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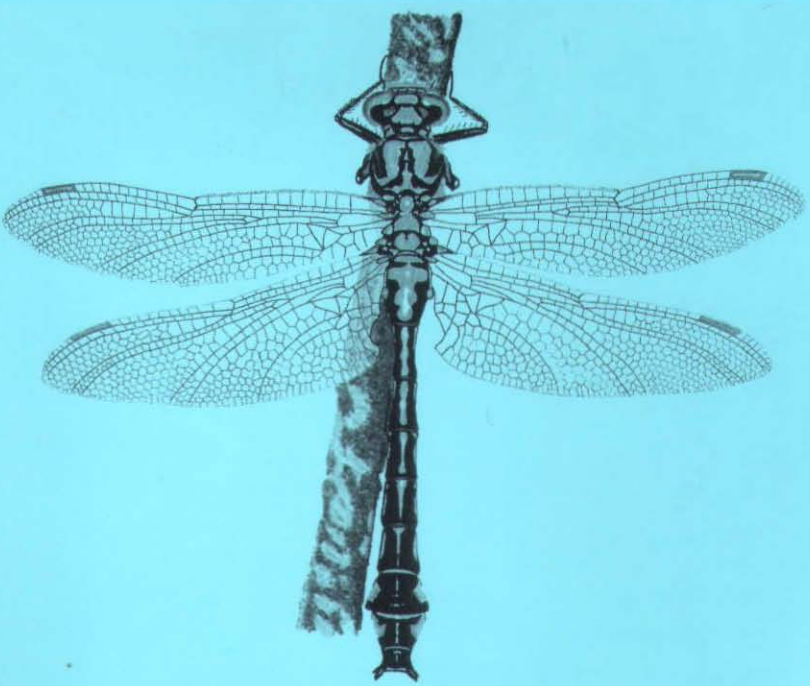

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Front cover illustration of a male Club-tailed Damselfly *Gomphus vulgatissimus* (L.) by Roderick Dunn.

Diversity of dragonflies in dune ponds at Birkdale Sandhills, Sefton Coast, Merseyside

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Introduction

The Sefton Coast sand-dune system in north Merseyside is regionally important for dragonflies and damselflies with 16 species recorded, of which at least 11 breed (Hall & Smith, 1991; Smith, 1997, 1999). Odonata are mainly associated with ponds excavated in existing dune slacks during the 1970s and early 1980s as breeding habitat for Natterjack Toads *Bufo calamita*. All have shallow margins and gently shelving sides. However, most of the ponds are no longer used by the toads and have been colonized by a rich variety of aquatic plants and animals, including dragonflies. The fact that some ponds are sheltered by nearby woodland, scrub or dune ridges may have increased their attractiveness to these insects (Hall & Smith, 1991).

Birkdale Sandhills (210ha; Grid Reference SD 310140), which is the northern part of the Ainsdale & Birkdale Sandhills Local Nature Reserve, contains a fine selection of man-made ponds. There are 13 that were excavated during 1976 and 1977 in the slacks east of the coastal road (Fig. 1), plus two groups of World War II bomb-craters. These, together with a 1980s scrape in the mobile dunes west of the coastal road, form a convenient unit for study. This paper describes the species richness and diversity of adult Odonata at the Birkdale ponds over two summers and relates these to environmental factors.

Methods

Visits were made in June, July, August and early September during 1994 and 1995. As recommended by Moore & Corbet (1990), warm, sunny days with light winds were chosen and recording took place within two hours of solar noon. Ponds were located using a slack map on which sites were already identified by a numbering system (Fig. 1). The margin of each pond was walked slowly on each visit, all adult Odonata being identified and counted with the aid of binoculars. Numbers of the more abundant species were estimated in groups of five. Any evidence of breeding, such as the presence of teneral insects, mating pairs or oviposition, was noted. General observations were made on environmental factors pertaining to individual sites. These included whether or not the pond dried up during the study period, the extent of aquatic and marginal vegetation and the degree of shelter from dune ridges and scrub patches. In addition, the lengths of

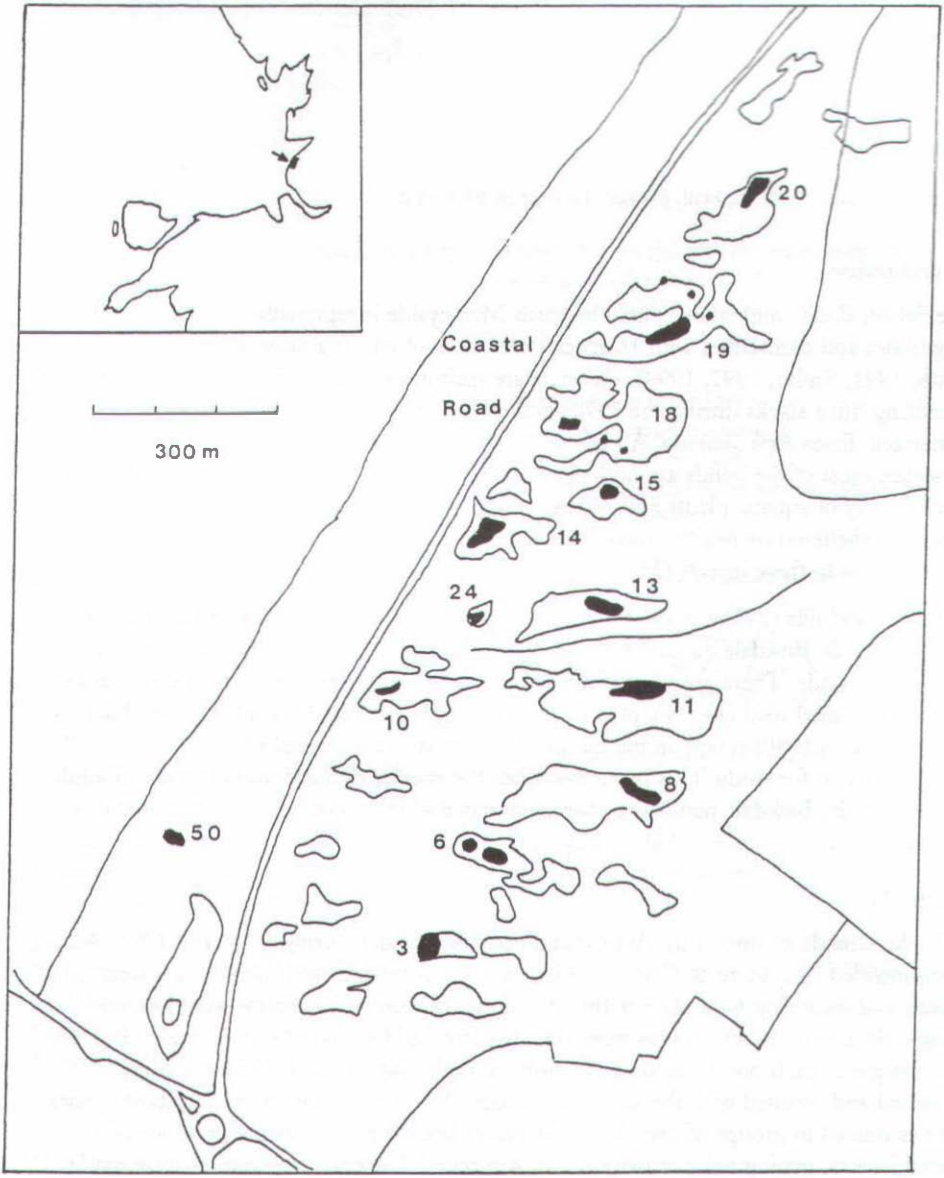

Figure 1. Study site within the Birkdale Sandhills, showing wet-slack outlines and positions of ponds and bomb-craters (shaded and numbered). Inset: location of study area in northwest England.

pond margins were obtained from a Geographic Information System operated by the Sefton Coast Management Scheme.

Data were pooled separately for the bomb-craters in slacks 18 and 19 and for the two small ponds in slack 6, making a total of 15 sites in the study area. Total numbers of individuals were calculated as the maximum count for each species at each site during the two years.

There are many different ways of assessing species diversity, ranging from simple species richness (the total number of species recorded per site) to more complex indices which take into account the numbers of individuals of each species or dominance measures which are weighted towards the abundance of the commonest species. Magurran (1988) provides a detailed review and also recommends the most useful diversity indices, four of which were adopted for this study as follows:

1. Species richness (S). This has been used successfully in many ecological studies and provides an extremely useful assessment of diversity (Magurran, 1988). It is also relatively simple to measure.

2. The log series index (α). Taylor (1978) has argued strongly in favour of the log series index because of its ability to discriminate between sites and the fact that it is not unduly influenced by sample size. The large number of investigations into the behaviour of α makes it an excellent candidate for a universal diversity index (Magurran, 1988). This species abundance model is tedious to calculate but it can be read from the nomograph provided by Southwood (1966).

3. Margalef's diversity index (Dmg):

$$\mathrm{Dmg} = \frac{(S-1)}{\ln(N)}$$

where S is the species richness, N is the total number of individuals sampled per site, and ln denotes the natural (or Napierian) logarithm. Margalef's index offers a combination of the number of species recorded and the total number of individuals summed over all the species. However, it is primarily a measure of species richness. Ease of calculation is a great advantage of this index but it is sensitive to sample size (Magurran, 1988).

4. Berger–Parker index (d):

$$d = \frac{N_{max}}{N}$$

where N_{max} = the number of individuals of the most abundant species and N is again the total number of individuals sampled per site. The Berger–Parker index is a measure of species dominance that expresses the proportional abundance of the most numerous species. It is independent of species richness but is influenced by sample size. Nevertheless, May (1975) concludes that it is one of the most satisfactory diversity measures available. It is also easy to calculate. The reciprocal form of the index (1/d) is adopted here so that an increase in its value accompanies an increase in diversity and a reduction in dominance (Magurran, 1988).

Table 1. Maximum counts of dragonflies at the fifteen Birkdale Sandhills sites, 1994–1995.

Site no.	Species and maximum count														No. of
	Ls	Cp	Ec	Ie	Ag	Aj	Ai	Lq	Ld	Ss	Sa	Sf	Sd	Total	Species
3	60	10	80	20	1		2	2		35		1	1	212	10
6	30	7	40	10	2		1	1	1	30	3	3		128	11
8	30	10	35	5				6		5		5	1	97	8
10	30	10		20						15				75	4
11	70	30	20	20	1					10	2	4	2	159	9
13	25	1	30	5						5			1	67	6
14	20	20	20	10	2			6		20	3	1	1	103	10
15	30	20	75	15	2		1	1	1	10	1		1	157	11
18	6	10		1							2	2		21	5
18bc	10	15	5	5	1			1		6	1			44	8
19	20	5	30	5	2			4		15				81	7
19bc	22	10	1	5				1			1			40	6
20	30	5	10	5						20				70	5
24	24	10	30	5	1			1		8	1	1		81	9
50	3	2	5	50	1	1		1		15				78	8
Total	410	165	381	181	13	1	4	24	2	194	14	17	7	1413	

Ls: *Lestes sponsa*
Cp: *Coenagrion puella*
Ec: *Enallagma cyathigerum*
Ie: *Ischnura elegans*
Ag: *Aeshna grandis*
Aj: *A. juncea*
Ai: *Anax imperator*
Lq: *Libellula quadrimaculata*
Ld: *L. depressa*
Ss: *Sympetrum striolatum*
Sa: *S. sanguineum*
Sf: *S. flaveolum*
Sd: *S. danae*
bc: bomb-craters

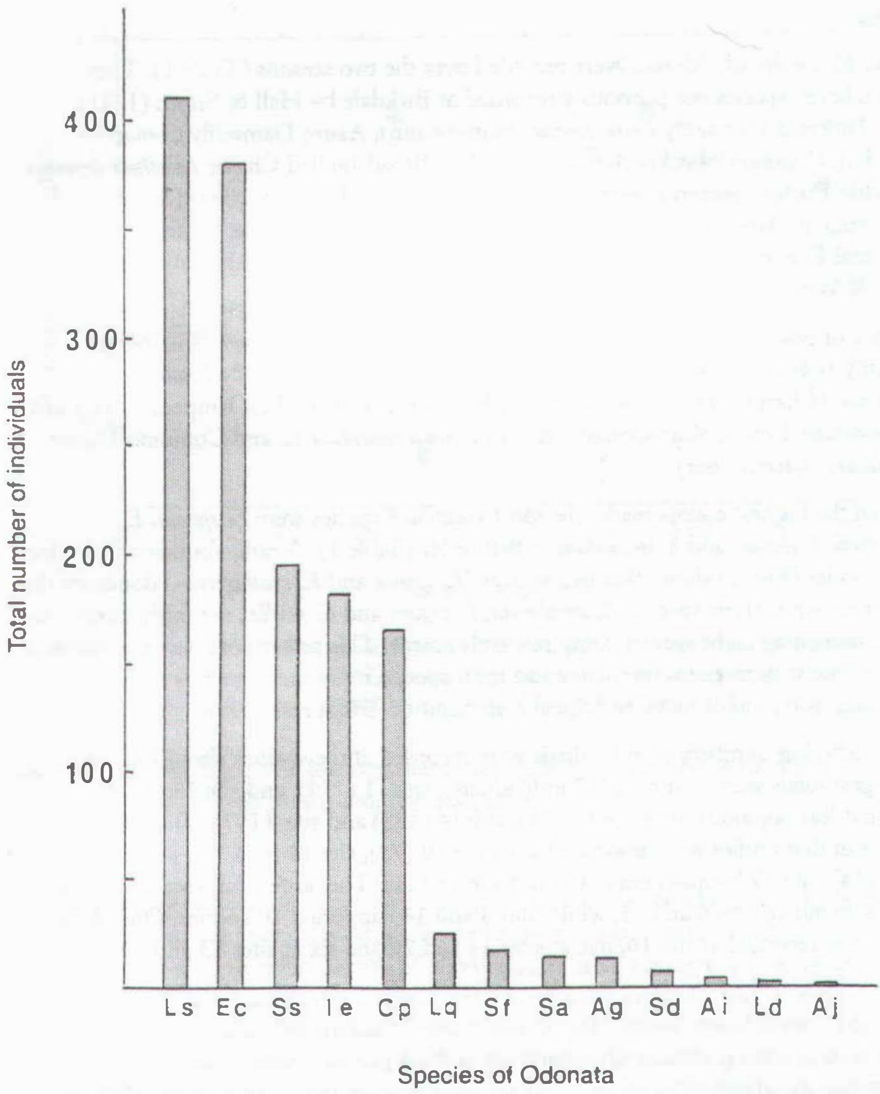

Figure 2. Rank abundance plots of the thirteen species of Odonata counted during the study.

Ls: *Lestes sponsa*
Ec: *Enallagma cyathigerum*
Ss: *Sympetrum striolatum*
Ie: *Ischnura elegans*
Cp: *Coenagrion puella*
Lq: *Libellula quadrimaculata*
Sf: *Sympetrum flaveolum*
Sa: *Sympetrum sanguineum*
Ag: *Aeshna grandis*
Sd: *Sympetrum danae*
Ai: *Anax imperator*
Ld: *Libellula depressa*
Aj: *Aeshna juncea*

Results

In total, 13 species of Odonata were recorded over the two seasons (Table 1). They included seven species not previously recorded at Birkdale by Hall & Smith (1991), namely Emerald Damselfly *Lestes sponsa* (Hansemann), Azure Damselfly *Coenagrion puella* (L.), Common Hawker *Aeshna juncea* (L.), Broad-bodied Chaser *Libellula depressa* L., Ruddy Darter *Sympetrum sanguineum* (Müller), Black Darter *S. danae* (Sulzer) and Yellow-winged Darter *S. flaveolum* (L.). The last named is a rare migrant from continental Europe, only noted in August 1995 when there was a major influx to Britain (Silsby & Ward-Smith, 1997).

Evidence of possible/probable breeding was obtained for eight species: Blue-tailed Damselfly *Ischnura elegans* (Vander Linden), Common Blue Damselfly *Enallagma cyathigerum* (Charpentier), *C. puella*, Brown Hawker *A. grandis* (L.), Emperor Dragonfly *Anax imperator* Leach, Four-spotted Chaser *L. quadrimaculata* L. and Common Darter *S. striolatum* (Charpentier).

Based on the highest counts made, the most abundant species were *L. sponsa*, *E. cyathigerum*, *I. elegans* and *S. striolatum* in that order (Table 1). A rank abundance plot for the 13 species (Fig. 2) shows that two species (*L. sponsa* and *E. cyathigerum*) dominate the community, while three species (*S. striolatum*, *I. elegans* and *C. puella*) are fairly numerous, and the remaining eight species being relatively scarce. This pattern of a few abundant species, some with medium frequency and most species represented by relatively few individuals, is typical of many ecological communities (Magurran, 1988).

Widely differing numbers of individuals were recorded at the various sites (Table 1). The largest totals were at site 3 (212 individuals), site 11 (159), and site 15 (157). Somewhat less populous were site 6 (128), site 14 (103) and site 8 (97). The lowest numbers of dragonflies were associated with site 10 (75), site 13 (67), site 18 bomb-craters (44), site 19 bomb-craters (40) and site 18 (21). The largest number of species (11) was found at sites 6 and 15, while sites 3 and 14 supported 10 species. Only four species were recorded at site 10, five at sites 18 and 20 and six at sites 13 and 19 bomb-craters.

The positive relationship between the total numbers of individuals and the length of the margin at each pond is statistically significant at the 5 per cent level (see Fig. 3). Logarithmic transformations of the totals are used because the untransformed data are not normally distributed.

The four sets of diversity indices are shown in Fig. 4. Species Richness (**S**), the log series index (α) and Margalef's Index (**Dmg**) have a similar pattern with high values for sites 3, 6, 11, 14, 15, 18 bomb-craters and 24. Sites 10, 13, 18 and 20 produced diversity indices with low values, the others being intermediate. The Berger–Parker Index (**1/d**) provides a rather different picture with site 14 by far the most diverse and little variation

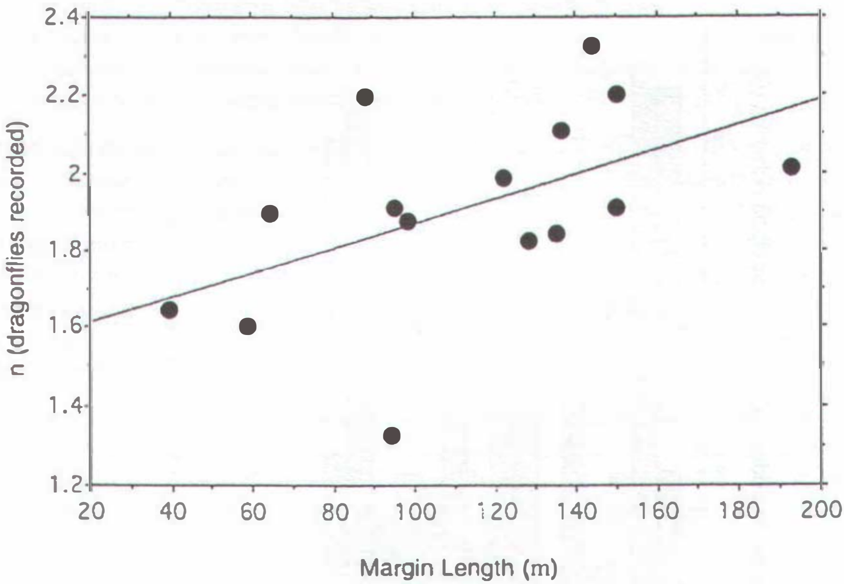

Figure 3. The relationship between the logarithm of the total number of individual dragonflies recorded (D) and the margin length (ML) for the 15 pond sites. The linear regression is positive and statistically significant ($\ln(D) = 0.003ML + 1.55$, probability = 0.049, $r^2 = 0.27$).

amongst the other sites. The low dominance rating of site 14 seems to be due to maximum counts of only 20 for four species (Table 1).

Discussion

Clearly, a variety of environmental variables will influence the numbers and diversity of dragonflies at different ponds, even within a relatively compact area like Birkdale Sandhills. Pond size, or rather length of pond margin, is an example. Males of many species of Odonata are territorial and space themselves out around a water body (Moore, 1964). Therefore, the longer the margin the more dragonflies are likely to be present. This relationship was found in the present study (Fig. 3). However, the r^2 value of 0.27 (where r is the correlation coefficient) shows that only 27 per cent of the variation in numbers of individuals is accounted for by margin length, leaving 73 per cent attributed to other, unknown, factors. Some of these may be the basic requirements for a 'good' dragonfly pond (Merritt *et al.*, 1996). Those requirements considered most relevant to this study area are:

Pond holds water throughout the year.
No shading on the south side of the pond.

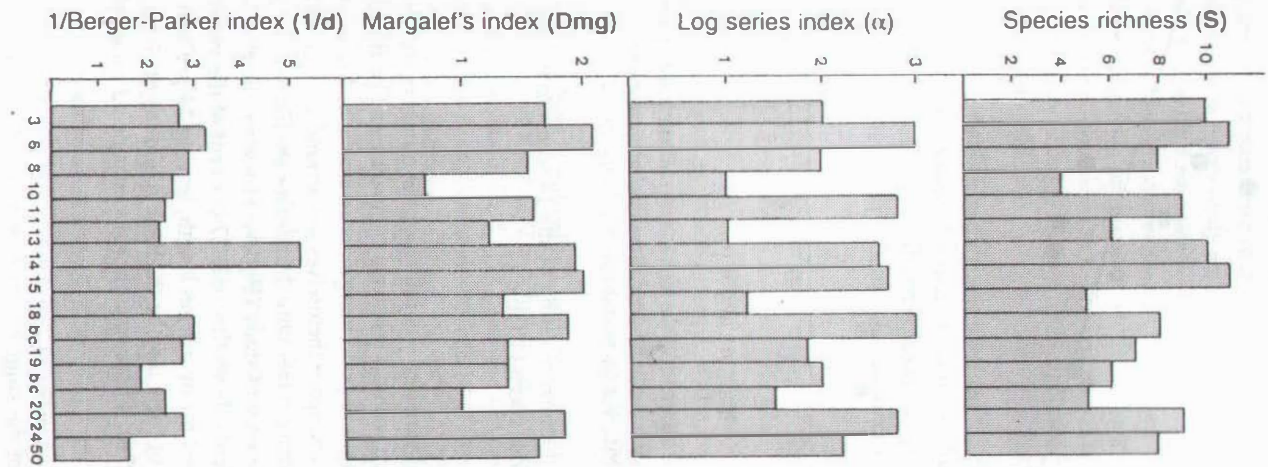

Figure 4. Diversity indices for the fifteen dragonfly sites studied at Birkdale (bc: bomb-craters).

Pond contains submerged, floating and emergent aquatic plants.
In exposed locations, there should be trees or bushes 10–50m from the pond and tall, rank grasses to provide shelter and resting areas for adults. In a sand-dune landscape, appropriately positioned dune ridges will also afford shelter.

Factors unfavourable to dragonflies include a tendency for the pond to dry up. In South Africa temporary water bodies may support many fewer species of Odonata and lower numbers of individuals than permanent water bodies (Clark & Samways, 1996). Dense growths of emergent plants may also be undesirable. A 27-year study of ponds at Woodwalton Fen, Cambridgeshire, demonstrated a decline of adult dragonflies with increasing growths of Common Reed *Phragmites australis*, perhaps because such stands impair flight and also shade the water surface, reducing the growth of submerged and floating plants (Moore, 1991).

The number of favourable (positive) and unfavourable (negative) factors for each of the Birkdale pond sites can be summed to provide a score for each site (Table 2). The table also relates these scores to three levels of dragonfly diversity. On the whole, the scoring system works well, with low diversity ponds scoring from –1 to 3, medium diversity ponds from 3 to 5 and high diversity ponds from 4 to 6.

Taking into account maximum counts of individuals (Table 1) and diversity, the 'best' ponds for dragonflies are sites 3, 11, 6, 15 and 14. All of these are characterized by permanent water and some form of shelter. Sites 3, 11 and 15, in particular, are partly surrounded by dense Sea-buckthorn *Hippophae rhamnoides* thickets over 2m high, while site 6 has a tall bed of Reed Canary-grass *Phalaris arundinacea* on its western margin and site 14 a high ridge of spoil along its westerly fringe. Other factors common to these sites are the presence of diverse aquatic vegetation, especially at site 14, and at least 50 per cent open water. Also, most have a relatively long margin, site 14 being the largest of all the ponds.

In contrast, the 'worst' dragonfly ponds at Birkdale, sites 10, 13, 18 and 20, lack most of the above features. Site 10 is fairly small and completely colonized by emergent aquatic vegetation, mostly Water Horsetail *Equisetum fluviatile*, while a tall hybrid rush *Juncus balticus* x *J. inflexus* dominates site 18. Sites 18 and 20 also share the added problem of the lack of permanent water. Pond 13 is exposed to the north and west and is frequently visited by dog-walkers, resulting in trampled margins and very little aquatic vegetation.

The two sets of bomb-craters fit less easily into this scheme, having a medium diversity of dragonflies despite their small size. However, they are quite well sheltered, have permanent water and rich aquatic plant life. Also, as they are much older than the other sites, there will have been more time for successful colonization by Odonata species.

This study suggests that the highest dragonfly diversity at Birkdale is associated with larger, more permanent dune pools with a balance between aquatic vegetation and open

Table 2. Environmental factors favourable (positive) and unfavourable (negative) to Odonata at the fifteen Birkdale Sandhills pond sites, related to three levels of diversity (H: high, M: medium and L: low).

Factors	Site numbers														
Favourable	3	6	8	10	11	13	14	15	18	18bc	19	19bc	20	24	50
Permanent water	+	+		+	+	+	+	+		+	+	+		+	+
Long margin	+	+	+		+	+	+				+		+		+
Aquatic vegetation	+	+	+	+	+		+	+	+	+	+	+	+	+	+
Open water	+	+	+		+	+	+	+		+	+	+		+	+
Shelter-scrub	+				+			+		+	+	+	+		
Shelter-topography					+		+			+		+	+	+	+
Shelter-grass		+		+			+		+						
Unfavourable															
Temporary water									–				–		–
Small size				–					–	–		–			
No open water				–					–						
Exposed						–									
Overall score	5	5	3	1	6	2	6	4	–1	4	5	4	3	4	4
Diversity	H	H	M	L	H	L	H	H	L	M	M	M	L	H	M

bc: bomb-craters

water, together with good shelter from terrestrial vegetation or dune topography. These are important findings for these insects in one of their prime northwest England locations.

In recent years, habitat management in the dune system has emphasized the control of woodland and scrub which have spread, particularly since the 1950s, at the expense of more typical open dune habitats and associated species (Atkinson & Houston, 1993; Smith, 1999). The latter include the Natterjack Toad, for which the Sefton Coast is one of its most important British localities. For breeding, this species requires shallow, unshaded pools, which often dry up in late summer. Most of the Birkdale ponds were dug for Natterjack Toads at a time when the water-table was very low, but only one of them (site 50) is now regularly used by the toads as most of them are too deep and the surrounding terrestrial vegetation too overgrown for foraging adults. Management to make the Birkdale ponds more suitable for Natterjack Toads would probably reduce their value for dragonflies, as sheltering scrub would have to be removed, many of the ponds made more shallow and livestock grazing introduced. Careful planning will be required to avoid such possible conflicts, for example by excavating new, permanent ponds along the eastern fringes of the Local Nature Reserve where dune scrub could be retained as part of the natural succession.

Acknowledgements

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Population studies of the Southern Damselfly *Coenagrion mercuriale* (Charpentier) in the New Forest. Part 8. Short range dispersal

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Introduction

An important part of the Biodiversity Action Plan for the Southern Damselfly *Coenagrion mercuriale* is to establish the potential of this species for dispersal. If *C. mercuriale* is capable of establishing further colonies naturally, at suitable locations within its existing range, then proposals for translocation or release of captive-bred insects to bolster current populations would not need to be considered. Very little is known about the detailed habitat requirements for this species, and the habitats of *C. mercuriale* in the UK are so diverse, that anything other than natural colonization carries a high risk of failure. In the New Forest there is little evidence for establishment of new colonies over the past 50 years. The few new sites discovered are probably the result of more thorough coverage by recorders and are offset by a similar number of sites which have been lost through prolonged summer drought or habitat change.

It has been established that *C. mercuriale* regularly move short distances along the same watercourse (Hopkins & Day, 1997), but are reluctant to pass sections of unsuitable habitat (Jenkins, 1998). Systematic attempts with marked insects to prove long distance dispersal have been disappointing. At Crockford in the New Forest, only two males have been recovered away from the marking area, both at distances of approximately 1km on, or near, the same stream (Hopkins & Day, 1997; Thompson & Purse, 1999). However the potential area for dispersal from this site is so large that the likelihood of recoveries is extremely low.

At Mill Lawn, Burley, an irregular series of drainage ditches run, in roughly 'herringbone' formation, from a narrow strip of upper mire below Bisterne Close, down through acid grass 'lawn', to drain eventually into the main watercourse, Mill Lawn Brook. The ditches are roughly parallel, some 75 to 150m apart, and support variable numbers of *C. mercuriale*. The individual colonies, if they can be considered as such, are very small compared to those at Crockford. It seemed that this site would be suitable for collecting useful information on short distance dispersal by marking adult damselflies on one or more ditches, releasing them, and then searching nearby ditches. The following advantages over previous work were identified:

a) Low numbers of damselflies would ensure that a high percentage of the population could be marked, although low population density might adversely affect dispersal.
b) The short distance between ditches, and other topological factors to be discussed, would encourage dispersal.
c) With such a small overall area, and the openness of areas adjacent to the ditches, searching could be relatively thorough compared to that in the Crockford area and thus provide a better chance of finding dispersed *C. mercuriale,* particularly females, which have proved elusive in previous studies.

An initial study was carried out in 1997 using four ditches at the western end of Mill Lawn. During the fortnight available, the weather was predominantly overcast and the number of *C. mercuriale* seen was much lower than anticipated. No dispersal was recorded and frequently the same insects were found on the same bush or stem for two or three days in succession, occasionally so inactive that they could be picked off by hand and marked. However, even under these conditions, reasonable numbers of *C. mercuriale* were active on a pair of ditches further to the west at Rooks Bridge. Marking experiments carried out at the latter site in June/July of 1999 are reported below.

Methods

The marking methods developed by Thompson & Purse (1999) were adopted. *C. mercuriale* from the east ditch were marked on the thorax with a white spot, and those from the west ditch were marked with a gold spot. Each individual was also marked with a black number on one wing, indicating the day of marking. The white spots were easily visible from a distance of 2–3m but a close focus monocular was needed to confirm gold spots and the numbers. However, there appeared to be no measurable difference in mortality between the white and gold marked damselflies with average lifetimes of about six days for males and about three days for females, in both cases.

Between 1000h and 1600h on each day, effort was concentrated on marking as many *C. mercuriale* as possible on one ditch only, and in searching both ditches for dispersed individuals. The surroundings of both ditches to approximately 2m either side, as well as the lower edge of the upper mire and the bottom cross ditch, were also searched on each day (Fig. 1). This usually allowed time for four to five passes up and down each ditch per day. The site was visited daily for 16 days from 26 June (Fig. 2), with one day aborted due to rain, and on the two subsequent weekends, by which time the populations were declining rapidly. Air temperature, wind direction, approximate wind speed, cloud cover and other Odonata present were recorded.

Results

Between 26 June and 11 July, 1223 insects were marked, 733 on the east ditch and 490 on the west ditch, of which 16 per cent and 19 per cent respectively were females (see Fig. 2). During a survey of *C. mercuriale* in the New Forest in 1998 (Stevens & Thurner,

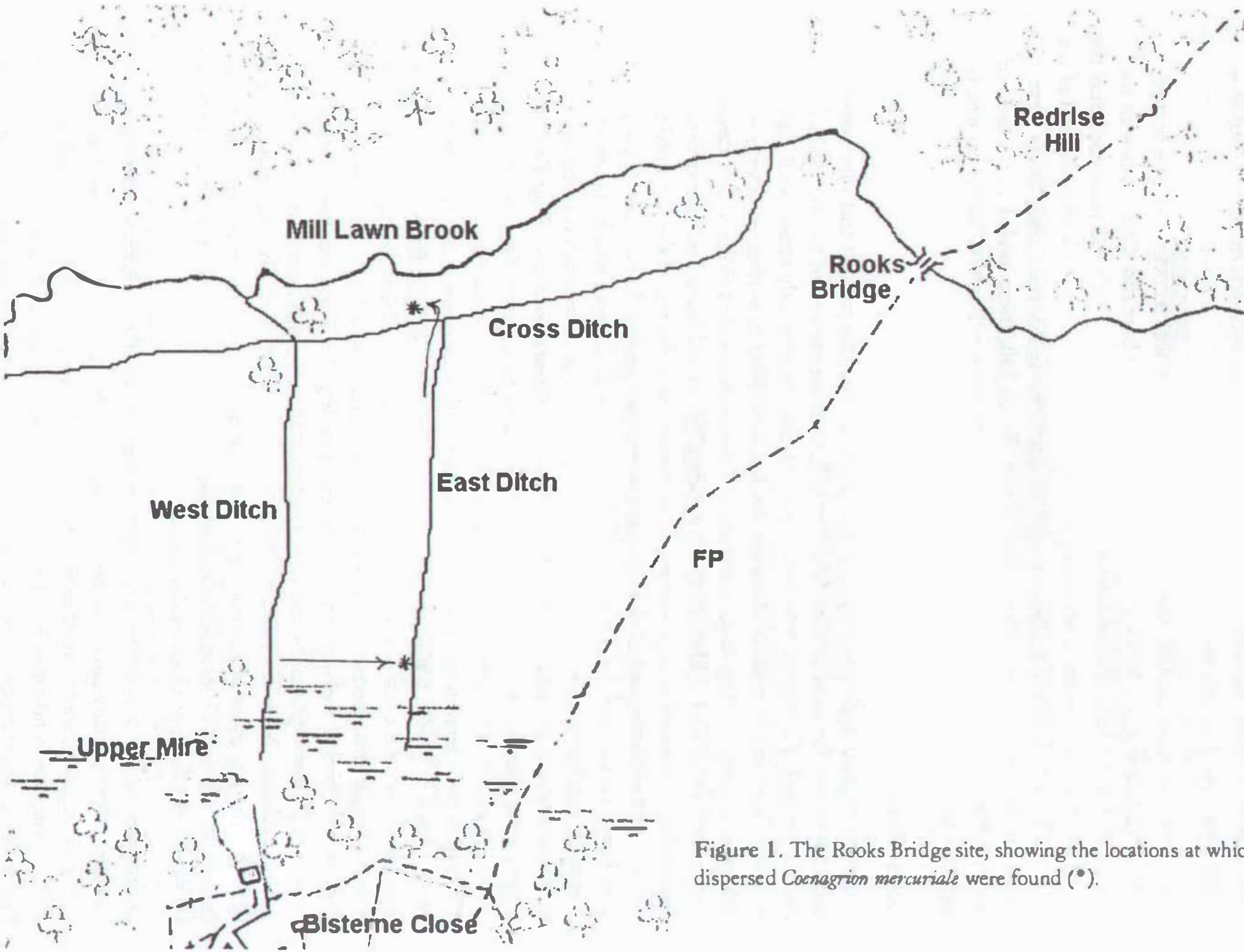

Figure 1. The Rooks Bridge site, showing the locations at which dispersed *Coenagrion mercuriale* were found (*).

1999), the maximum numbers of individuals on the east and west ditch recorded in a single pass were 132 and 96.

On 8 July, one male marked with a white spot on 5 July was recovered on the bottom cross ditch (see Fig. 1), about 4m along from the point where this ditch joins with the east ditch. On 11 July, one gold marked male from the west ditch was recovered near the top of the east ditch, seven days after marking. On 18 July, one week after the end of the main study period, totals of eight and fourteen previously marked *C. mercuriale* were found on the east and west ditches respectively. By 24 July, these totals had declined to one and five. On each of these dates, all individuals were still on the ditches on which they had been marked.

Discussion

Although the two ditches surveyed in this study are roughly parallel and vary between 75 and 150m apart for most of their 500m length, both are connected to, and drain from, the bottom end of a strip of mire which runs almost continuously above Mill Lawn. The mire itself contains several old drainage ditches, now filled to surface level with water and *Sphagnum* mosses, holding large numbers of *Coenagrion tenellum* (Villers) and *Orthetrum coerulescens* (Fabricius). Although this area was difficult and hazardous to examine thoroughly, *C. mercuriale* only seemed to be present near the top of the out-flowing ditches. At the bottom end of the site, the two parallel ditches do not flow directly into Mill Lawn Brook, but drain first into a shallow cross ditch from which the water eventually reaches the main stream at various points. The cross ditch is completely filled with vegetation, particularly Marsh St John's-wort (*Hypericum elodes*), Bog Pondweed (*Potamogeton polygonifolius*), Water Mint (*Mentha aquatica*), Lesser Spearwort (*Ranunculus flammula*) and Fool's-water-cress (*Apium nodiflorum*). Some *C. mercuriale* (one marked individual) were seen in this cross ditch together with *Coenagrion puella* (L.) from the brook. A few *C. puella*, *Calopteryx virgo* (L.) and one *Cordulegaster boltonii* (Donovan) were also seen on the lower stretches of the parallel ditches. Below the upper mire there is also a boggy area, intersected by short narrow runnels, which extends from the west ditch to one third of the way across to the east (see Fig. 1). This area does contain numerous *C. mercuriale* and these were marked with gold and counted in with the west ditch population. No white marked insects were recovered here. The map makes it quite clear that there is every opportunity for *C. mercuriale* to pass directly between the main ditches, as well as via the upper mire and bottom cross ditch, where there are no obvious barriers in the form of scrub or dry ground.

During the sixteen days of the main study period, the weather conditions were very variable, offering many opportunities for dispersal. On 26 June, hot dry weather gave way to changeable, cooler weather with the onset of a week of depressions lasting until the following weekend when hot dry conditions returned and continued until the end of July. During this changeable period, winds varied in strength from calm to Force 5, and

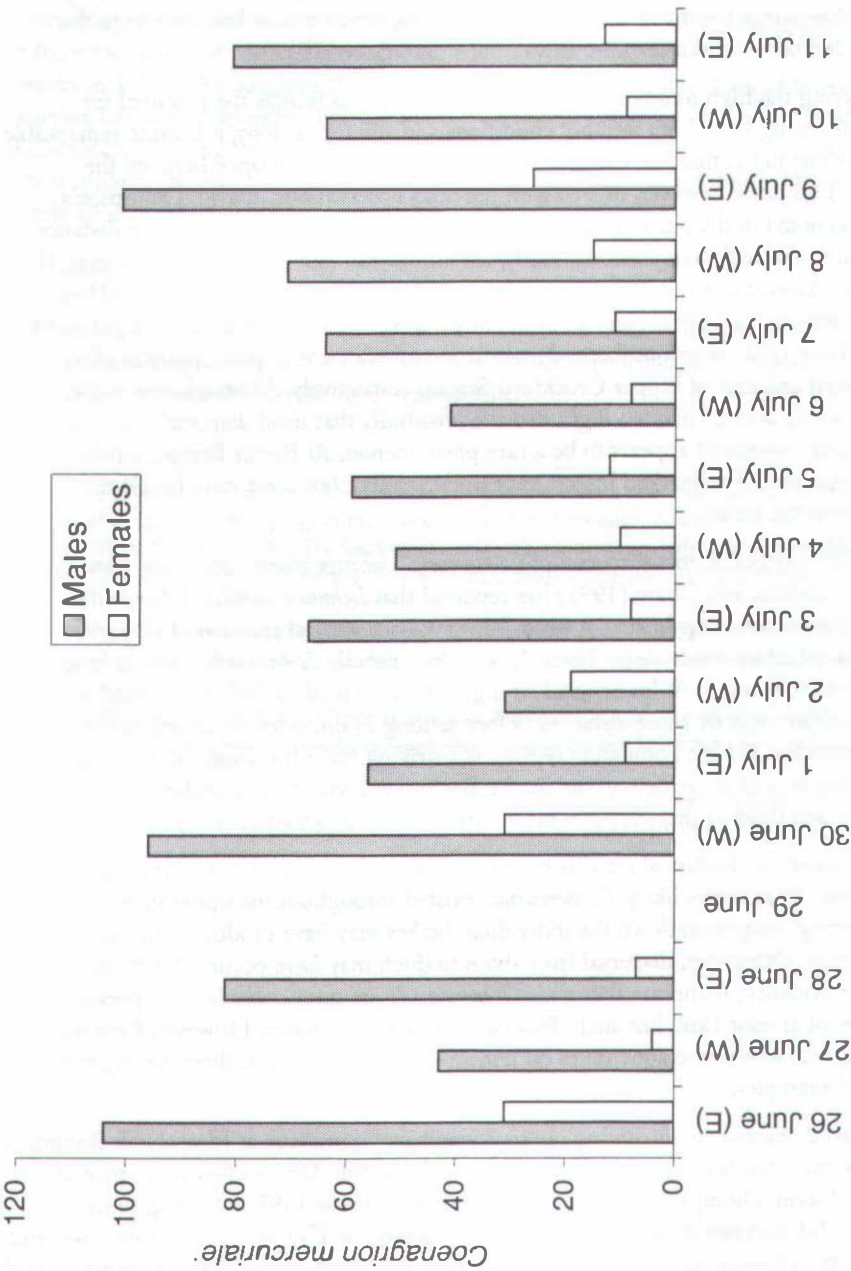

Figure 2. The total numbers of male and female *Coenagrion mercuriale* captured and marked each day. On any given day, individuals were marked on only one ditch, east (E) or west (W).

came from a wide variety of directions. Due to the funnelling effect of the valley, most winds blew across the ditches. On four days, winds blew more or less parallel to the ditches and calm conditions were experienced on only one day.

Considering the high number of *C. mercuriale* marked, as well as the potential for dispersal arising from both weather conditions and site topography, it is quite remarkable that only one individual was confirmed as crossing the short distance between the ditches. This does, however, fit well with previous observations. David Thompson's group, as noted in the introduction, have recorded only two examples of long distance dispersal in the last three years. Similarly, the author has found single males at over 1km from Crockford Stream on only two occasions since 1984: one at Two Bridges Pond (Grid reference SZ343997) and one to the east at SZ351996. However, on 6 June 1986 and 12 June 1994, large numbers of male *C. mercuriale* were seen at distances of up to 0.5km west and east of Upper Crockford Stream respectively. Although this might suggest a coordinated maiden flight and the possibility that most dispersal occurs at this stage, mass movement appears to be a rare phenomenon. At Rooks Bridge, a relatively high proportion of unmarked insects appeared each day, but none were found more than 3-4m from the water.

It has been suggested that dispersal of *C. mercuriale* occurs when insects are disturbed in windy conditions and Cham (1993) has reported that *Ischnura pumilio* (Charpentier) soar up and are carried away in strong wind. However, the natural reaction of *C. mercuriale* when disturbed in winds above Force 3, is to drop rapidly downwards into the base of the nearest vegetation. At lower wind strengths they do tend to drift down wind when disturbed, but only fly short distances before settling again, often returning to the water within minutes. If high population density is a driving force for dispersal, then this may explain the lack of movement at the Rooks Bridge site, where the population density is at best only one third of that found in most parts of the Crockford complex.

Unfortunately, no historical records have been traced for the man-made drainage ditches in the area. If, as seems likely, *C. mercuriale* existed throughout the upper mire prior to ditch cutting, migration down the individual ditches may have produced the present distribution. Otherwise, dispersal from ditch to ditch may have occurred. On the available evidence, it appears that male *C. mercuriale* are quite capable of dispersal over distances of at least 1km, but such dispersal is a rare occurrence. However, the successful establishment of a new colony relies on female dispersal, for which there are at present no recorded examples.

In the last 2 years some intriguing observations have been made at Horsebush Bottom, a long narrow ditch flowing into Lower Crockford Stream. After a 20-year absence of records, David Thompson found five *C. mercuriale* there in 1998, following three unsuccessful searches earlier the same season (Stevens & Thurner, 1999). One male and a breeding pair were recorded near the same position in 1999. The ditch is mainly gravel bottomed and dries rapidly in summer, given a few days of dry weather. The sightings mentioned above were followed by dry spells, during which the ditch dried completely apart from two stagnant pools. The ditch remained dry for three weeks in 1998 and for five weeks in 1999. This suggests that either there is regular recolonization, or the ova can survive temporary drought. The nearest established populations are at East Boldre, 1km distant but holding very low numbers of *C. mercuriale*, or on the Crockford Stream and its tributaries, where the nearest *C. mercuriale* are at a distance of 0.5km. This is definitely an area that would repay regular monitoring.

Acknowledgments

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Colonization by White-faced Darter *Leucorrhinia dubia* (Vander Linden) of the East–West Ditch at Chartley Moss NNR, Staffordshire, with notes on its status at other pools

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Introduction

Leucorrhinia dubia has bred for many years at two pools on Chartley Moss. At its main site, Shooters Pool, annual numbers of flying adults have been of the order of 1,000 in recent years, with over 2,000 in 1996. The other long-established breeding population has been at Dead Pine Gulch. Both pools are holes through the floating peat raft in the western basin of the Moss extending to deep water below. A rising lens of peat plugged Dead Pine Gulch some years ago, and this has gradually become vegetated so that the amount of free water is now minimal, and it is likely that the *L. dubia* population here will soon become extinct. Chartley Moss and Shooters Pool have been described by Bailey (1992) and Beynon (1995, 1997a).

Individuals have been seen at other small pools, but until the last six years these pioneers were few in number and, with one brief exception, no breeding had been confirmed. However, at two pools dug specifically to provide suitable breeding sites, regular breeding has occurred in small numbers since 1994–95.

Other, often ephemeral, pools may appear on the raft of the western basin depending on hydrodynamics and winter rainfall, and most attract territorial males. At two soaks, relatively high numbers have emerged since the first proof of breeding in 1999. They lie immediately to the south of Shooters Pool and are shown on historic maps. Europa is the larger of the two, some 30m south of Shooters. The other, Callisto, is a further 60m south-south-west. During hot summers in the early 1990s, both dried to little more than slight depressions, marginally damper than the surrounding *Sphagnum* raft. It is possible that *L. dubia* bred here before 1990 but was overlooked, and breeding ceased when the soaks dried. However, the wetter winters and springs of the mid to late 1990s increased their size and the weight of water deepened the saucer-like but still shallow depressions they occupy. Open water has persisted in both throughout recent years.

A significant recent development has been the colonization by *L. dubia* of the largest water body on the Moss, the East–West Ditch. The Ditch also supports enormous numbers of *Sympetrum danae* (Sulzer) – on 7 August 1993 well over 15,000 were present – and seems well on the way to producing seasonal totals of *L. dubia* in excess of 1,000. Fewer than ten adults were recorded annually between the mid 1980s and 1995. The population has increased rapidly since the first proof of breeding in 1995. About 850 adults emerged in 1998, and a careful census during emergence in 1999 produced a minimum of 826, with a probable population of *c.* 1,240. No accurate count was made in 2000, but emerging adults were seen along the whole length of the Ditch for the first time. Active emerging adults appeared on all the 19 sections into which the Ditch is dammed, except the first and last. Both species appear to thrive in similar habitat conditions; indeed *S. danae* 'replaces' *L. dubia* on the Moss as a season progresses.

Sites for Odonata on Chartley Moss

1. Dead Pine Gulch

This lies in a very small shaded glade completely surrounded by woodland 240m north of Shooters Pool. Over 30 years ago, it was open water, but in the early 1970s an island was created when a lens of peat rose to the surface. This became quickly colonized by vegetation including Birch (*Betula pubescens* and *B. pendula*) and Scots Pine (*Pinus sylvestris*). In 1975 there was still a reasonable area of free water, but this had become a marginal crescent by the late 1980s. By 1990 it was minimal. The emerging population of *L. dubia* has since declined from *c.*40 in 1994. No emerging adults or exuviae were found in 2000. On 9 July 1994 the pH was 3.9.

2. Cage Pool

This is a small soak 305m north of Shooters Pool. It lies in an open glade surrounded by woodland, except on the west where it opens on to the western basin of the Moss. Since 1996 it has increased in area and depth, almost certainly due to the damming of an adjacent ditch. This raised water levels and increased the weight of water lying on the raft. It dried in most summers before 1996, but now it usually retains some water, despite the raft rising below it in July and August. *L. dubia* has bred in small numbers since the first proof of breeding in 1994. In 1999 emergence probably totalled *c.*70. *Sympetrum flaveolum* (L.) bred here following immigration in 1995, and again in 1996. On 9 July 1994 the pH was 4.5.

3. Wood Pool

The pool was dug in 1992, 85m north-east of Shooters Pool, specifically to attract *L. dubia*. It lies on the edge of woodland and the open western basin. It has a peat base and a small central island. Despite drying completely in 1995, it supports a number of breeding Odonata, including small numbers of *L. dubia*. The first proof of breeding of this species occurred in 1995.

4. Cotton Pool

This was dug in 1991 in a fairly open site between two areas of woodland, 92m south-east of Shooters Pool. It is very similar to Wood Pool, and also dried out in 1995. Although not proven, *L. dubia* is likely to breed.

5. Shooters Pool

This is the core site for *L. dubia*. Details of the population have been given elsewhere (Beynon 1995, 1997a, 1997b, 1998).

6. Europa

Unlike any of the other pools, except Callisto, Europa has not developed any obvious marginal vegetation. Its size varies with rainfall, and so its edges merge gradually into the surrounding vegetation of Heather (*Calluna vulgaris*), Cross-leaved Heath (*Erica tetralix*), Bog Rosemary (*Andromeda polifolia*) and, most importantly, Common Cotton-Sedge (*Eriophorum angustifolium*). This is the main emergence support here for *L. dubia*, and extends well out into the free water in fairly open growth on the west, south and east edges. In 1995 free water was maintained throughout the summer for the first time for some years, and in 1997 it was a quite significant pool during a particularly wet June. It is likely that successful egg laying by *L. dubia* occurred for the first time then, as the first exuviae were found in 1999. In the spring and early summer of 1999 and 2000, the free water surface was larger than Shooters Pool. Four visits were made in early June 1999 and up to 15 adults were seen at one time, with mating pairs and ovipositing females. Thirty exuviae and emerging adults were counted, with emergence estimated at more than 50.

In 2000, despite poor June weather, six visits revealed up to 30 adults, 15 mating pairs, and several ovipositing females on any one occasion. A minimum of 50 emerging and 40 teneral adults were counted in June, leading to an estimated emergence of over 200 for the whole season.

7. Callisto

At first sight this is an unimpressive patch of water, no more than 4m by 3m in June, just qualifying as a pool. Here the dominant *Eriophorum angustifolium* is just a little sparser than on the surrounding bog. Nevertheless, several Odonata breed, including four species of Zygoptera, two species of *Sympetrum*, *Libellula quadrimaculata* L. and *Anax imperator* Leach. At the only visit in 1999 there were five exuviae, one emerging adult and one mating pair of *L. dubia*. This was the first proof of breeding of *L. dubia* for the 'pool'. The site was slightly wetter in 2000 when three visits in June revealed a minimum of 66 exuviae and 26 separate emerging adults. Up to 20 adults, six mating pairs and two ovipositing females were present on one visit. It is estimated that up to 200 individuals emerged in 2000.

Three small path-side pools between Dead Pine Gulch and Wood Pool were dug in 1988 (Bailey, 1992). These were initially successful, with territorial males, copulating pairs and ovipositing females present in 1989. In 1990, egg laying was observed at one pool and three larvae were found in September. However, no emerging adults have been observed, and although occasional males hold territories in some years, no further egg laying has been seen. The pools now dry completely each summer.

8. The East–West Ditch

No systematic visits were made to the E–W Ditch before 1993, and from 1994 to 1997 observations concentrated on Shooters Pool. The current Ditch is 400m long and *c.* 5m wide, with the eastern half slightly narrower than the western. It runs down the centre of the 17ha eastern basin, which consists of peat up to 7m thick. It appears as one of eight main drainage ditches on the Moss on a map of 1798, draining from west to east. By 1859, some of these earlier ditches no longer appear on maps, but the E–W Ditch had been extended a further 320m over the 25ha floating raft of the western basin to cross the whole Moss. This complete ditch drained both east and west from the raised centre of the western basin. The later part has now also disappeared, leaving only a remnant at the extreme west end, which is maintained to drain a small area of fen, rather than bog. The ditch is the most significant water body on the eastern basin, which also contains a smaller ditch running north–south at its west end; another small ditch two-thirds of the way along to the east; and some tiny pools.

Between 1986 and 1989, English Nature (EN) constructed a series of dams along the Ditch to reverse the drying out of the Moss. They vary in construction with peat; timber; steel; polythene and peat; and timber, polythene and peat all used. The dams cut the Ditch into 19 sections varying from 11m to 40m in length (see Table 2), of differing depths, none being much deeper than 1m in winter. In very dry summers those at the west end can dry out. After damming, most sections gradually became colonized by *Sphagnum* to a varying extent. This colonization increased very rapidly in the summers of 1998 and 1999, so that with few exceptions most now have more than 90 per cent cover. It is noticeable that those with almost complete semi-submerged *Sphagnum* produce far more emerging adults of *L. dubia* than clearer sections, although not all *Sphagnum* filled sections are equally productive. This was particularly obvious in 1998, before the extra *Sphagnum* growth mentioned above. In contrast, *S. danae* emerges in a nearly uniform spread along almost the whole Ditch, and did so even before the increased *Sphagnum* colonization. Despite its basically similar habitat requirements, *S. danae* is not dependent on *Sphagnum*. In August 1993, pH readings varied from 3.9 at the west end to 3.4 at the east. Over the majority of the sections the values were 3.5 or 3.6.

The direct distance from Shooters Pool to the west end of the Ditch is 190m east-north-east and there is a band of mature woodland just over 100m wide between the two. The most obvious colonization route for *L. dubia* would be across the open Moss to Wood

Pool (85m), and then along a corridor cut through the woodland in 1989–90 (108m). However, many immature *L. dubia* from Shooters Pool roost in the band of woodland, and some undoubtedly reach the Ditch over the trees, particularly in windy conditions. The prevailing wind is from the south-west. It is interesting that the first proof of breeding for both Wood Pool and the Ditch was obtained in 1995.

Coincidental with the spread of *L. dubia* was a huge increase in the populations of *L. quadrimaculata* on all the water bodies and particularly on the Ditch (at least 500 in 1998). There was also a decrease in *Libellula depressa* L. from a seasonal total of at least 20 adults to virtually nil in 1998. There were signs of a small recovery in 1999, and more were seen in 2000. The Ditch has been its stronghold at Chartley Moss. It is possible that *L. depressa* is showing a cyclical change, while *L. quadrimaculata* seems to be increasing in range and numbers nationally.

Table 1. *L. dubia* on the East–West Ditch, Chartley Moss, on 19 May and 22 May 1998

Systematic counts of exuviae and emerging adults made on two visits, 19 May 1998 (0930–1130h BST) and 22 May 1998 (0830–1200h BST). Adults were not counted on 22 May but were present on all sections except S19, together with many mating pairs. Doubling the S5–S12 count (see text) produces a total of 351 exuviae and non-associated emerging adults for 19 May. The total for 22 May was 188.

Section	Date	Exuviae	Emerging Adults	Adults	Mating Pairs
S1	22/05/98	Nil			
S2	22/05/98	8			
S3	22/05/98	5			
S4	22/05/98	26	2		
S5	19/05/98	19	3		
S6	19/05/98	6	2		
S7	19/05/98		1	2	1
S8	19/05/98	3		3	1
S9	19/05/98	2		3	2
S10	19/05/98	5			2
S11	19/05/98	2			2
S12	19/05/98	13	1	Many	1
S13	19/05/98	210	27		
S14	19/05/98	87		8	3
S15	22/05/98	2			
S16	22/05/98	7	1		
S17	22/05/98	3	1		
S18	22/05/98	43			
S19	22/05/98	Nil			
N–S Spur	22/05/98	2	1		

NB On S13 there were 100 exuviae on the north edge and 85 on the south edge. At least 25 were on, or lying below, a small twig projecting through the *Sphagnum*.

The sections of the Ditch are numbered from S1 at the west end to S19 at the east. S1 and S19 are very different from the others. S1 is shallow and almost completely vegetated with large clumps of Purple Moor-grass (*Molinia caerulea*), very little *Sphagnum*, and only tiny patches of free water. S19 is mostly clear water heavily shaded by trees and connects with the surrounding lagg ditch. The North–South Spur is a smaller ditch, dammed using peat, which runs south from, and is connected to, S14.

In Tables 1 and 3, data for individuals in the four stages of emergence and on first or second maiden flights, or crippled during emergence (Beynon, 1995), have been consolidated to a single total for 'Emerging Adults'.

Field Observations on the East–West Ditch 1993–1997

No visits were made during the flight period in 1993. Assuming a semi-voltine (2-year) lifecycle, the first emerging adults seen in 1995 would have come from eggs laid this year. In 1994, thirteen visits were made during the flight period. Single adults were seen on 6 June, 24 June and 26 June. Eleven visits were made during the flight period in 1995. Adults and emerging adults were seen on four occasions. A newly emerged adult and two exuviae provided first proof of breeding on 23 May at S13 (in both 1998 and 1999 this section had by far the highest number of emerging adults). One teneral, three males, three old males and three mating pairs were present on 22 June. Four males were present at S1 to S4 on 29 July (S1 to S3 dry). One male was present at S4 on 30 July.

In 1996, fifteen visits were made during the flight period. Adults were seen on six occasions. On 15 June several males were seen at each of S1 to S6. On 16 June over 20 males were present at S1 to S6; a newly emerged adult and two exuviae were found at S8; and a male was seen on the N–S spur. On 13, 14 and 20 July, four males were present at S4 with a mating pair on both 13 and 20 July. On 22 July an egg-laying female was present at S9. In the poor summer of 1997, adults were seen on four out of seven visits. On 27 May a teneral adult was present at S1 and individual males at S4 and S7. A male was present at S19 on 31 May; an immature female was seen on 5 July and a male on 23 July.

Field Observations on the East–West Ditch 1998

It was unfortunate that more regular visits could not be made in 1998, as this was the first year when a sizeable population emerged on the Ditch. The first adults emerged on the Moss at Shooters Pool on 11 May (Bill Furse, pers. comm.). It is probable that emergence on the Ditch began on about the same date, as 10 exuviae and several adults, including one mating pair, were observed on S13 on 17 May (Bill Furse, pers. comm.). From 7 May, with few exceptions, minimum night air temperatures had exceeded 10°C with day temperatures often above 25°C.

On 19 May a systematic count of emerging adults and exuviae was made on selected sections (using binoculars with the ability to focus down to 2m). Counts were made of the north edges only of S5–S12 and the whole perimeter of S13. Only adults were recorded on S14. From the results of the S13 count (and later observations), the numbers of emerging adults and exuviae recorded from the north sides of S5–S12 were doubled to produce the day total. This differed from 1999, when there were considerably more emerging adults on the north sides – see Table 3. On 22 May counts were made over all the sections not covered above, including the N–S Spur (Table 1). Over 90 per cent of the emerging adults and exuviae were on new growth *Molinia caerulea* close to and sometimes overhanging the water's edge. Others were on *Calluna vulgaris*, Hare's-tail Cotton Sedge (*Eriophorum vaginatum*), and *Betula* spp. Higher numbers were present on S4, S5, S12, S13, S14 and S18. All these sections are relatively shallow with dense *Sphagnum* and practically no free water.

No further counts were made until after the very poor weather of June and the first three weeks of July. Approximately six adults were seen on 22 July and the last two, mature males, on 2 August. Estimates of the numbers of emerging adults on non-visit days were made taking into consideration weather conditions and the numbers counted when on site (Beynon, 1997a). This suggests a minimum 1998 population on the E–W Ditch of between 800 and 850.

Field Observations on the East–West Ditch 1999

In 1999 it was possible to make almost daily visits from the start of the emergence period. The period from September 1998 to April 1999 was the mildest (and wettest) in the Midlands for many years, and this probably contributed to extraordinarily early first emergence dates for several species. For example, *L. quadrimaculata* first emerged on 1 May compared to first dates for the previous five years of 29, 23, 25, 14 and 13 May. *L. dubia* was even earlier. In the early afternoon of 27 April, a teneral adult was disturbed from the north edge of S5. No others had been seen on both banks from S3–S13, and it seems likely that this was the first individual to emerge. This is the earliest recorded date for the site. First dates for the previous five years at Shooters Pool were 12, 3, 13, 1 and 11 May. The weather over the next six days was fine, often very hot from early in the morning, with daily maximum temperatures generally over 20°C. During this period 46 per cent of the emergence for the year occurred (571 individuals from a total of 1238). Emergence at Shooters Pool began a week later, and continued for ten days after emergence had finished on the Ditch (Table 4). This was almost certainly due to the difference in water temperature. Metamorphosis is triggered by photoperiod, but is then temperature dependent (Corbet, 1962). The shallow sections of the Ditch warm up far faster than Shooters Pool, which has a depth of *c.* 14m and extends into the basin below the western raft. The majority of the 1999 population of the Ditch emerged in the two weeks following 27 April, but good numbers continued on S13 for a further four days. The last few stragglers appeared in the first week of June. Table 2 summarizes the 1999 results. As in 1998, the highest emergence came from S4, S5, S13, S14 and S18. In 1998, S13 produced more than a quarter of the emerging adults, and over a third in 1999.

Although S12, S13 and S14 are superficially identical, the numbers emerging (34, 424 and 84 respectively) differed greatly. The spring water depths of the three sections (taken as a mean of four measurements along the centre of each section) were 95cm for S12, 63cm for S13 and 47cm for S14. Mean spring water depths for S4 and S5 measured 95cm and 98cm respectively. It seems unlikely that these differences in water depth can explain the differences in emerging adults. The sides of the sections shelve quite steeply over the first 50cm from the bank, and the bottoms are uneven, with the first few centimetres made up of soft peat and detritus. The percentage of *Sphagnum* cover given in Table 2 for the five sections also seems unlikely to explain the differences in the

Table 2. *L. dubia* on the East-West Ditch, Chartley Moss, 1999.

This table provides information on the length of each section; the mean of four temperature measurements taken at a depth of 10cm; an estimate of the *Sphagnum* cover; the number of occasions each section was visited between 27 April and 12 June; the actual number of emerging adults and new exuviae counted; an estimate of the number of emerging adults on days when the section was not visited (see Beynon, 1997a); and the estimated total of emerging adults for each section.

Section	Length (m)	Temp. (°C)	*Sphagnum* Cover	Visits	Actual Emerging Adults	Estimate for Non-Visit Days	Total
S1	40	–	n/a	2	1	0	1
S2	13	-	95%	9	0	0	0
S3	14	12	100%	11	41	23	64
S4	24	11	100%	11	172	66	238
S5	21	14	100%	11	124	44	168
S6	25	8	95%	5	14	25	39
S7	11	11	100%	6	11	14	25
S8	20	7	95%	4	3	13	16
S9	14	11	95%	3	1	6	7
S10	14	6	10%	4	0	0	0
S11	27	9	80%	6	8	18	26
S12	27	9	75%	6	9	25	34
S13	27	9	100%	15	358	66	424
S14	27	9	90%	3	28	56	84
S15	21	–	100%	3	0	0	0
S16	32	–	100%	2	7	12	19
S17	18	–	100%	2	14	19	33
S18	18	–	100%	2	35	25	60
S19	12	–	5%	1	0	0	0
1999 Totals for the East–West Ditch					826	412	1238

numbers emerging. Even where small open patches of water account for incomplete surface cover, the submerged *Sphagnum* is more or less continuous at a depth of only a few centimetres. Since *L. dubia* larvae live within the submerged *Sphagnum*, rather than on the bottom, there appears to be some other factor operating. *Sphagnum* is clearly important as S10 has *Sphagnum* only in thin patches against the bank; is much deeper than 1m and much cooler; and produced no emerging adults at all in 1999.

An obvious visual difference between S13 and its immediate neighbours is the bank and marginal vegetation. All three have some *Eriophorum vaginatum*, a few small scrub *Betula* spp., and much *Molinia caerulea* growing up to the waters edge. However, unlike the other two, S13 also has extensive *Calluna vulgaris*, up to 80cm high right up to and in many places overhanging the water. On the south edge it is almost continuous; on the north it extends in all over about 75 per cent of the edge. S13 is therefore more sheltered than its neighbours, and thus may also have a slightly warmer microclimate. It could therefore be more attractive to adults, both for males holding territory and females arriving to copulate and oviposit.

Details of the counts made on S13 in 1999 are given in Table 3. Collection of exuviae was not systematic because of the close proximity of emerging adults, and the likely damage to the vegetation. Although exuviae can often be identified as fresh, a total count for a visit will include some of those counted previously, as well as others associated with

Table 3. Emergence of *L. dubia* on S13 of the East–West Ditch in 1999.

	North Bank		South Bank	
Date	Exuviae	Emerging adults	Exuviae	Emerging adults
1 May	17	22	2	1
2 May	39	11	2	4
3 May	87	17	10	7
6 May	115	7	24	7
9 May	n/a	7	n/a	6
11 May	n/a	4	n/a	1
15 May	55	0	26	2
19 May	30	0	20	2
20 May	20	0	0	2

The data for the following dates are combined totals for both banks

4 May	n/a	16
23 May	4	0
29 May	17	2
1 June	n/a	1
6 June	7	0
12 June	No new exuviae	

adults emerging on previous days. Thus a crude total of exuviae will involve multiple counting and be of limited value. By counting only those exuviae that are clearly fresh or in new situations, a minimum total can be calculated, together with an estimate of the number of emerging adults on non-visit days (Beynon, 1997a). It is estimated that about 5 per cent of emerging adults and exuviae remained uncounted, hidden in the vegetation. Also, exuviae falling on to the *Sphagnum* quickly become waterlogged and are easily overlooked. Only on three days was an exuvia or recently emerged adult found on either of the short eastern or western ends of S13 and these were added to the total for the south edge for that visit. Where no separate north and south counts are given the figures are combined totals for both banks. From these data, the greater numbers emerging on the north as opposed to south edge is clear (in contrast to 1998). This should be expected as the north edges are in full sun from dawn onwards, while parts of the south of S13 receive no direct sun because of shading by *Calluna vulgaris*. As already noted (Beynon, 1995), most emergence and subsequent maiden flights occurred before noon, but in good weather stragglers continued throughout daylight. Some adults emerging late in the day remained on their supports overnight and took their maiden flights the following day.

Discussion

Although small numbers of pioneers were seen on the Ditch for about 15 years from the early 1980s, proof of breeding of *L. dubia* was not established until 1995. Even then numbers were low until there was a marked increase in the population in 1998 and 1999. This increase could be linked to the unprecedented high population at Shooters Pool in 1996 (over 2,000 flying adults), which would have provided a greater source for immigration. The 2-year (semi-voltine) life cycle of *L. dubia* fits this explanation very neatly. Certainly more adults were seen on the Ditch in 1996 than in previous years. More pertinent may be the increased colonization by *Sphagnum* of many sections of the Ditch, an increase which did not really become significant until 1995–96. There is practically no emergent vegetation in the Ditch. Thus of the two substrates preferred by *L. dubia* for oviposition, amongst emergent *Eriophorum* at the bank-side or on semi-submerged *Sphagnum* (Beynon, 1995), *L. dubia* used the tiny patches of water occurring on the surface of the dense *Sphagnum* rafts. The subsequent survival of larvae may have increased in their now more favourable habitat.

Another interesting observation concerns the length of the emergence period. It is evident from Table 4 that this shortened over the six-year observation period, and that *L. dubia* at Chartley Moss seems to be increasingly conforming to the phenology of a 'spring species' (Beynon, 1997a; Corbet *et al.*, 1960).

With the demise of the population on Thursley Common (Mike Thurner, pers. comm.), Chartley is now the most southerly site for *L. dubia* in Britain. It also has the largest concentrated adult population, which must now exceed 3,000 annually, and is increasing.

Table 4. Emergence and Flight Periods for *L. dubia* at Chartley Moss 1994–1999

Year	Site	Emergence First Date	Emergence Last Date	Duration	Last Adult	Flight Period
1994	Shooters Pool	11 May	9 July	60 days	9 Aug	91 days
1995	Shooters Pool	3 May	9 July	68 days	14 Aug	104 days
1996	Shooters Pool	13 May	16 July	65 days	18 Aug	98 days
1997	Shooters Pool	1 May	21 June	52 days	26 July	87 days
1998	Shooters Pool/E–W Ditch	11 May	20 June	41 days	2 Aug	84 days
1999	E–W Ditch	27 April	5 June	40 days	24 July	89 days
1999	Shooters Pool	2 May	15 June	44 days	24 July	84 days

NB. In 1997, the records ignore the possibly aberrant adults seen on 24 September, one of which had emerged *c.*17 September (Beynon, 1998). As a consequence of poor weather in June and July, the last date of emergence has been estimated for 1998.

The definitive reasons for this are still somewhat unclear. What seems most relevant for the recent colonization and rapid increase on the East–West Ditch is the marked increase of semi-submerged *Sphagnum* on this particular water body.

Gratifyingly the progress of *L. dubia* at Chartley Moss continues to pose intriguing questions. Apart from those discussed above, why for example should S2, S10 and S15 apparently produce no emerging adults in 1999 in contrast to 1998? The damming of the Ditch into sections seems to have fortuitously produced an almost ideal experimental site.

Acknowledgements

Once again I thank Tim Coleshaw, EN Site Manager, for information and patience, and Bill Furse for company and records.

Access

The Moss is privately owned and is an extremely hazardous site. Access is ***by permit only***. Applications for permits can be made to EN at Attingham Park, Shrewsbury.

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Observations of the Red-veined Darter *Sympetrum fonscolombei* (Sélys) at Bake Lakes in Cornwall during 2000

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Following successful breeding at Bake Lakes each summer since 1997, regular visits were again made to the site in 2000 to monitor the breeding activity of *Sympetrum fonscolombei* (Sélys). Between 29 April and 21 October 2000, a total of 48 visits were made. In comparison to 1999, substantially more adult *S. fonscolombei* were encountered during the early summer of 2000, resulting in a proportionately higher number of emerging dragonflies later in the season. However, in comparison to 1998, far fewer dragonflies emerged (Pellow, 1999,2000) (see Fig. 1).

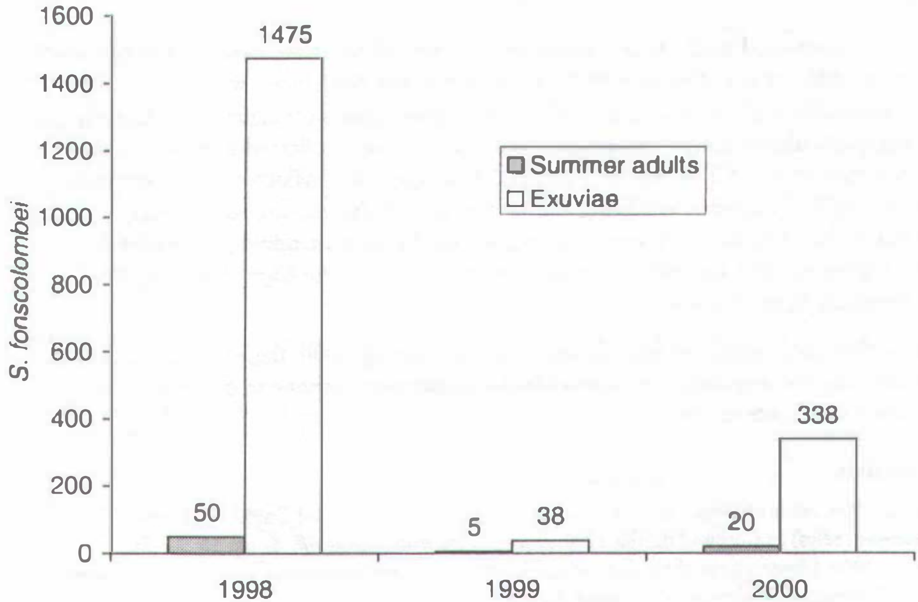

Figure 1. Maximum totals of mature adult *Sympetrum fonscolombei* observed during summer at Bake Lakes and totals of exuviae collected during the following September and October.

The first adult *S. fonscolombei* were not observed until 15 July, when three mature males were present. It is possible that emerging adults may have been overlooked earlier in the season due to poor weather during May and most of June, but it is also possible that the adults observed were new immigrants. It may be more than coincidence that these observations of *S. fonscolombei* corresponded with sightings of Lesser Emperor *Anax parthenope* (Sélys) and the first record of Four-spotted Chaser *Libellula quadrimaculata* L. at this site. However, 15 July does correspond with the dates for the first sightings of mature adults for the two previous years, on 18 July 1998 and 5 July 1999.

The adult population of *S. fonscolombei* increased to 14 on 17 July, with a maximum of over 20 recorded on 21 July. Copulating pairs and oviposition were observed on 21 July and 22 July. During favourable weather conditions, adult males were easily located, patrolling low over the open water of the pool, well away from the water margins. The majority of adult females were observed either in tandem or during oviposition. Sightings of lone adult females were relatively scarce.

The last observation of mature adults was made on 11 August when three individuals were still present. No further sightings were made until 11 September when ten immature *S. fonscolombei* were noted, including three taking their maiden flight. A total of 26 exuviae were also collected, suggesting that emergence had commenced a few days earlier.

Emergence continued until 16 October, when one teneral adult was observed at its site of emergence. Most dragonflies emerged during mid to late September, with counts of 84 on 16 September, and 86 on 22 September. Emergence generally occurred in the early morning, particularly under clear, sunny skies. Exuviae were collected until 21 October by which date a total of 338 had been located. This figure is considered to be very close to the total of *S. fonscolombei* emerging during this period. No mature adults were observed at the site after 11 August. Although several immature adults were sighted during September and appeared to establish territories along the edge of Mirage Pool, none remained to reach maturity.

With another successful breeding season completed during 2000, there would seem to be no reason why this population of *S. fonscolombei* should not continue to become established at this site in 2001.

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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 1994.

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

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

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

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