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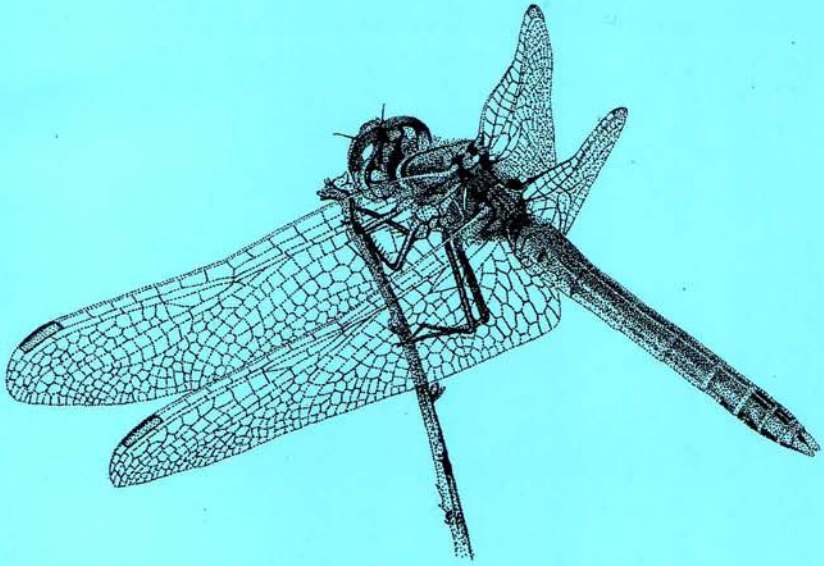

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Front cover illustration: *Sympetrum fonscolombii* by Gill Brook, from a photograph by Peter Allen

Submerged oviposition behaviour in the Large Red Damselfly *Pyrrhosoma nymphula* (Sulzer) on the Isle of Lewis

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Summary

The Large Red Damselfly *Pyrrhosoma nymphula* was observed and photographed in oviposition at two locations on the Isle of Lewis in the summer of 2007. The usual method was for the male, with the female in tandem, to land on a stem of the Bogbean *Menyanthes trifoliata* and then, with both grasping the stem, the female to start laying eggs in the stem, progressing downwards until her abdomen was about half submerged, while always holding her wings clear of the surface. On one occasion a female grasped a leaf with the abdomen three quarters submerged and the wing tips immersed. On 1 July the female of a pair became completely submerged. In all cases the male remained in the sentinel position while contact guarding the female.

Introduction

Contact guarding is normal in most coenagrionids (Corbet, 1999). Complete submergence of the female during oviposition is also the main, or even the exclusive, behaviour for certain members of this family (Corbet, 1999) including some species of *Coenagrion* (Sawchyn & Gillott, 1975) and *Enallagma* (Bick, 1972; Fincke, 1986; Cham, 2008). In some species in other coenagrionid genera it may be facultative, e.g. *Cercion* (Naraoka, 1990) or infrequent, e.g. *Chlorocypha* (Miller, 1995) and *Ischnura* (Matsuki, 1969; Jurzitza, 1986; Fincke, 1987; Kano, 1989; Cordero, 1994). However, there appear to be no published records of the occurrence of complete submergence in *Pyrrhosoma*.

The depth to which submerged females descend varies with the species (Corbet, 1999). For example, *Lestes sponsa* only descends about 1cm (Itô & Eda, 1977), whereas *Enallagma* has been recorded descending to a depth of about 1m (Macan, 1964). The duration of submergence is also variable and can often be between 30min and 1h (Corbet, 1999), as in *Enallagma* (Doerksen, 1980; Miller, 1990); Fincke (1986) reported an average submergence time of 18.4m for *Enallagma hageni*.

The Large Red Damselfly *Pyrrhosoma nymphula* is a typical contact guarding coenagrionid and is one of the commoner and most widespread damselflies in Britain, extending from the south coast of England as far north as the Orkneys (Brooks, 1997). The following is an account of the location, conditions and the sequence of events during oviposition of this species.

The Location

The location was a small depression in the moorland, situated between a burn called Allt Raonadale (100m to the south) and Loch Gillevat (80m to the north). The depression lies 850m from the cliff top on the north-east coast of Lewis (British National Grid Reference NB 512442). The depression is roughly 1m lower in level than the surrounding moor and contains two bog pools surrounded by very damp *Sphagnum* lawn vegetation. The larger pool contains a good growth of bogbean *Menyanthes trifoliata* – plenty to serve as useful perches for oviposition but not so dense as to completely obscure views. The surrounding low bank is considerably drier and the vegetation is mainly composed of heather *Calluna vulgaris*, woolly hair-moss *Racomitrium lanuginosum* and purple moor-grass *Molinia caerulea*. The low bank provides some shelter from the wind and, when conditions are good – which is not very often – it is an ideal location for observing the local Odonata.

Methods

I always take my telescope for more detailed observation and so that I can avoid trampling the margins of the pools, which are fragile. Indeed, all of the vegetation within the depression is delicate and I take care to walk on it as little as possible – barefoot if weather permits. In June and July I approached from the Allt Raonadale (south-west) side of the pools so as not to disturb the pair of Red-throated Divers and their chick on nearby Loch Gillevat. Photographs were taken of the Large Red Damselfly *Pyrrhosoma nymphula* during oviposition sequences. The camera used was a Sony Cybershot, DSC–N2 which provided timing to the nearest second.

Observations

In the summer of 2007 pairs of Large Red Damselflies *Pyrrhosoma nymphula* were observed during oviposition. The normal sequence of oviposition was observed on a number of occasions throughout the summer of 2007. The male remained in contact with the female throughout and adopted an upright stance, the sentinel position. The female then proceeded to lay her eggs in a stem of Bogbean, progressively working her way down the stem but keeping her wings out of the water. On one occasion I observed the female move even lower so that the tip of her wings just broke through the surface film. However, on one occasion (on 1 July) I observed a female submerging completely as she laid eggs in a stem of Bogbean. In both of these instances the male assumed the normal position, contact guarding the female.

Conditions on the morning of 1 July were perfect. There was no wind, and the light was bright and clear. By 0915h the sun was high and had warmed up the ground. The area was audibly humming with the sound of wings. Both Large Red Damselflies and Common Blue Damselflies *Enallagma cyathigerum* were perching on the low banks and flying around the pools. There were many single male Common Blues taking up

positions at the margins of the bogbean pool, whilst the Large Reds tended to perch further back on the heathers of the bank. The Common Blues were particularly aggressive in flight over the pool, and single males frequently harassed pairs attempting oviposition. One Common Blue male became fatally trapped in a spider's web in the bogbean. I photographed both it and a backswimmer lazily eating a bug below the water surface. At 1015h I spotted a pair of Large Reds coming to the pool in tandem and I photographed them in oviposition on a stem at the sphagnum-filled edge. The same pair then quickly moved to a bogbean stem in the water where I photographed them at 1017h. They were the only pair of Large Reds in oviposition that I could see. At that moment a Four-spotted Chaser *Libellula quadrimaculata* flew up from Allt Raonadale and proceeded to fly around the bogbean pool at high speed, dipping its tail-end in the still water and making a considerable noise. The pair of Large Reds flew to another bogbean stem at this point and I noted the position before turning my attention to the Four-spotted Chaser. A second Four-spotted Chaser arrived on the scene and they proceeded to have several very noisy mid-air clashes. The powerful flight and aggressive behaviour of the Chasers was quite electrifying in the little amphitheatre and I was curious to see what effect, if any, this had on the damselflies.

The Submerging Sequence. At 1032h I found a pair of Large Red Damselflies on the stem where I had last seen the earlier pair. I assumed they were the same pair and that they had not moved since the arrival of the Chasers. At this point the female was submerged with about a quarter of her wings immersed. I photographed them at 1032.01h in this position and then took a series of photographs as the female went

Table 1. The timing of the submerged oviposition sequence of a female Large Red Damselfly. At each time in the table a photograph was taken.

Time (BST)	Position of female
10.32.01	Head, body and 1/4 of wings submerged
10.32.17	Head, body and 1/4 of wings submerged
10.32.38	Head, body and 2/3 of wings submerged
10.32.50	Head, body and 3/4 of wings submerged
10.32.59	Head, body and 3/4 of wings submerged
10.33.06	Head, body and all but wing tips submerged
10.33.14	Moment of full submersion
10.33.21	Full submersion
10.34.47	Full submersion
10.34.54	Begins to rise
10.35.06	Head near surface
10.38.17*	Clear of water and moved up the stem
10.38.24	Remain in position on the stem
10.40.04	Remain in position on the stem

* At this point I had to change the camera battery and so missed the exact time of surfacing.

Plate 1. A pair of ovipositing *Pyrrhosoma nymphula* (a) as the female starts to submerge, (b) total submergence of the female, (c) during re-emergence of the female and (d) re-emerged. The plant is Bogbean, *Menyanthes trifoliata*.

further under water (Plate 1). This happened so delicately that the magical circle of tension on the water surface remained until she was fully submerged, remaining so for two or three minutes (Table 1). When she emerged again there were water droplets hanging on her wings. The pair remained on the stem for a minute or two and then flew off in tandem, out of sight in the bogbean leaves at 1040.05h.

Discussion

In a three-year study of *Pyrrhosoma nymphula* at a site in Yorkshire (Skipwith Common), where the oviposition site was densely covered with the leaves of the Broad-leafed Pondweed *Potamogeton natans*, in all but one case the female was contact guarded by a male while she laid her eggs in the stems of the leaves (Bennett & Mill, pers. com.). Although the female submerged a large part of her abdomen as she laid eggs progressively down a stem no instance of complete submergence was recorded. The location of the submerged oviposition sequence in the current study differed in that the female oviposited into stems of bogbean and the density of plant cover was less, thereby allowing a female to submerge quite easily. To the best of my knowledge this is the first reported case of complete submergence in *Pyrrhosoma nymphula*, although it has been witnessed by Steve Cham (pers. comm.), and hence this genus should thus be added to the list of coenagrionid genera where such oviposition is infrequent, such as *Chlorocypha* (Miller, 1995) and *Ischnura* (Matsuki, 1969; Jurzitza, 1986; Fincke, 1987; Kano, 1989; Cordero, 1994). The time that the female was submerged, two or three minutes, was notably less than the average female submergence time in *Enallagma hageni* (Fincke, 1986), which is perhaps what would be expected in a species that does not usually behave in this fashion.

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Three-winged Southern Hawker, *Aeshna cyanea* (Müller, 1767)

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Summary

In June 2007 about two dozen Southern Hawkers *Aeshna cyanea* emerged from my small garden pond. One of the emerged specimens was missing its left forewing and, although the other three were fully formed, it was unable to fly. It is suggested that the damage to the larval wing sheath occurred at a late stage in larval development thereby allowing too little time for sufficient regeneration to take place.

Introduction

When a predator holds on to the leg of an odonate larva (or on to a caudal appendage in a zygopteran) the appendage can be shed near its base by a process called autotomy (Corbet, 1999). In the case of a leg, the autotomy plane is at the base of the femur (Tillyard, 1917; Parvin & Cook, 1968). When such an appendage has been lost it is steadily regenerated, as can be observed at succeeding moults, but tends to remain smaller than the other appendages. Legs and caudal appendages regenerate at a predictable rate (Child & Young, 1903; Baker & Dixon, 1986). There is little information in the case of damage to a wing sheath but some regeneration can occur (Seidenbusch, 1991, 1994).

Observations

Because the weather was very wet and fresh, the emerged imagines spent three to four days on the leaves of *Typha*. After three days the females were bluish and the males had a completely bluish abdomen. Presumably this would change to the mature green colouration after they had matured and the weather had become warmer. However, this reminded me of Sternberg's papers on thermoregulation (Sternberg, 1993, 1996). However, although the bluish colour (androchromic bluish in females) is thought to be an 'overheating-protection' phenomenon, more widespread in southern regions, here it seemed to be a phenomenon caused by cold and wet weather.

After one male had been sitting hidden in the sedges for five days, I collected it to see if there was any problem. When I saw that it had only three wings I knew the reason for its long stay. The left forewing was totally absent and, although its other three wings were fully developed, it was unable to fly. At first I thought it to be an accident and it had lost

Plate 1. Exuvia of the three-winged *Aeshna cyanea* showing the damaged wing bud (⟶).

the wing in escaping from a bird. However, because I could not see a wing base but only a tubercular protrusion I argued that it could have emerged already is this condition. Hence I immediately looked for its exuvia and indeed, using binoculars, I could see that, although the exuvia had four wing sheaths, the left forewing sheath was shrunken and had a dark thickening in its basal third (Plate 1). Detailed examination of the wing sheath revealed that there had been a complete interruption between the basal third and the rest of the sheath.

Discussion

If a developing wing is lost or damaged at a fairly early stage in larval development, the regenerative mechanism can compensate to a certain extent (Seidenbusch, 1991, 1994). However, the resultant imaginal wing may then be shorter and have irregular (chaotic) venation. Thus it is argued that, in the case described here, the damage to the wing sheath must have happened in a very late, or even last, instar and hence there was no time for sufficient regeneration to occur to produce a functional wing. Any attempt to fill the wing with haemolymph during emergence would fail. The reason for complete interruption of all the main veins (costa, subcosta, radius and median) is unclear.

Could the kinked wing sheath have occurred due to an accident? In this small pond there are no fishes, no obvious presence of frogs and few raptorial insect larvae. Baker & Dixon (1986) suggested that increased density of larvae leads to an increased frequency of intra-specific wounding. Hence, I argue that probably the high density of *A. cyanea* larvae in the pond had caused feeding pressure and led to cannibalistic acts; in this case cutting or biting through the veins in the wing sheath.

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Criteria for determining key Odonata sites in Great Britain

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Introduction

A British Odonata recording scheme was initiated by the Biological Records Centre in 1968. Continued by the British Dragonfly Society's (BDS) Dragonfly Recording Network in 1996, this scheme has played an important role in enhancing the understanding of the distribution and status of British Odonata species (Merritt *et al.*, 1996, Daguet *et al.*, 2008). In addition the scheme has sought to develop a register of key Odonata sites to allow better long-term monitoring and protection of important sites. However, despite the initiation of the Key Sites Project (Merritt, 1988), the Rare Dragonfly Project (McGeeney, 1996) and the Key Sites Register Project (Perrin, 1999), the goal of a national register of key Odonata sites has yet to be fully realised.

Through these key sites projects, the national scheme has played a central role in promoting a more rigorous approach to the recording of Odonata. From the onset of the Key Sites Project, the importance of collecting proof of breeding and estimation of population size has been emphasised and promoted through publication of a national recording card and the national scheme's recording software package, DARTER. Over the last 20 years the emphasis on recording breeding and not just presence of Odonata species has resulted in the accumulation of a valuable national source of information regarding the status of breeding populations of Odonata species within British sites.

This article describes the development of criteria for the determination of key Odonata sites in Britain. By emphasising the importance of proof of breeding and estimation of population size, the criteria build upon the approach taken within the national Odonata recording scheme's Key Sites Project, promoting the continuation of recording breeding and abundance evidence and complementing the conservation agencies' criteria for the determination of SSSI designation (NCC, 1989).

Methods and Analysis

In the SSSI criteria for Odonata (NCC, 1989), recognition of a site as a candidate for SSSI designation is based on either the presence of a strong population of one of 18 selected species (Table 1) or the occurrence of an outstanding assemblage of species, as identified from confirmed breeding records gathered over a previous three year period.

In developing key site criteria this approach was followed and updated to include information from sources published since the publication of the SSSI guidelines. The SSSI guidelines were further modified to allow recorders to reasonably assess and monitor Odonata populations at their local sites, taking into account time and resources generally available, as well as practical limitations encountered within sites and in the recording of proof of breeding.

Table 1: The 18 species selected to recognise a site as a candidate for SSSI designation, within the SSSI criteria for Odonata (NCC, 1989).

Zygoptera	Anisoptera
Lestes dryas	*Aeshna coerulea*
Coenagrion mercuriale	*Aeshna isosceles*
Coenagrion scitulum	*Brachytron pratense*
Coenagrion hastulatum	*Gomphus vulgatissimus*
Coenagrion armatum	*Cordulia aenea*
Ischnura pumilio	*Somatochlora metallica*
Coenagrion pulchellum	*Somatochlora arctica*
Ceriagrion tenellum	*Oxygastra curtisii*
	Libellula fulva
	Leucorrhinia dubia

In drawing up these criteria for the determination of key sites, evidence was taken from both the analysis of records held within the national Odonata dataset and from local knowledge provided by vice-county recorders, local Odonata experts and members of the BDS Dragonfly Conservation Group. Analyses followed IUCN recommendation for the determination of threat categories (IUCN, 2001). These recommendations included calculation of area of occurrence (number of tetrads) and extent of occurrence (estimation of area of range) for each species. In addition the total number of species present in each vice-county was calculated. Within these key site criteria the main changes made in respect to those given in the SSSI guidelines were:

1. Local areas were redefined to incorporate areas covered by Local Record Centres and Wildlife Trusts, while taking into account current coverage provided by Odonata vice-county recorders.
2. Species deserving individual representation in site selection were re-assessed in accordance with the updated IUCN threat categories used in the revision of the Red Data List for Odonata (Daguet *et al*, 2008, Taylor, 2008). In accordance with the approach taken by previous key site projects, this list of species was extended to include species assessed as deserving recognition at a local level.
3. Number of species regarded as an outstanding assemblage at a local level were

re-assessed by analysis of records held in the national dragonfly database and from knowledge provided by local Odonata experts.

4. Evidence needed to determine the presence of a breeding population was broadened to include a number of Odonata stages. Evidence of breeding was defined according to criteria set out by the Dragonfly Conservation Group (Taylor, 2003).
5. A strong population was defined subjectively according to the abundance categories used in the national recording scheme's RA83 Odonata recording card.
6. The period of recording over which sites are assessed was increased from three to ten years to allow for a realistic time frame.
7. Sites not fulfilling key site criteria were recognised as probable or possible key sites to indicate their unconfirmed value and to encourage further monitoring of these sites.

Definition of local areas

To allow these criteria to be used for the identification and management of local sites of conservation importance, 39 local areas were defined. These areas were defined by combining one or more vice-counties, to match Local Record Centres and Wildlife Trusts areas where possible. With the present limited number of Scottish Odonata recorders, further division of Scotland into a number of local areas was not thought appropriate. As limited information was available for the Channel Isles, Isle of Man, Greater London (vice-county of Middlesex) and Northern Ireland these areas were excluded from the criteria. It is hoped that with improved information these areas may be included in future revisions of the criteria.

Nationally important species

Species of national importance were redefined according to the list of species recognised as under threat in the latest revision of the Odonata Red Data List (Daguet *et al*, 2008, Taylor, 2008). This list, including 12 species recognised within the SSSI guidelines and 13 species recognised within the Rare Dragonfly Project (McGeeney, 1996), consists of four species regarded as 'Endangered' (*Coenagrion mercuriale*, *Coenagrion hastulatum*, *Aeshna isosceles*, *Leucorrhinia dubia*), two species regarded as 'Vulnerable' (*Aeshna caerulea*, *Somatochlora metallica*) and six species regarded as 'Near Threatened' (*Lestes dryas*, *Ischnura pumilio*, *Coenagrion pulchellum*, *Somatochlora arctica*, *Libellula fulva*, *Gomphus vulgatissimus*). In addition, *Ceriagrion tenellum* was included due to its national scarcity. However, both *Brachytron pratense* and *Cordulia aenea* were excluded in this revised list. In contrast to the SSSI guidelines the three species regarded as extinct in Britain, *Coenagrion scitulum*, *Coenagrion armatum* and *Oxygastra curtisii*, were excluded from the list of nationally important species. Future revisions of these criteria may include these species if they are found to have re-colonised Britain.

Regionally important species

Additional species recognised as important at a local level were determined for each local

area. Species were only considered for inclusion in a regionally important list if they bred in at least one vice-county within the local area, occurred in less than 10% of the tetrads in a vice-county or were deemed by a local Odonata expert as an important species. Four Zygoptera species (*Calopteryx virgo*, *Calopteryx splendens*, *Platycnemis pennipes*, *Erythromma najas*) and 14 Anisoptera species (*Brachytron pratense*, *Aeshna juncea*, *Aeshna grandis*, *Aeshna cyanea*, *Aeshna mixta*, *Anax imperator*; *Cordulegaster boltonii*, *Cordulia aenea*, *Libellula depressa*, *Libellula quadrimaculata*, *Orthetrum cancellatum*, *Orthetrum coerulescens*, *Sympetrum danae*, *Sympetrum sanguineum*) were identified as regionally important in one or more of the 39 local areas.

Vagrant and recent colonising species were excluded from this list of regionally important species. These included four species (*Erythromma viridulum*, *Anax parthenope*, *Sympetrum fonscolombii*, *Sympetrum flaveolum*) that may be considered for inclusion in the next revision of the criteria.

Species diversity

The total number of species required at a site to fulfil the species diversity criterion was re-assessed for each of the local areas. The required diversity thresholds, equivalent to the outstanding assemblages of the SSSI guidelines, were based on 60% of the number of breeding species occurring within each vice-county. These numbers were then modified according to local expert knowledge and the species diversities of adjacent vice-counties before being simplified into three diversity groups. The highest group, with a minimum threshold of 14 species, occurred predominately in southern England. The intermediate group, with a threshold of 11 species, occurred predominately in mid- and eastern England and Wales. The lowest diversity group, with a threshold of eight species, occurred in northern England and Scotland.

In determining species diversity, emphasis was placed on counting only those species which had abundant breeding populations at a site. Species with small or non-breeding populations were deemed to contribute to the determination of possible key sites as opposed to probable or confirmed key sites. This emphasis on the importance of a diversity of species with abundant breeding populations resulted in a lower diversity threshold than those found within the SSSI guidelines (NCC, 1989).

Proof of breeding

Since the publication of the SSSI guidelines for Odonata, proof of breeding criteria have been formalised by the BDS Dragonfly Conservation Group (Taylor, 2003). These criteria were used in the key site criteria such that the presence of a successful breeding population corresponds to Taylor's (2003) 'Confirmed Successful Breeding' and 'Probable Successful Breeding'. A successful breeding population is identified from the observation of either exuviae, larvae, pre-flight emergents or oviposition. Possible breeding at a site, corresponding to Taylor's (2003) criteria of 'Possible Breeding',

equates to copulating pairs. Observation of territorial behaviour or mixed sexes at a site, included within Taylor's (2003) criteria, are not used in the key site criteria as they are not routinely recorded on the RA83 Odonata recording card.

Abundance

The 'strong population' of the SSSI guidelines is defined for key sites using the abundance categories on the RA83 recording card. Abundance is based on the highest abundance category recorded for any stage. The Dragonfly Conservation Group agreed on appropriate thresholds for 'abundant populations'. These thresholds were defined for each species and a general rule for both Zygoptera and Anisoptera formulated. Thus for zygopterans, a strong population was taken as an abundance of 'D' (21–100 individuals) or greater and for anisopterans 'C' (6–20 individuals) or greater. However, exceptions were made for two zygopterans (*Lestes dryas* and *Ischnura pumilio* were given a threshold of 'C') and seven anisopterans (*Aeshna mixta*, *Libellula quadrimaculata*, *Orthetrum cancellatum*, *Orthetrum coerulescens*, *Sympetrum striolatum*, *S. danae* and *S. sanguineum* were given a threshold of 'D').

Applying the criteria to determine key Odonata sites

Together, these criteria identify key sites by the presence of an abundant breeding population of at least one nationally or regionally important species, or a diversity of species, recorded over a 10-year period. The criteria may be applied in a stepped approach, identifying sites as Possible Key Sites where records of both abundance and breeding data are lacking; Probable Key Sites where the abundance criterion is met but only possible breeding is established; or Confirmed Key Sites where both the abundance and successful breeding criteria are met. At sites where the abundance threshold has not been met, an alternative population persistence criterion can apply, whereby proof of breeding must have been observed in at least two years of the 10-year period under review (Fig. 1).

This stepped approach confirms key sites whilst still recognising those sites where further recording could elevate them to key site status. The criteria may therefore be used to target future recording at particular sites and for monitoring populations of Odonata at important sites. The inferences for the four categories identified are:

1. **Non-Key Site** – site where no importance or species diversity criteria have been met. A non-targeted approach to future recording should be applied, continuing to look for evidence of important species or greater diversity.

2. **Possible Key Site** – site with either important species or a diverse range of species, but with no evidence of meeting the abundance threshold or breeding status criteria. At these sites a more targeted approach should be applied to future recording, concentrating on gathering evidence for abundance and breeding, especially for species of recognised importance.

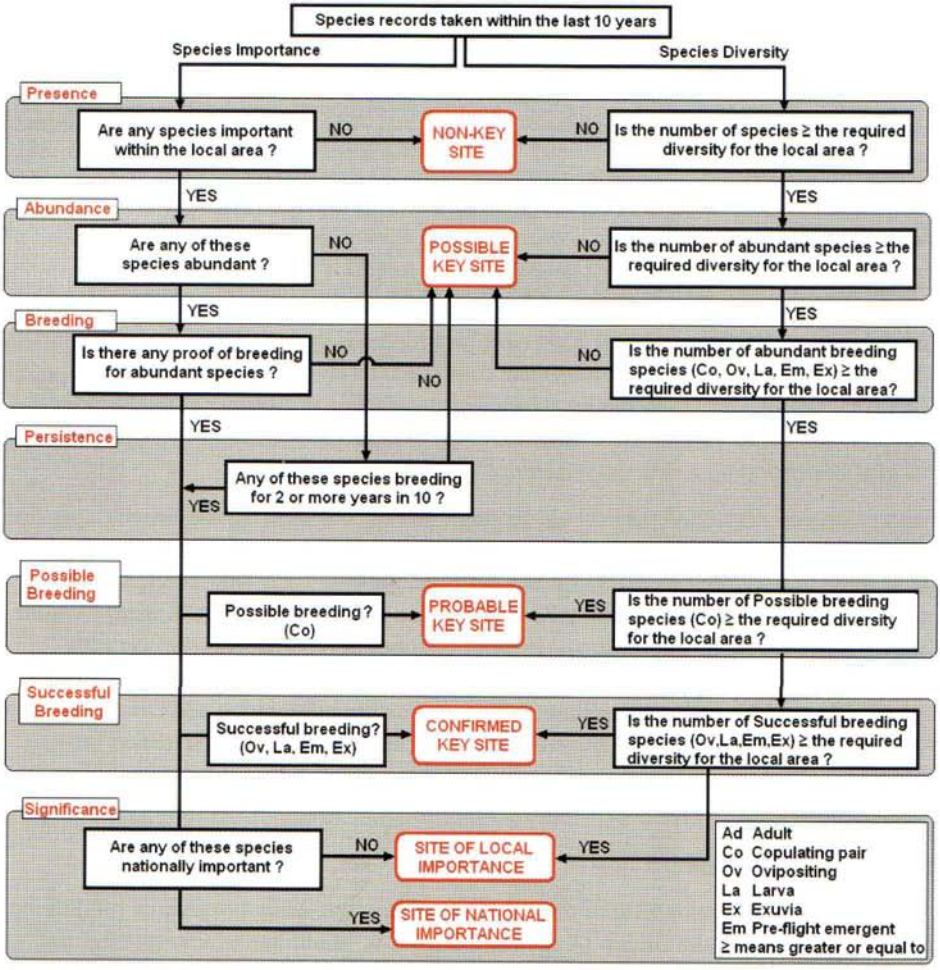

Figure 1. Flowchart depicting the application of criteria for the determination of key Odonata sites.

3. **Probable Key Site** – site with abundant or persistent populations of important or diverse number of species but with evidence that possible breeding of these populations occurs at the site. A targeted approach should be applied to future recording, concentrating on gathering evidence for successful breeding of populations of the important or diverse species.

4. **Confirmed Key Site** – site with abundant or persistent successfully breeding populations of important or diverse number of species. Sites containing species of national importance should be recognised as 'sites of national importance' and theses

should be analogous to SSSI quality. Sites with species of regional importance should be recognised as 'sites of regional importance' and should be recognised as local [wildlife] sites (*sensu* Defra, 2006) for local development planning purposes. A targeted approach should be applied to future recording at both of these types of confirmed key sites, monitoring the status of the populations of the important or diverse species.

Conclusions

These criteria for the determination of key Odonata sites follow those applied by previous key site projects run by the National Odonata Recording Scheme and the guidelines for the designation of SSSI sites for Odonata. By complementing these earlier projects, the criteria will help towards the continued development of the national Odonata dataset, increasing the importance of this dataset as a resource for Odonata research and conservation, and contribute to the Dragonfly Recording Network realising its goal of developing a national register of key Odonata sites.

As key sites are identified they should be promoted to, and used by, the country agencies to aid decisions on SSSI notification and to local record centres and planning authorities to assist with development planning. For example, these new key site criteria have been adopted by the Devon Biodiversity Records Centre for determining its 'County Wildlife Sites' (DBRC, 2007). This followed iterative analyses of records from two decades (1987–96 and 1997–2006), which helped to ensure that the criteria were useable and produced sensible results (Smallshire, in prep.). Further information and developments of these key site criteria, the National Odonata recording card and information on recording Odonata in Britain may be obtained through the British Dragonfly Society's website (http://www.dragonflysoc.org.uk/).

Acknowledgements

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Migrant and dispersive dragonflies in Britain during 2007

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Summary

The 2007 dragonfly season was one of contrast. April 2007 was the warmest April on record, but although resident species started flying unusually early, little of note was reported on the migrant front. Mid-summer was often wet to very wet, with temperatures somewhat lower than in many recent summers. Some short spells of hot settled weather were however observed, and these were often associated with migratory influxes and/or enhanced internal dispersal. Although there was no repetition of the dramatic migrations of 2006, the year was thus far from uneventful. Red-veined Darter *Sympetrum fonscolombii* once again occurred in good numbers, and Lesser Emperor *Anax parthenope* also maintained a strong presence. Several unusual 'one-off' sightings were similarly made – notably a Norfolk Hawker *Aeshna isosceles* reported from Hampshire and a female Willow Emerald Damselfly *Lestes viridis* reported from Suffolk. This latter record is only the third report of the species from Britain in the last hundred years.

Account of species

Notable sightings reported to the BDS Migrant Dragonfly Project during 2007 are detailed below; background meteorological information is from the Met Office (2008).

***Calopteryx splendens* (Harris) – Banded Demoiselle**

A male was observed at Breney Common, Cornwall, on 1 September (DT), some 35km from the nearest known breeding site. The most interesting dispersive event of the year was, however, a series of records of individuals seen along the beach at various eastern coastal sites during the hot weather of early August. One was seen at West Runton, Norfolk, on 1 August (via PT), another was on Blakeney Point, Norfolk, on 5 August (RPo) and three males were reported from a nearby coastal site on the same date. Two were also noted going south at Spurn Point, East Yorkshire, on 7 August (BS). While some of these sightings may relate to individuals dispersing from inland, there is circumstantial evidence that the species may also occasionally be able to cross the North Sea. A male was, for instance, noted along with Yellow-winged Darters *Sympetrum flaveolum* in grass by the shore at Sizewell, Suffolk, early in the morning of 2 August 1995, right at the start of the famous darter invasions of that year (Mendel & Marsh, 1996).

***Lestes dryas* Kirby – Scarce Emerald Damselfly**

There were several reports during the year from northern East Anglia at sites away from the species' Brecklands strongholds. A female photographed near Market Weston, Suffolk, on 27 August (MF) was the first county record, while in Norfolk individuals were seen at two sites in Norwich, three near Holt and one near Fakenham (via PT). A few of these various sightings may perhaps refer to previously undiscovered but well-established breeding colonies, but the species has clearly also shown significant dispersal during 2007 and/or the immediate preceding years.

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

A female was photographed near Trimley, Suffolk, on 17 August 2007, having perhaps first arrived during the hot spell towards the beginning of the month (Brame, 2008). This is the first report of the species in the UK since the discovery of an exuvia at Cliffe Marshes, Kent, during 1992 (Brook & Brook, 2004). Prior to this, *L. viridis* had also been noted from near Hastings, Sussex, sometime around 1980 (D. Chelmick, pers. comm.). These are the only recent records. In the nineteenth century the species had been described as doubtfully British by McLachlan (1884), and a specimen once in the British Museum (but now apparently lost) was labelled as being from Shenley, Hertfordshire, in 1899 – though this record has sometimes been queried since the collector also travelled in continental Europe during that year (Gladwin, 1997).

The species is well established on the near Continent, where there is some suggestion of modern range expansion, or at least a benefit from urbanisation (Dijkstra & Lewington, 2006; Goffart *et al.*, 2006). On Jersey in the Channel Isles the species was noted as breeding in the mid-twentieth century, but may have declined (or been overlooked) for a period (Silsby & Silsby, 1988). It is, however, now again a regular breeder, currently being well-established (Long & Long, 2000; R. Perchard, pers. comm.). It seems possible that individuals may be reported more frequently from Britain in years to come.

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

In contrast to the events of 2006, which saw yet further major range expansion by this recent colonist (Parr, 2007), the 2007 season saw little of particular note from much of southern England. However, there was evidence for continuing movement (immigration?) from a number of east coast sites. Some 280 were counted along the coastal spit of Blakeney Point, Norfolk, on 5 August (RPo), and the first records for Spurn, East Yorkshire, were made on this same date (BS). Approximately 200 were present at Eccles-on-Sea, Norfolk, during early August despite a poor showing by the resident population during the year (NB).

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

On 5 August a total of 78 were counted along Blakeney Point, Norfolk, (RPo), together with a range of other migratory/dispersive species such as Small Red-eyed Damselfly *E. viridulum*, Emperor *Anax imperator* and Ruddy Darter *Sympetrum sanguineum*. Over

100 were present at Holkham Woods, Norfolk, on 2 October during a period of brisk easterly winds that resulted in a significant fall of avian 'drift migrants' along the east coast of England (Parr, 2008).

***Aeshna isosceles* (Müller) – Norfolk Hawker**

A male was photographed at Titchfield Haven, Hampshire, on 26 August (KL). With this being both far from the species' normal distribution in Britain and also exceptionally late – the flight season is more typically finished by the end of July (Brooks & Lewington, 1999) – an immigrant from the Continent is probably involved. Although from a more typical area, two *A. isosceles* seen at Catfield Fen, Norfolk, on the same day in August (DWe) might just possibly also be migrants. There does seem to be a developing trend in recent years for late season records that likely refer to immigrants. Singles have thus also been noted at Landguard Point, Suffolk, on 1 August 1991 (Mendel, 1992), at Messingham, Lincolnshire, on 28 August 1997 (Parr, 1998), and at Spurn, East Yorkshire, on 20 July 2003 (Parr, 2004).

***Anax imperator* Leach – Emperor**

There was an interesting series of records from eastern coastal sites on 5 August that is highly suggestive of some form of migratory movement (like its close relative the Lesser Emperor *A. parthenope*, *A. imperator* is also a known migrant – though the presence of large numbers of resident individuals often makes detection of movement difficult). Thus a total of 13 were counted along Blakeney Point, Norfolk (RPo), and ten were seen at a nearby site in coastal north Norfolk where generally at most only singletons are reported. Three were also observed going south at Spurn Point, East Yorkshire (BS). The 5 August was notable for being a very hot day with southerly winds across much of the UK and south to southeasterly winds over the near Continent (WeatherOnline, 2008).

***Anax parthenope* Sélys – Lesser Emperor**

Individuals were noted at several sites (see Fig. 1) where oviposition had earlier been observed during the big influx year of 2006 (Parr, 2007), suggestive of successful breeding involving a one-year lifecycle. In particular, at Swillbrook Lakes NR in the Cotswold Water Park a teneral male was noted on 5 June (GH) with further individuals seen over the next few days. There were also sightings from Wintersett, West Yorkshire, on 8 July (PMc, SD), and at Chew Valley Lake, Somerset, on 3 and 6 August (RM). *A. parthenope* had similarly been reported during 2006 at Maxey Gravel Pits, Cambridgeshire, and although oviposition was not then directly noted, intermittent sightings of further individuals during August 2007, with a peak count of 5–9 on 5 August (KD), is again highly suggestive of successful breeding. Other 'repeat' sightings at Radley, Oxfordshire (SB) and especially at Brockholes Quarry, Lancashire (AHo) may similarly refer to local breeding, as may at least some records from Dungeness, Kent, where the species is now recorded annually (PA, DWa).

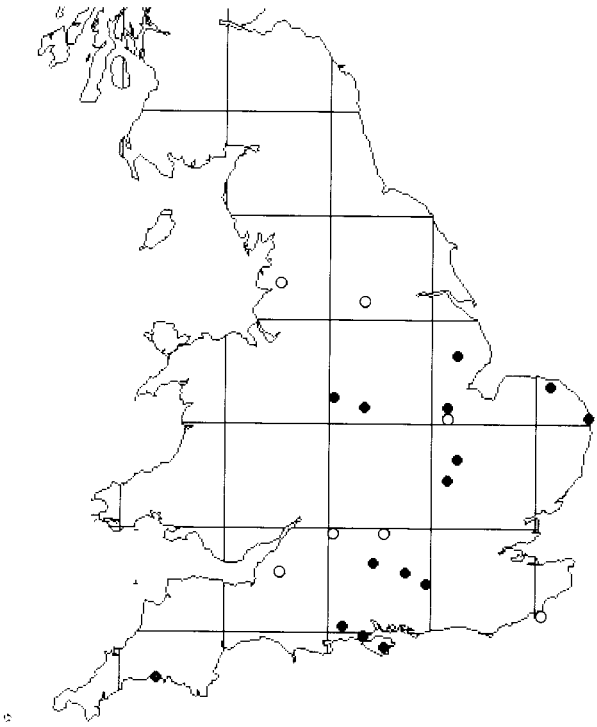

Figure 1. Distribution of sightings of Lesser Emperor *Anax parthenope* in Britain during 2007. Grey circles refer to sites at which individuals had also been seen in 2006.

In addition to the reports of presumed locally-bred individuals, substantial fresh immigration also took place during the year (Fig. 1), particularly during July and the period 3–11 August. Notable sightings included the first records for Thursley NNR, Surrey, on 8 July (KD) and for Chartley Moss NNR, Staffordshire, on 10 August (TB). Ovipositing pairs were also observed at Lound Waterworks, Suffolk, on 3 August (DH) and at Felbrigg Lake, Norfolk, on 5 August (RL). Oviposition was similarly noted during early August 2007 at the possibly established breeding sites of Maxey Gravel Pits, Cambridgeshire (KD) and Dungeness, Kent (via PA). While sightings were down in number from the record-breaking totals of 2006 the species thus continues to maintain a strong presence and its foothold in Britain appears to be strengthening (Fig. 2).

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

There were no substantiated records from Britain during the year, the last having been in 2004 (Parr, 2005), although reports of 'possibles' are occasionally received. While there is still no evidence for breeding, the species has, however, been seen regularly in the Channel Isles over the last few years. During 2007, a male was seen and photographed at Grouville, Jersey, on 17–18 July (RPe).

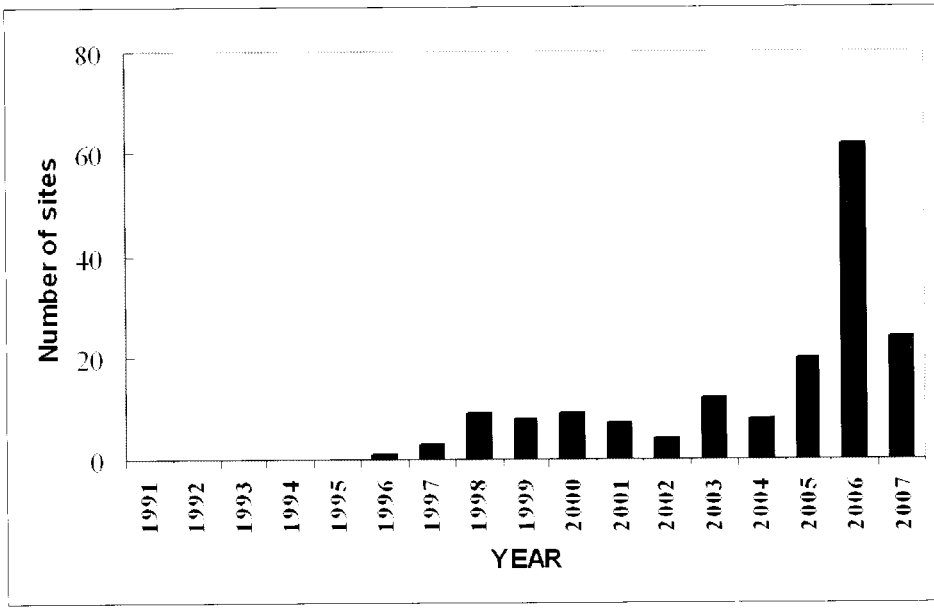

Figure 2. Numbers of sites at which Lesser Emperor *Anax parthenope* has been recorded in Britain each year since 1991 (there is only one, unconfirmed, record prior to this).

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

It was an uneventful year for the species, with little sign of large-scale movement. Singles were caught at MV light on the Bawdsey Peninsula, Suffolk, on 8 and 13 August (MD); such individuals attracted to light are thought to often be migrants (Parr, 2006). Several hundred were also present at Holkham Woods, Norfolk, on 2 October during a period of brisk easterly winds that resulted in a significant fall of avian 'drift migrants' along the east coast of England (Parr, 2008).

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

A female was seen at Dawlish Warren, Devon, on 6 September (via DS), a date that also saw Lesser Emperor *A. parthenope* reported from nearby south-east Cornwall. Appearances of *S. vulgatum* in Britain have always been highly erratic and, although several were seen in eastern England during the famous darter invasions of 1995 (Attridge, 1996; Heath, 1996), this is the first record for a decade. The close similarity of this species to other darters, and in particular Common Darter *S. striolatum*, may however mean that it is to some degree overlooked. Detailed scrutiny of any unexpected darters is thus to be encouraged, especially as there are yet other similar-looking *Sympetrum* species that may potentially appear in Britain.

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

Summer 2006 saw the largest-ever recorded immigration of *S. fonscolombii* into Britain and an autumn generation of locally-bred individuals resulting from rapid larval development was noted from at least 16 sites (Parr, 2007). It was anticipated that further emergences would be recorded during spring 2007, though the contribution of the previous autumn generation to this phenomenon is uncertain since these individuals typically disappear (disperse or migrate) before sexual maturity is reached (Parr, 1999; Pellow, 1999). In the event, early season tenerals and/or immatures were seen at the 'traditional' breeding sites of Middleton in Lancashire (PMa) and Spurn in East Yorkshire (BS), and emergences were similarly confirmed at Lower Bruckland, Devon (via DS). A late stage larva was also noted at Rhydymwyn Nature Reserve, Clwyd, on 30 June (AHa). A scattering of records of more mature adults from other sites where they had been seen during 2006 (see Fig. 3) may perhaps additionally refer to local breeding, though particularly in southern counties fresh immigration cannot be ruled out. Such immigration was indeed noted during 2007, and appeared fairly widespread judging by the number of sightings from well-watched sites where the species had not

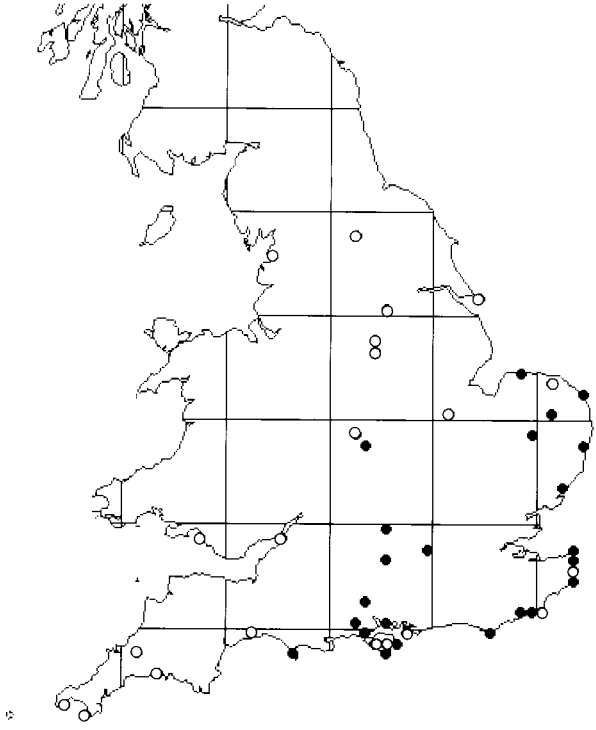

Figure 3. Distribution of sightings of Red-veined Darter *Sympetrum fonscolombii* in Britain during spring/summer 2007. Grey circles refer to sites where individuals had also been seen in 2006.

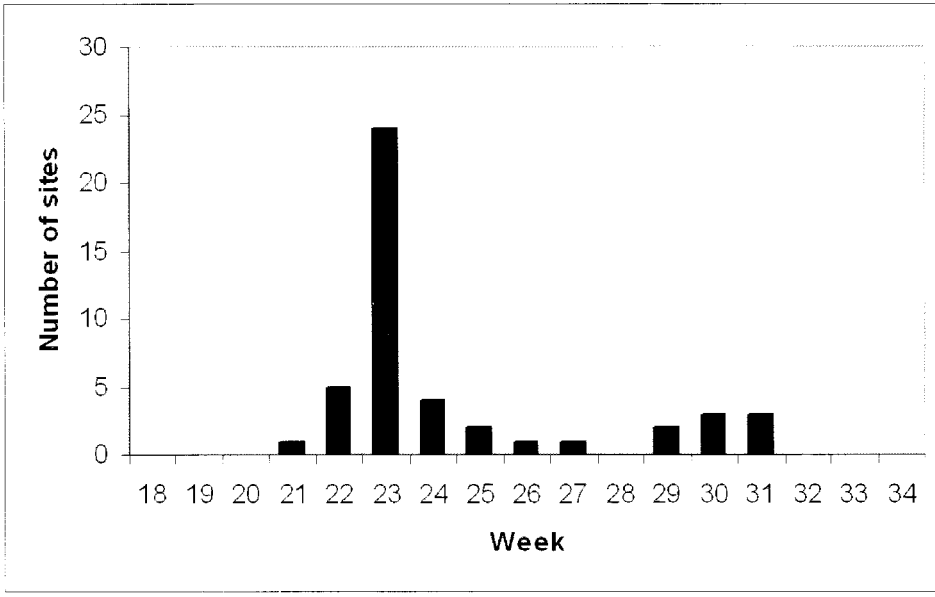

Figure 4. The timing of first appearances of Red-veined Darter *Sympetrum fonscolombii* at sites in Britain during spring/summer 2007. Week 23 = 4–10 June, week 30 = 23–29 July.

been recorded the year before (Fig. 3). It is also worth noting that, on 24 May, one individual, clearly a migrant, visited a small fishing boat ca. 20 miles north of Guernsey, Channel Islands (RH). Overall, most sightings of *S. fonscolombii* during the summer came during the period 1–13 June (Fig. 4), a time that also saw significant arrivals of immigrant Lepidoptera such as Painted Lady *Vanessa cardui* and Diamond-back Moth *Plutella xylostella* (e.g. Solly *et al.*, 2008; Spence, 2008). Another small peak (perhaps a second wave of arrivals?) also occurred during late July–early August (Fig. 4).

Following the productive spring/summer, autumn emergences were again noted from several sites and it was clear that an early onset of breeding activity had allowed time for a second generation to develop to emergence despite the generally poor summer. First emergences were noted on 6 September in Berkshire, and over the course of the next few weeks at least six further breeding sites (another in Berkshire, plus sites in Cornwall, Devon, Hampshire, the Isle of Wight and Cambridgeshire) were discovered. At Crookham Common, Berkshire, nearly 200 exuviae were found during September (AHi). Away from known breeding sites there were, however, few autumn records.

***Sympetrum flaveolum* (L.) – Yellow-winged Darter**

It was a quiet year for the species. A female was noted at Whisby, Lincolnshire, on 16 June (RJ), and two males were seen at Rainham Marshes, Essex, on 17 June (HV).

These dates are significantly earlier than the bulk of reports from Britain and, especially since the Whisby individual at least was clearly immature, the records may perhaps refer to successful local breeding following the influx of 2006 (Parr, 2007). It is, however, conceivable that these sightings relate to Continental individuals caught up in the migrations of Red-veined Darter *S. fonscolombii* that were taking place at the time. Slightly later in the season, a male and female of unknown provenance were reported from Tottingham, Norfolk, on 8 July (via PT).

Conclusions

Despite the indifferent summer, the year was quite an eventful one for migrant species. Some sightings clearly reflected successful local breeding following the mass immigrations of 2006 but significant fresh arrivals were also seen. Two periods of movement were particularly apparent. Red-veined Darter *S. fonscolombii* appeared in good numbers during the warm weather of early June, and another hot spell in early August saw interesting sightings of a range of migratory/dispersive species, particularly along the east coast of England. In addition to these two large-scale events a number of one-off sightings of other unusual species also took place in late summer, suggesting the occurrence of additional smaller-scale migration events.

The combination of immigration and local breeding is likely to represent the future situation for many migrants, with the detailed balance varying from year to year and species to species. It will be interesting to see just how many species succeed in establishing permanent populations in Britain, in the way that Small Red-eyed Damselfly *E. viridulum* has done. It is however to be remembered that for many migrant/dispersive species the concept of fixed, self-supporting, permanent breeding sites may be over-simplistic. Studies of the breeding biology of migrants at our latitudes should prove highly informative.

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Maps in this article were prepared using DMAP software from Dr. A. Morton.

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The Norfolk Hawker *Aeshna isosceles* and Water Soldier *Stratiotes aloides*: a study of their relationship at Castle Marsh, Suffolk and elsewhere in the Broads 1991–2004

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Summary

The relationship between Water Soldier *Stratiotes aloides* and the Norfolk Hawker *Aeshna isosceles* was studied at the Suffolk Wildlife Trust Nature Reserve at Castle Marsh, 1991 to 2004. During that period *S. aloides* was affected by saline pollution of the northern part of the reserve and by changes in management. It decreased slightly and then increased considerably. The numbers of territorial male *A. isosceles* remained fairly similar throughout the period. *A. isosceles* was mainly, but not only, found on dykes with thick monocultures of *S. aloides*. The presence of territorial males on dykes with little or no *S. aloides* was possibly due to their being driven out of the better habitats by more successful individuals. The situation at Castle Marsh was found to be typical of most of the Broadland area. However, *A. isosceles* occurred in the upper Waveney valley and on the Hundred River where the water courses had no *S. aloides* but which did have thick growths of other aquatic plants, notably Common Bladderwort *Utricularia vulgaris* and Frogbit *Hydrocharis morsus-ranea*. *A. isosceles* occurred at densities broadly similar to those in *S. aloides* dykes, its preferred habitat. Interspecific aggression between *A. isosceles* and the males of six other species was studied. It mainly occurred with *A. grandis* and with *L. quadrimaculata*; although it occurred frequently it had no discernible effect on the distribution of the species concerned. Both *S. aloides* and *A. isosceles* are under the threat of extinction from rising sea levels caused by climate change. The natural recolonisation of the Fens, where both species are now extinct, is shown to be unlikely. Therefore an experimental study at Wicken Fen NNR – the most suitable Fenland site – has been initiated. *S. aloides* has been reintroduced. If the reintroduction is successful, and if it is necessary, *A. isosceles* will also be reintroduced.

Introduction

Stratiotes aloides, which occurs in Europe and Siberia, is a striking aquatic perennial plant. In winter it sinks to the bottom and in spring rises to the surface. In England it flowers but does not reproduce sexually. When conditions are right it forms dense monocultures which completely cover the water surface. It occurs in water of pH 6.5 to

8.5 and is very susceptible to chlorine and hence to brackish water. Eutrophication allows it to be out-competed by emergent plants (Preston & Croft, 1997).

Aeshna isosceles occurs widely in the Mediterranean region, in Central Europe and into Western Asia (Askew, 1988). On the Continent it breeds in a wide range of habitats: for example, in southern Germany it lays its eggs on mud and old plant material in reedy gravel pits but in northern Germany it lays eggs in ditches with *S. aloides* present (Jürgen Ott – personal communication). In East Anglia, females usually oviposit in dykes containing *S. aloides*. *A. isosceles* emerges earlier in the year than other aeshnid species except for the Hairy Dragonfly *Brachytron pratense*. The males, like other aeshnids, are territorial and, like the Migrant Hawker *Aeshna mixta*, they quite often perch by the water's edge.

In England both *A. isosceles* and *S. aloides* are now virtually restricted to dykes in the grazing marshes of Norfolk and Suffolk which lie below or just above sea level (Mendel, 1992; Merritt *et al.*, 1996; Preston & Croft, 1997). Therefore they are seriously threatened by rising sea levels caused by climate change, and their future in England will increasingly depend on conservation measures.

Both *S. aloides* and *A. isosceles* used to occur in the Fens (Perring *et al.*, 1964; Heath, 1999) but both are now extinct there. The Fens are less threatened by rising sea levels than the Broads and hence the best hope for maintaining these species in Britain is to support their return to the Fens.

In England the distribution of *A. isosceles* closely reflects that of *S. aloides* and the relationship between the two species is relevant to their conservation in England. Clearly *S. aloides* is not dependent on *A. isosceles* but to what extent is *A. isosceles* dependent on *S. aloides*?

Methods

Castle Marsh is an ideal site for studying these species because it has large populations of both and it is a nature reserve of the Suffolk Wildlife Trust. It is therefore assured of a long term future and management favourable to both species as long as climate change allows.

The work started in 1991 when Owen Leyshon began his study of both species there for his MSc thesis at the University of East Anglia (Leyshon, 1992; Leyshon & Moore, 1993). Also in 1991 members of the British Dragonfly Society visited Castle Marsh to see whether it was possible to undertake a long-term study of *A. isosceles* by its members. In the event the logistics of doing this proved to be impossible, so I undertook to build on Owen Leyshon's study as far as I could, living 90 miles from Castle Marsh.

Most of my work consisted in assessing the numbers of *S. aloides* and *A. isosceles* over the 14 year period from 1991–2004 and making observations on *A. isosceles* behaviour which

might explain the relationship between the dragonfly and the plant. Recording and assessing the numbers of *S. aloides* plants in the 4,000m of the dyke system studied was laborious but presented no major problems. However, the distance between my home and Castle Marsh presented difficulties for studying *A. isosceles*, as I could not visit the site sufficiently frequently to record the total number of *A. isosceles* emerging by counting exuviae. I had therefore to use counts of territorial males within three hours of solar noon

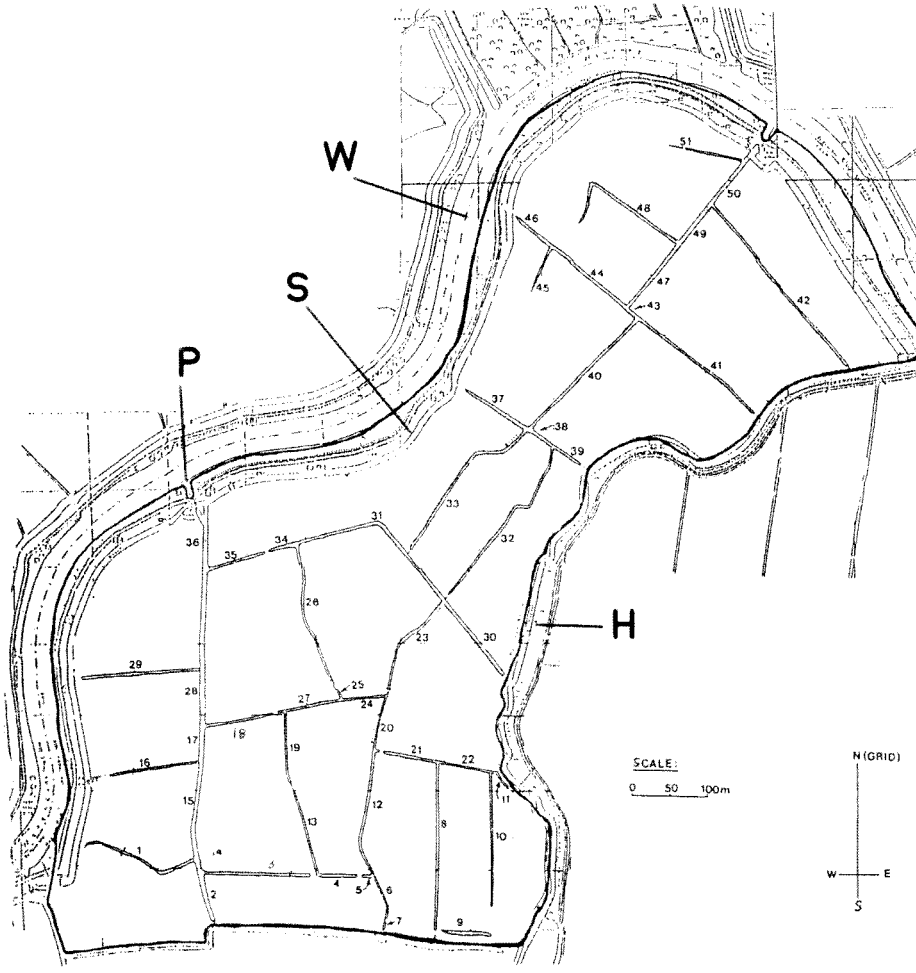

Figure 1. Castle Marsh Reserve with numbered dykes. H, The Hundred (high level) Dyke; P, Pump; S, The Soke Dyke; W. River Waveney.

on fine days to provide an index of populations. There were great difficulties in doing this: even when I could choose to visit the site when weather forecasts suggested that conditions should be right, the weather often changed by the time I got to the site. In fact only on seven occasions were my counts reasonably comprehensive. This paper is based on the records made on these occasions, but they were fully supported by the numerous other records made under sub-optimal conditions, and where these add new information they are included in the text. Despite its methodological imperfections I believe that this study provides a valid summary of the broad changes in the populations of the two species at Castle Marsh and throws a light on their relationship.

The positions of the dykes at Castle Marsh are shown in Figure 1. The length of each dyke was measured on an Ordnance Survey map and is shown to the nearest 5m. The dykes varied in length from 15m to 240m with a mean length of 111m. Nearly 80% were in the range 40–200m.

Comprehensive surveys of the populations of *S. aloides* in the dykes were made in 1991, 1999 and 2004. In 1991 Owen Leyshon counted all *S. aloides* plants in the dykes. I did not have the time in 1999 and 2004 to count plants individually so I made estimates by assessing the area of each monoculture and multiplying it by the average number of plants found to occur in a representative sample. I also counted all other plants which occurred in small groups or individually. For each dyke a total value for the dyke was obtained by adding these counts to the estimated number in the monocultures. Since the number of plants in a dyke might be related to the length of the dyke the data are expressed as the mean number of plants per metre of dyke. To allow for any discrepancies between estimates of plant numbers, they have been converted to broad categories of density levels (Table 1) in the tables (Tables 2, 4 & 5). In practice there was little difference between density levels and equivalent broad categories of numbers of plants in each dyke. Hence the number of plants did not have a close link with the length of the dyke.

On each visit to Castle Marsh the number of territorial male *A. isosceles* present on each dyke was recorded. In the study on interspecific interaction between *A. isosceles* and other species at Castle Marsh and elsewhere the nature of each encounter was recorded.

Table 1. Number of plants per metre at each 'density level'.

Level	No of plants/metre
0	None
1	0.1–1.0
2	1.1–10.0
3	>10.0

Results

S. aloides

The data on *S. aloides* in the Castle Marsh dykes from 1991, 1999 and 2004 show that plant numbers and hence density levels differed greatly between dykes and between years (Tables 2, 4). A density level of 3 indicated that the dyke held one or more dense monocultures of plants, whereas levels 1 or 2 generally indicated either an early stage of colonisation or a decline (level 1 often indicated the escape of plants from well populated areas into dykes which were not suitable for the species). Level 0 indicated that the dyke was unsuitable for *S. aloides*.

The number of dykes with *S. aloides* in them fell from 22 in 1991 to 16 in 1999 but had increased to 31 by 2004. The number of plants counted and estimated was about 16,000 in 1991, about 14,000 in 1999 and about 39,000 in 2004. The number of dykes with the highest density level (3) increased from 5 in 1991 to 8 in 1999 and 14 in 2004.

The dykes fell into five topographical categories (Table 1). They are described below and what occurred in them from 1991 to 2004 is summarised.

South West Area

This comprises three cul de sac dykes and is sheltered by trees by the bank of the River Waveney. There was a general increase in *S. aloides* from 1991 to 2004, the improvement being due to changes in water management.

South East Area

This consists of four dykes, three of which are bordered by ungrazed land and one (8) which is grazed on the west side but not on the east. The large population of *S. aloides* in dyke 8 has changed little throughout the 14 year period although the number of reeds has increased since 1995. Dykes 9, 10 and 11 had become overgrown by emergent plants in 1999. There was insufficient time to survey them adequately that year but there were clearly few, if any, plants in these dykes (Table 2). However, in 2004, when they were carefully surveyed, I found 140 plants in Dyke 10 and so there must have been some there in 1999. The declines in *S. aloides* in these three dykes over the study period were due to lack of grazing, which allowed emergent plants to crowd out *S. aloides*.

Central area

This large group of 15 dykes contains both cul de sac dykes, which are best for *S. aloides* (Leyshon & Moore, 1993), and dykes with some water flow. *S. aloides* occurred in 13 of the dykes in 1991 but only in small numbers. There was little change until 1999 when plant densities had increased in seven dykes and declined in seven but large populations occurred in three. By 2004 densities had risen or remained the same in 14 dykes and in eight of these there were large populations. In only one dyke had the density level declined. The changes can all be attributed to changes in water management.

Table 2. The numbers and density levels of Water Soldier *Stratiotes aloides* at Castle Marsh in 1991, 1999 and 2004. See Table 1 for density levels; x, overgrown by emergent plants and few, if any, *S. aloides* present; * *S. aloides* assumed to be absent (see text).

			1991		1999		2004	
Dyke Area	number	Length (m)	Number plants	Density level	Number of plants	Density Level	Number of plants	Density Level
Southwest	1	150	482	2	2547	3	1414	2
	16	120	0	0	264	2	3120	3
	29	155	65	1	1960	3	2735	3
Southeast	8	220	3755	3	3612	3	3630	3
	9	70	796	3	x	x	0	0
	10	170	2381	3	x	x	140	1
	11	40	0	0	x	x	0	0
Central	3	125	0	0	192	2	2750	3
	4	50	9	1	5	1	490	2
	5	20	52	2	0	0	80	2
	6	60	0	0	0	0	70	2
	7	15	46	2	312	3	400	3
	12	170	274	2	0	0	2700	3
	13	115	52	1	642	2	1980	3
	18	90	137	2	1128	3	1800	3
	19	100	417	2	1476	3	2120	3
	20	75	111	2	10	1	2180	3
	21	80	187	2	960	3	528	2
	22	70	79	2	60	1	610	2
	24	60	384	2	612	3	1540	3
	25	20	106	2	20	1	140	2
	27	70	298	2	26	1	1770	3
North	23	145	0	0	0	0	18	1
	26	170	2250	3	0	0	215	2
	30	120	2510	3	0	0	2690	3
	31	240	0	0	*	*	0	0
	32	240	1340	2	*	*	5210	3
	33	230	230	1	*	*	230	1
	34	40	0	0	*	*	0	0
	35	65	0	0	*	*	0	0
	37	100	0	0	*	*	30	1
	38	40	0	0	*	*	1	1
	39	35	0	0	*	*	60	2
Pump Dykes	2	70	0	0	0	0	130	2
	14+15	140	0	0	0	0	70	1
	7	50	0	0	0	0	13	1
	28	195	0	0	0	0	13	1

North area

The dykes in the North area were subjected to flooding by water from the Waveney which was presumably slightly saline. This must have been the main cause of the declines observed between 1991 and 1999. Probably only in dykes 26 and 30 in the south of the area did *S. aloides* survive the flooding which occurred on February 24th 1993.

Dyke 23 contained no *S. aloides* in either 1991 or 1999 but a few plants were present in 2003 and 2004.

Dyke 26 retained its very large population until 1995, but by 1998 very few plants remained; none was present in 1999. Plants were present again in 2003 but it had only regained 215 plants by 2004.

Dyke 30 suffered a great decline of *S. aloides* due to accidental clearing out in 1993. Only a few plants were found in 1998 and none in 1999, but plants were present in 2003 and by 2004 the population was similar to that in 1991.

Dykes 31–39. In 1991 only dykes 32 and 33 had any *S. aloides* present. In 1999 searches for *S. aloides* were confined to the most southerly dykes in this region (23, 26 and 30). Since no *S. aloides* were found in them it was assumed that none would be present in dykes 31–39, since these were nearer the River Waveney, the source of saline pollution (Table 2). Dyke 32 had 1340 plants in 1991; only 343 plants were left on the surface of the dyke in 1993 but by 2004 the population of *S. aloides* was much greater than in 1991. Dyke 33 had 230 plants in 1991 and only dead plants in 1993, but in 2004 it had the same number of plants as in 1991. In 2004 dyke 38 had a single plant and dyke 39 had 60 plants.

Dykes 40–51 in the extreme north of the reserve were only surveyed in 1991. Only dyke 40 had a few *S. aloides*. These 12 dykes were not included in subsequent surveys.

The Pump Dykes

The five dykes which make up this drainage channel lead to the pumping station by the river Waveney and the flow makes them unsuitable for *S. aloides*. No plants were observed in 1991 or 1999 and only small numbers occurred in each section in 2004. Probably most of these had floated in from adjoining dykes which held populations of *S. aloides*.

Other dykes

The water courses surrounding the reserve – the high level Hundred dyke on the east side and the Soke dyke on the west and north sides running beside the Waveney – were clearly unsuitable for *S. aloides* and were not studied in detail. The lower level water course on the south side of the reserve did contain 33 *S. aloides* plants in 1999 but otherwise none was seen.

In the course of this study the Suffolk Wildlife Trust dug new dykes parallel to dykes 2, 17, 28 and 36. They were not surveyed, but by 2004 the more southerly ones contained some *S. aloides*.

The results from all the dykes strongly suggest that the *S. aloides* population has greatly benefited from continuous grazing in most areas of the reserve and from changes in water management undertaken to improve conditions for *S. aloides* and other aquatic species. The northern area suffered severely from incursions of flood water from the River Waveney but has recovered. Whether new works being undertaken on the banks will allow further colonisation of the North Area and withstand the effects of rising sea levels remains to be seen.

A. isosceles

The earliest adult I saw was on 24 May 1999. Since *A. isosceles* takes about 2–3 weeks to mature, this insect must have emerged at the latest in the second week of May. The latest I saw *A. isosceles* at Castle Marsh was on 23 July 2004 but elsewhere in the Broads the latest date I saw it was on 3 August 2004. The peak of the season seems to be at the end of June and the beginning of July.

On my visits to Castle Marsh I searched for *A. isosceles* on 37 dykes and saw them on 35. Owing to the vagaries of the weather and the time available to me, many of the counts were made under conditions which were not optimal. The counts made under the best conditions were made on 6 July 1991 (by Owen Leyshon), 11 June 1993, 13 June 1996, 12 June 2000, 31 July 2000, 19 June 2001, 16 June 2003 and 22 June 2004 (Table 3). The 1991 count included females that were not ovipositing. Leyshon's combined total for dykes 1–33 was 88. He estimated 20% of the insects were females, hence the figure of 70 males (Table 3). I found that females do little feeding by water and, when they arrive at water, they are quickly taken by males and hence, under most conditions, the number of free females present is considerably less than 20% of the total. Thus 70 may be an underestimate. (Four *A. isosceles* were recorded in 1991 on dykes other than 1–33 but these are not included in the total). The numbers at the two peaks of the season (the fourth week in June 2004 and the first week in July 1991) were similar.

Table 3. Total Number of male Norfolk Hawkers *Aeshna isosceles* at dykes 1–33 at Castle Marsh, 1991–2004.

Date	Season	Number of males
6 July 1991	Peak	70*
11 June 1993	Early	21
13 June 1996	Early	23
12 June 2000	Early	43
31 July 2000	Late	29
19 June 2001	Early	27
16 June 2003	Early	39
22 June 2004	Peak	67

* estimate – see text.

Table 4. Number of Norfolk Hawkers *Aeshna isosceles* at different stages of the flight season related to density levels of Water Soldier *Stratiotes aloides*. See Table 1 for density levels; • There was little apparent difference between the numbers of *S. aloides* in 1999 and 2000 but the plant counts were much more comprehensive in 1999. Hence these are shown in the table with *A. isosceles* counts in 2000 related to them; x, overgrown by emergent plants and few, if any, *S. aloides* present; * *S. aloides* assumed to be absent (see text).

Season		Mid		Early		Late		Mid	
		6 July 1991		12 June 2000		31 July 2000		22 June 2004	
Area	Dyke	Insect No	Plant level	Insect No	Plant level•	Insect No	Plant level•	Insect No	Plant level
Southwest	1	2	2	10	3	4	3	7	2
	16	2	0	3	2	2	2	3	3
	29	1	1	6	3	1	3	6	3
Southeast	8	13	3	7	3	4	3	4	3
	9	1	3	0	x	0	x	0	0
	10	8	3	0	x	0	x	0	1
	11	1	0	0	x	0	x	0	0
Central	3	1	0	0	2	2	2	7	3
	4	0	1	0	1	0	1	2	2
	5	1	2	0	0	0	0	0	2
	6	2	0	0	0	0	0	3	2
	7	2	2	0	3	1	3	1	3
	12	7	2	0	0	2	0	4	3
	13	0	1	0	2	1	2	1	3
	18	3	2	4	3	2	3	2	3
	19	2	2	2	3	1	3	3	3
	20	5	2	2	1	0	1	1	3
	21	3	2	5	3	1	3	1	2
	22	2	2	0	1	0	1	2	2
	24	3	2	0	3	1	3	3	3
	25	1	2	0	1	0	1	0	2
	27	3	2	1	1	2	1	0	3
North	23	3	0	0	0	0	0	3	1
	26	14	3	0	0	0	0	1	2
	30	6	3	0	0	0	0	3	3
	31	3	0		*		*	1	0
	32	10	2		*		*	4	3
	33	0	1		*		*	0	1
	34	1	0		*		*	0	0
	35	0	0		*		*	0	0
	37	0	0		*		*	0	1
	38	1	0		*		*	0	1
	39	2	0					0	2
Pump Dykes	2	0	0	0	0	2	0	1	2
	14+15	0	0	2	2	3	0	3	1
	17	0	0	0	0	0	0	0	1
	28	0	0	1	1	0	0	1	1

The overall conclusion is that, despite the changes in water quality and *S. aloides* numbers, the total population of adult territorial male *A. isosceles* remained broadly similar throughout the period of the study.

The relationship between *A. isosceles* males and *S. aloides*

The numbers of male *A. isosceles* observed in each dyke were recorded for mid season 1991, early season and late season 2000 and mid season 2004 (Table 4). From these data and from information obtained over the whole 14 year study it was clear that not only did the number of *A. isosceles* on a particular dyke change in the course of the season but it also changed between years. A detailed analysis confirms that, whatever the stage of the season, *A. isosceles* on average occurred more frequently on dykes with a high density (level 3) of *S. aloides* than on those with a lower density (levels 2 and 1) or with none of the plants (Table 5).

Table 5. The average number and range of male Norfolk Hawkers *Aeshna isosceles* in dykes with different levels of Water Soldier *Stratiotes aloides* at different stages of the season. The number of dykes surveyed on each date varied between 26 (in 2000) and 37 (in 1991); hence exact comparisons cannot be made. However, the general pattern can be seen.

Date & Season	Density level of *S. aloides*	Number of dykes in each density level	Male *A. isosceles* in the dyke Average number	range
6 July 1991	3	5	8.4	1–14
Mid season	2	13	3.2	1–10
	1	4	2.5	0–1
	0	15	1.1	0–3
12 June 2000	3	8	5.3	0–10
Early season	2	3	1.0	0–3
	1	5	0.7	0–2
	0	9	0	0
31 July 2000	3	8	1.9	1–4
Late season	2	3	1.6	1–2
	1	5	0.5	0–2
	0	9	0	0
16 June 2003	3	14	2.1	0–8
Early season	2	9	1.1	0–3
	1	6	0	0
	0	4	0	0
22 June 2004	3	14	3.0	0–7
Mid season	2	10	1.4	0–6
	1	8	0.9	0–3
	0	5	0.2	0–1

How can these observations be explained? Probably as follows: female *A. isosceles* select places with dense waterweed in which to oviposit and, at Castle Marsh, these largely consist of *S. aloides*. As a result male *A. isosceles* congregate in such areas either because they see the females there or learn that that is where they go or, just possibly, they have an inherited response to seek out large quantities of waterweed. Whatever the reason territorial behaviour will force some males – generally slightly immature or old ones – to patrol areas with little or no *S. aloides*. This explanation is supported by the fact that no *A. isosceles* were seen on dykes with no *S. aloides* at early or late seasons when dragonfly populations were low but only at midseason in 1991 and 2004 when they were high (Table 5). The reason that more dragonflies were seen on dykes with no *S. aloides* in 1991 (nine insects) than in 2004 (one insect) was probably because in 1991 there were many fewer *S. aloides* plants and many fewer dykes with high densities of plants. Therefore, as dragonfly numbers were similar in both years, there was much greater competition for *S. aloides* sites in 1991 than in 2004.

The relationship of adult male *A. isosceles* with the males of other species

The numbers of male *A. isosceles* by water are clearly affected by territorial encounters. As a result the population of male *A. isosceles* rarely exceeds nine males per 100 m of dyke – the Highest Steady Density of the species. This density was observed on small stretches of favourite habitat in a few dykes but was never exceeded over the whole length of the dyke. All encounters between male *A. isosceles* led to aggression. In a sample study, 25% of this took the form of fierce attacks; in the rest the attacked male avoided the attacking insect by moving away.

Interspecific aggression is common among aeshnids and in some circumstances, e.g. in small ponds, can result in the male of one species chasing out those of other aeshnid species (Moore, 2000). There is also aggressive action between *A. isosceles* and libellulid species.

The flight season of *A. isosceles* overlapped with those of four other aeshnid species: the Hairy Dragonfly *Brachytron pratense*, the Emperor Dragonfly *Anax imperator*, the Brown Hawker *Aeshna grandis* and the Southern Hawker *Aeshna cyanea*, and with two large libellulid species the Scarce Chaser *Libellula fulva* and the Four-spot Chaser *Libellula quadrimaculata*. The species with which it had most opportunity to interact were *B. pratense*, whose flight season largely coincided with its own, and *L. quadrimaculata*, which was very numerous over all of its season. Fourteen separate studies were made at Castle Marsh and Carleton Coville in Suffolk and at Ludham in Norfolk on the interactions between *A. isosceles* and the other species over the 1991–2004 period (Table 6). The following observations resulted:

(1) On at least one occasion an *A. isosceles* was observed to make a determined attack on a male of each of the four species *B. pratense*, *A. imperator*, *A. grandis* and *L. quadrimaculata* and an aggressive pursuit of a male of each of *A. cyanea* and

L. fulva. Individuals of *A. imperator*, *A. grandis* and *L. quadrimaculata* were seen to make a determined attack on a male *A. isosceles* or, in the case of the last two, to pursue it aggressively. In the other three species, *B. pratense*, *A. cyanea* and *L. fulva* the action consisted of at least one aggressive pursuit of an *A. isosceles*.

(2) Most of the determined attacks and aggressive pursuits were between *A. isosceles* and the other two brown species, *A. grandis* and *L. quadrimaculata*. However, only on one occasion was a *L. quadrimaculata* observed to chase an *A. isosceles* away from the dyke and this was an immature *A. isosceles*. On several occasions *L. quadrimaculata* moved away from the dyke after being attacked or pursued by an *A. isosceles*, but when the *A. isosceles* left their territories the *L. quadrimaculata* quickly returned to the dyke.

Table 6. Interactions between male Norfolk Hawkers *Aeshna isosceles* and other species of dragonfly. →, interaction; a, often resulted in physical contact; b, one *A. isosceles* investigated the *A. imperator*; c, the *A. isosceles* avoided the *A. grandis*; d, after a *L. quadrimaculata* pursued an *A. isosceles* the latter often behaved aggressively towards the *L. quadrimaculata* but both remained by the dyke; *, on numerous occasions little or no contact between these species was observed but the number was not recorded.

Interacting species	Type of interaction			
	Determined attack[a]	Aggressive pursuit	Slight aggression	Little or no contact
A. isosceles → *B. pratense*	4	7	0	1
B. pratense → *A. isosceles*	0	5	2	2
A. isosceles → *A. imperator*	1	0	0	2[b]
A. imperator → *A. isosceles*	1	0	0	0
A. isosceles → *A. grandis*	3	10	0	1[c]
A. grandis → *A. isosceles*	2	5	0	0
A. isosceles → *A. cyanea*	0	1	0	0
A. cyanea → *A. isosceles*	0	1	0	0
A. isosceles → *L. quadrimaculata*	9	67	2	*
L. quadrimaculata → *A. isosceles*	6	122[d]	1	*
A. isosceles → *L. fulva*	0	1	0	0
L. fulva → *A. isosceles*	0	1	0	0

It is concluded that, despite much interaction between *A. isosceles* and other anisopteran species, it is most unlikely that the total populations of adult male *A. isosceles* are much affected by the presence of adult males of other anisopteran species. Accordingly the relationship between *A. isosceles* and *S. aloides* is unlikely to be affected. However, Suutari *et al.* (2004) have shown experimentally that, in Finland, the larvae of the Green Hawker *Aeshna viridis* – a species which is very closely associated with *S. aloides* – is kept out of the middle and outer parts of *S. aloides* plants by the larvae of *A. grandis*. Therefore a similar situation may occur between *A. grandis* and *A. isosceles*.

Castle Marsh in the Broadland Context

Castle Marsh lies at the southern end of the range of *S. aloides* and *A. isosceles* in the Broadland area, which extends about 42km along the North Sea coast of Norfolk and Suffolk. Few if any populations of the two species occur more than 19km from the coast. Visits were made to 30 sites known to have populations of *S. aloides*, or that did have them in the recent past, or that looked suitable for the plant. The aims were:

(1) to determine how far the relationship between the plant and the insect at Castle Marsh was typical of the Broads as a whole.
(2) to determine the extent to which *A. isosceles* was restricted to areas with *S. aloides*.

Observations were concentrated on sites which were roughly similar in size: six visits were paid to Ludham and Strumpshaw and three to Upton Marshes and Carleton Coville. At these reserves there was a range of dykes from those with a high density of *S. aloides* to those with few plants or none. The number of dykes with *S. aloides* was considerably greater at Ludham and Upton than at the other two sites. The relationship between male *A. isosceles* and the density of *S. aloides* was similar to that at Castle Marsh and, as at Castle Marsh, Frogbit *Hydrocharis morsus-ranae* was frequently found with *S. aloides*. On occasion *A. isosceles* was seen patrolling dykes with no *S. aloides*. The territorial behaviour of *A. isosceles* was the same as at Castle Marsh. There were frequent attacks on, and aggressive pursuits of, other *A. isosceles* and reciprocal attacks with *L. quadrimaculata*. This species was sometimes attacked and sometimes ignored.

Smaller populations of *S. aloides* with *A. isosceles* were observed at:

- North Cove in the Waveney catchment.
- How Hill and by Barton Broad in the Ant catchment.
- In several places near Hickling Broad in the Thurne catchment.
- At Woodbastwick and near Burgh Saint Margaret in the Bure catchment.
- At Buckenham and Cantley in the Yare catchment.

The only site where *S. aloides* was abundant but no *A. isosceles* was seen was a small isolated stretch of ditch (24m long) in the Chet valley near Loddon. It is concluded that Castle Marsh was typical of other sites with large populations of *S. aloides* and *A. isosceles*.

A. isosceles* on sites with no *S. aloides

Female *A. isosceles* have been observed to oviposit on at least five species of aquatic plants other than *S. aloides* and occur in some dykes with only these species (Heath, 1999). On 27 May 1999 I found a recently emerged *A. isosceles* on the brink of a dyke at Upton in the South Walsham Marshes at some distance from the dykes in the Upton Marshes which held populations of both *S. aloides* and *A. isosceles*. Although I could find no exuvia the insect was unable to fly and it had almost certainly emerged from the dyke, which had no *S. aloides*. On 18 June 1997 I surveyed some dykes near Martham Broad in an area where there was no *S. aloides*. On one dyke I saw a male *A. isosceles* patrolling a dyke

with Fennel-like Pondweed, *Potamogeton pectinatus* and much open water and another male patrolling a dyke with algae and open water.

I received several reports from Toby Abrehart and others of *A. isosceles* occurring where there was no *S. aloides*. *A. isosceles* had been seen and their exuviae had been found in the Waveney valley, between Beccles and Bungay, and at the Hundred River, which runs parallel to the Waveney and enters the sea at Kessingland. So it was particularly interesting to see what aquatic plants were growing in these two localities and to determine the size and density of *A. isosceles* populations there. I was shown the upper Waveney site by Toby Abrehart. There I inspected about 1000m of dykes at Barsham Marshes a mile upstream of Beccles. They consisted of five dykes and a section of the counter drain of the Waveney. I saw 14 male *A. isosceles* and one female. The six water courses had a rich flora of aquatic plants: Common Bladderwort *Utricularia vulgaris* occurred in all six water courses, *H. morsus-ranae*, which occurs at Castle Marsh, in five, Floating Pondweed *Potamogeton natans* in three and other species in one or two. The population density of one male *A. isosceles* in 73m of water course was similar to many dykes at Castle Marsh.

On 25 June 2001 I inspected a 110m section of the New Dyke near Ellingham about 2km downstream from Bungay. Its flora consisted of Ivy-leaved Duckweed *Lemna trisulca*, Water Violet *Hottonia palustris*, Procumbent Marshwort *Apium nodiflorum* and algae. There were two male *A. isosceles* and one female. On 10 July 2000 I visited the Hundred River and counted four male *A. isosceles* on a 30m stretch of the river, whose flora consisted mainly of *P. natans*, Yellow Water Lily *Nuphar lutea*, Arrowhead *Sagittaria sagittifolia* and Water Plantain *Alisma plantago-aquatica*. Oddly I found no *A. isosceles* on a neighbouring ditch which contained much *H. morsus-ranae*, *L. trisulca*, *A. nodiflorum* and algae.

It is concluded from all these observations in Suffolk that *A. isosceles* prefers to breed in ditches with *S. aloides* but in its absence it will breed in dykes which have a rich submerged flora of other species, notably *H. morsus-ranae* and *U. vulgaris*, thus confirming the views of Heath (1999).

Discussion

The Conservation of *S. aloides* and *A. isosceles* in England

In the past, changes in the distributions of *S. aloides* and *A. isosceles* in Britain have resulted from changes in farming and drainage practises as well as from irregular flooding by fresh and saline water. They are excellently reviewed by Heath (1999). Now the species are threatened increasingly by rising sea levels caused by climate change. All their sites lie between about 1 metre below sea level and 2 metres above it. Many sites lie below sea level. Therefore urgent measures are required if the two species are to survive in England. As already noted, both species occurred in the Fens in the past (Heath,

1999; Friday & Harley, 2000). Therefore I have assessed the possibility of the two species recolonising the Fens naturally and, if that does not seem likely, the feasibility of reintroducing them deliberately.

Possibilities of natural recolonisation

The powers of natural dispersal of *S. aloides* are very limited. On the other hand *A. isosceles* is capable of travelling considerable distances away from its breeding areas. In June 2005 I was in Romania and in the marshland of the Danube Delta and saw *A. isosceles* both in areas with *S. aloides* and in those without it. To my surprise I later saw many *A. isosceles* in clearings in the large steppe forest of Babadag in the hilly country of Northern Dobruja, where there were no breeding habitats for the insect. Later I also saw them in an extensive area of saline lagoons and sand dunes on the Black Sea coast. Therefore it is not surprising that the occasional *A. isosceles* in England has been observed away from the Broads (Mendel, 1992; Heath, 1999), although whether these insects came from the Broads or from the continent is not known. At Minsmere only 21km south of what is probably the most southerly breeding place of the species – at Frostenden near Easton Broad – the insect has been reported several times but I have failed to find any suitable breeding habitat in the surrounding grazing marshes. However, the Minsmere records suggest that the species would colonise new habitats if the insects were suitable for it and were not far from the Broads. However, would they be able to colonise the Fens about 60km away? Taylor (2003) stated that *A. isosceles* had increased its numbers and had extended its range in the Waveney valley since 1990. These changes have apparently continued since then. The most westerly population of *A. isosceles* today appears to be near Ellingham in the Waveney valley and the easiest way the species could colonise the Fens would be by flying up the Waveney valley and down the Little Ouse valley. The two rivers both originate from the Redgrave and Lopham National Nature Reserve. In 1994 I found neither *S. aloides* nor *A. isosceles* there, although some of the habitat looked suitable for them. Further down stream in the upper valley of the Little Ouse the RSPB is restoring marshy conditions at their Lakenheath reserve, but the water there is probably too acidic for *S. aloides*. An *A. isosceles* was observed at Lakenheath in 1996 (Tunmore,1999); it left no progeny. It was presumably transported there as a larva when reeds were introduced from Norfolk.

Further down the Little Ouse valley there are no suitable sites for *S. aloides* and few, if any, elsewhere in the Cambridgeshire fens. However, Wicken Fen NNR, in the catchment of the Cam and 20km south west of the Little Ouse, may be the exception. It is relatively unpolluted and used to have *S. aloides* and *H. morsus-ranae* and still does have *U. vulgaris* (Friday & Harley, 2000). *S. aloides* survived near Stretham only 6km from Wicken until 1961 (Perring *et al.*, 1964). *A. isosceles* was recorded from Swaffham Fen, 3km from Wicken, in the nineteenth century (Imms, 1938).

A. isosceles may eventually become less dependent on *S. aloides* but under the imminent threat of climate change we cannot rely on this happening, so it is prudent to press ahead

with attempts to reintroduce both species to Wicken Fen; it is the most suitable site for the purpose. Therefore, since 1998 I have been exploring the possibility, and in 2004 The National Trust, the owners of the Reserve, gave the go-ahead for making an attempt to reintroduce *A. isosceles* following a successful introduction of *S. aloides*. The project is now underway: administrative permission to reintroduce the species has been given, two new dykes have been dug and in 2007 *S. aloides* from the Norfolk Broads was introduced into them. If the introduction of *S. aloides* is successful but no *A. isosceles* colonise them naturally, larvae of *A. isosceles* will be introduced from the Norfolk Broads. Meanwhile the programme is being monitored and kept under review.

Acknowledgements

I would like to thank Owen Leyshon for providing the baseline of this study, the Suffolk Wildlife Trust for permission to study *S. aloides* and *A. isosceles* on their reserve at Castle Marsh, and especially Mike Harding, the Reserve Manager, and John Oakley, the Warden, who provided useful information about the management of the Reserve. I thank all those in Suffolk and Norfolk who shared information with me about sites they know well, especially Toby Abrehart, whose knowledge about locations of *A. isosceles* in the south of its range was particularly valuable. I would like to thank Beryl Ranwell for providing an invaluable base nearby whenever I needed it throughout the period of the study. And finally my thanks to my wife Janet for much help in typing and criticising this paper.

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The biting midge *Forcipomyia paludis* as a parasite on dragonfly wings: a species not recorded from Britain for more than 70 years (Diptera: Ceratopogonidae)

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Summary

The biting midge *Forcipomyia paludis* has only been recorded from British odonates in the first half of the last century. All known records are from the type locality, Wicken Fen, Cambridgeshire, the last in June 1936. It is suggested that a useful approach for gathering further information is to check odonate photographs. Special attention should be drawn to oval brownish spots on odonate wings.

Introduction

Forcipomyia (Pterobosca) paludis (Macfie, 1936) is a biting midge, only 1.8mm in size, which sucks haemolymph from the veins of odonate wings (Wildermuth & Martens, 2007). It is the only ceratopogonid species known to parasitise adult dragonflies in Europe and 55 species of odonate have so far been recorded as hosts. Only females have been found on adult dragonflies, where they are attached to either side of the wings with a preference for the basal half, and mostly facing the wing base (Plate 1). The records of midges attached to odonate wings date from mid-May to the beginning of August (Martens *et al.*, 2008).

Forcipomyia paludis was first recorded on 2 July 1935 at Harding's Piece, Wicken Fen, Cambridgeshire, when the British odonatologist John Cowley collected one midge attached to a male *Coenagrion pulchellum* and one to a female *Lestes*, together with their hosts. On the basis of these two specimens, Macfie (1936a) described *Pterobosca paludis* as a new species. In his paper he pointed to a remark of Michelmore (1929) who mentioned the capture of an imago of *Aeshna grandis* at Wicken Fen in August 1926 carrying a number of minute black flies on its wings. Also based on information by J. Cowley, Macfie corrected in a subsequent publication (Macfie, 1936b) the identity of the female *Lestes* as *Lestes sponsa* and not *L. dryas* as stated earlier (Macfie, 1936a). Cowley (1936) himself also gave a brief account of his records. In June 1936 the Society of British Entomology visited Wicken Fen and several members made a special search for the ceratopogonid midge. They recorded specimens on *Coenagrion pulchellum*, *Ischnura elegans*, *Enallagma cyathigerum*, *Brachytron pratense* and *Libellula quadrimaculata* (Edwards 1937).

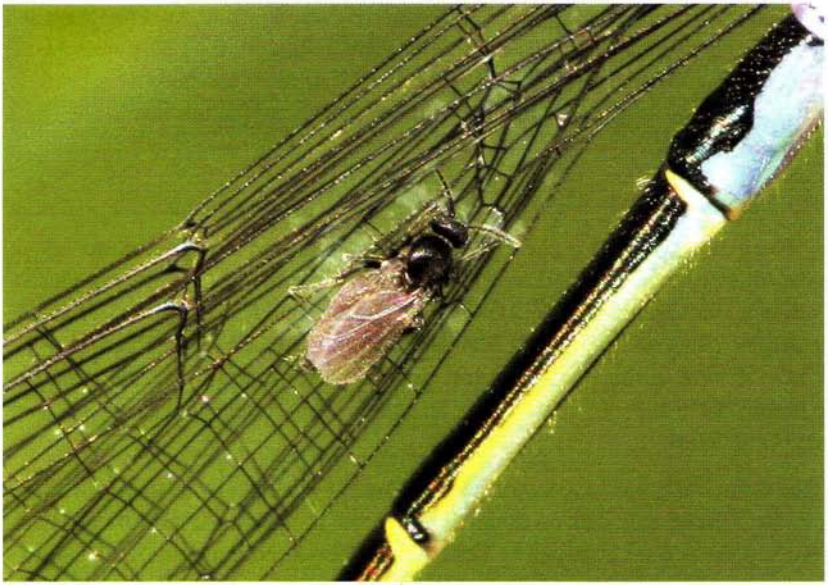

Plate 1. Male *Ischnura elegans* with biting midge (*Forcipomyia paludis*) attached to the right hind wing. Barchetsee, Switzerland, 26 July 2008. Photo by B. Schneider.

Plate 2. Male *Cordulia aenea* with two biting midges (*Forcipomyia paludis*) attached to the left fore wing (small white circle) and at least six midges on both of the right wings clearly seen as shadows on the reed blade (large white circle). Wetzikon, Switzerland, 2 July 1981. Photo by H. Wildermuth.

Recent data originate from France, Switzerland, Austria, Germany and Sardinia, with a few from Sweden and Croatia (Martens *et al.*, 2008). By re-analysing all data available on *Forcipomyia paludis* (Martens *et al.*, 2008) we realized that there has been no recent record from Great Britain and it appears from the literature that Wicken Fen is still the only known British locality.

How to find the species

The midges are often overlooked in the field. In the case of netted odonates many individuals detach from their host and escape (Martens *et al.*, 2008). A useful approach is to check odonate photographs (Plate 2). The midges are recognizable as dark spots with a characteristic pattern. The insect's head and prothorax are clearly visible and contrast with the shadow of the wings in dorsal view. In most cases the head is orientated towards the thorax of the host. In ventral view an oval brownish spot can be seen on one of the odonate wing veins.

We expect that a check of photographs will produce recent records on the presence of this species in Britain and new data on its hosts and on its geographic distribution. We do not believe that the species is extinct in Great Britain, even though there has been no record for more than 70 years.

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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 format either on disk or by e-mail.

Typewritten manuscripts should be produced using black ribbon, double-spaced, on one side of the page only and with margins at least 25mm at the left, top and bottom. Text pages should be numbered and footnotes avoided.

Words that are to appear in italics (e.g. names of genera and species, though not of families) should be underlined if an italic font is not available.

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 2004.

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 this form:

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

Longfield, C. O. 1949. The dragonflies of the London area. *The London Naturalist* **28**: 90–98.

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Figures should be prepared in black ink, and scaled to allow a reduction of 1.5 to 3 times.

Every legend for each table and illustration should allow its contents to be understood fully without reference to the text. The approximate position of each table and figure should be indicated in the text.

SCIENTIFIC AND ENGLISH NAMES OF BRITISH ODONATA

ZYGOPTERA	DAMSELFLIES
Calopteryx splendens	Banded Demoiselle
Calopteryx virgo	Beautiful Demoiselle
Chalcolestes viridis	Willow Emerald Damselfly
Lestes dryas	Scarce Emerald Damselfly
Lestes sponsa	Emerald Damselfly
Ceriagrion tenellum	Small Red Damselfly
Coenagrion armatum	Norfolk Damselfly
Coenagrion hastulatum	Northern Damselfly
Coenagrion lunulatum	Irish Damselfly
Coenagrion mercuriale	Southern Damselfly
Coenagrion puella	Azure Damselfly
Coenagrion pulchellum	Variable Damselfly
Coenagrion scitulum	Dainty Damselfly
Enallagma cyathigerum	Common Blue Damselfly
Erythromma najas	Red-eyed Damselfly
Erythromma viridulum	Small Red-eyed Damselfly
Ischnura elegans	Blue-tailed Damselfly
Lestes barbarus	Scarce Blue-tailed Damselfly
Pyrrhosoma nymphula	Large Red Damselfly
Platycnemis pennipes	White-legged Damselfly

ANISOPTERA	DRAGONFLIES
Aeshna caerulea	Azure Hawker
Aeshna cyanea	Southern Hawker
Aeshna grandis	Brown Hawker
Aeshna isosceles	Norfolk Hawker
Aeshna juncea	Common Hawker
Aeshna mixta	Migrant Hawker
Anax (Hemianax) ephippiger	Vagrant Emperor
Anax imperator	Emperor Dragonfly
Anax junius	Green Darner
Anax parthenope	Lesser Emperor
Brachytron pratense	Hairy Dragonfly
Gomphus vulgatissimus	Common Club-tail
Cordulegaster boltonii	Golden-ringed Dragonfly
Cordulia aenea	Downy Emerald
Oxygastra curtisii	Orange-spotted Emerald
Somatochlora arctica	Northern Emerald
Somatochlora metallica	Brilliant Emerald
Crocothemis erythraea	Scarlet Darter
Leucorrhinia dubia	White-faced Darter
Libellula depressa	Broad-bodied Chaser
Libellula fulva	Scarce Chaser
Libellula quadrimaculata	Four-spotted Chaser
Orthetrum cancellatum	Black-tailed Skimmer
Orthetrum coerulescens	Keeled Skimmer
Pantala flavescens	Wandering Glider
Sympetrum danae	Black Darter
Sympetrum flaveolum	Yellow-winged Darter
Sympetrum fonscolombii	Red-veined Darter
Sympetrum nigrescens	Highland Darter
Sympetrum pedemontanum	Banded Darter
Sympetrum sanguineum	Ruddy Darter
Sympetrum striolatum	Common Darter
Sympetrum vulgatum	Vagrant Darter

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CONTENTS

ALICE STARMORE Submerged oviposition behaviour in the Large Red Damselfly *Pyrrhosoma nymphula* (Sulzer) on the Isle of Lewis 45

R. SEIDENBUSCH Three-winged Southern Hawker, *Aeshna cyanea* (Müller, 1767) 51

GRAHAM FRENCH & DAVE SMALLSHIRE Criteria for determining key Odonata sites in Great Britain 54

ADRIAN J. PARR Migrant and dispersive dragonflies in Britain during 2007 . 62

NORMAN W. MOORE The Norfolk Hawker *Aeshna isosceles* and Water Soldier *Stratiotes aloides*: a study of their relationship at Castle Marsh, Suffolk and elsewhere in the Broads 1991–2004 71

ANDREAS MARTENS & HANSRUEDI WILDERMUTH The biting midge *Forcipomyia paludis* as a parasite on dragonfly wings: a species not recorded from Britain for more than 70 years (Diptera: Ceratopogonidae) 88

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