that, if photoperiod were the only controlling factor, emergence would occur at the same time each year. Tyrrell (2012) has already established that higher temperatures at a specific site will stimulate earlier emergence so photoperiod alone is not the only controlling factor. In this study, temperature differences have been negated when considering emergence at two different latitudes in England, and an association between solar radiation levels and emergence has been established.

Both photoperiod (day length) and light intensity increase as the year progresses from winter to spring, increasing their cumulative effect. If a period of unseasonably sunny weather is experienced for a given time of year in one year compared to another, although actual day length will be the same, the cumulative amount of sunlight received will be greater in the former (also the average temperature may be higher). In any event this may promote earlier emergence.

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