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Front cover illustration of a male Scarce Chaser *Libellula fulva* Müller by Roderick Dunn.

# Habitat and development of larvae of the Azure Hawker *Aeshna caerulea* (Ström) in northern Scotland

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## Summary

Breeding of the Azure Hawker *Aeshna caerulea* (Ström) in northern Scotland is confined to very shallow bog-pools (15–20cm deep), which may limit competition with *A. juncea* (L.). Eggs of *A. caerulea* undergo a winter diapause and larvae normally have a three year life-cycle. During periods of drought there is heavy mortality of larvae. Slightly deeper parts of a pool may serve as 'retreat' areas. The number of larvae that survive to emergence is very low. Cohort-splitting is noticeable by September/October of the 1st larval year but is variable, perhaps dependent upon the availability of food.

## Introduction

The breeding habitat of *A. caerulea* was completely unknown for many years. The first mention of the species in Scotland was '... made by a Mr Wilson, as recorded by De Sélys in the "Revue des Odonates" (1850) ...'. It was rediscovered in June 1864 (Morton, 1899). It was 1952 before larvae were first dredged 'in numbers' in Perthshire from 'The bogs or so-called moss-hags, (which) are a soggy sponge-like mass of sphagnum with a minimum of water showing only exceptionally.' (Fraser, 1953). There was little further information until Gabb (1985) found a freshly emerged female and its exuvia beside a large bog-pool in Wester Ross. Only very recently have details of breeding sites (Clarke *et al.*, 1990) and larval development (Clarke, 1994) been published.

## Habitat

Since 1989, RWJS and EMS, joined by MAR in 1994, have made exploratory visits to two bog-pool systems beside Loch Maree (57°40' N, 5°26' W) on the shallow slope between the main road and the Loch (*c.* 20m a.s.l.). Much of the area is peat-covered (but extensively cut some 100 years ago) and is broken by rocks and rocky outcrops. These bog-pool complexes comprise a mosaic of pools, mainly small and shallow, and a few which are larger and deeper. The ground flora is Heather (*Calluna vulgaris*), Deergrass (*Trichophorum cespitosum*), Common Cottongrass (*Eriophorum angustifolium*) and White Beak-Sedge (*Rhynchospora alba*), Bog Myrtle (*Myrica gale*) and hummocks of Woolly Fringe Moss (*Racomitrium lanuginosum*). The area is bleak, exposed and wind-swept.

Sampling for larvae began in 1993 and, after extensive searching of the main bog-pool areas, it became obvious that *A. caerulea* larvae were found almost solely in certain types of pool. Such pools have several features in common. They are rather small with an area of *c.* 1–8m$^2$ and a winter water depth of *c.* 15–20cm. The emergent vegetation is rather sparse short sedge (usually cotton-grass) and the surrounding banks are peaty with some *Sphagnum*. The substrate is soft peaty detritus of varying depths to the underlying bedrock. These pools tend to be on the perimeter of, or away from, the main bog-pools, perhaps because the latter tend to be deeper. However some larvae may occur in the main bog-pool system, often at the edges of the slightly deeper waters.

In June 1994, at a British Dragonfly Society (BDS) meeting, up to 14 people, after a preliminary teach-in, set to work looking for larvae in the two study bog-pool systems. Some 325 *A. caerulea* were caught and measured from 19 pools. Totals from three of these pools were 47, 37 and 37 larvae. There was general agreement that *A. caerulea* larvae were found in numbers only in the one type of bog-pool structure as described above. Several deeper pools were searched without success.

Following on from this meeting several odonatists have found *A. caerulea* larvae in many other bog-pools north of the Great Glen and in the Rannoch Moor area. The basic structure of all of these sites is similar to that of the Loch Maree pools. The most variable feature is water level, which alters considerably between wet and drought conditions. There is an interesting variation in pool structure in areas with less rainfall in mid and east Highlands. Some three miles east of the south end of Strathnaver (58°25' N, 4°14' W), six larvae (9–24mm long) were collected from one bog-pool during a very dry spell. This pool had a slightly sloping base with typical sparse sedges growing from the shallower two-thirds of the pool, most of which had been exposed by the drought. Below the line of sedge the water deepened to perhaps 30cm at a sheer peat bank. *A. caerulea* larvae were found along the narrow edge of sedges, which was still under water. At Forsinard (a Royal Society for the Protection of Birds Reserve), some 15 miles further to the east, this phenomenon was even more marked. In one bog-pool system 12 *A. caerulea* and one *A. juncea* larvae were taken from a 7 × 3m pool with one small area some 25–30cm deep, the remainder no deeper than 15cm. In total, 32 *A. caerulea* larvae were found in seven small pools all of them *c.* 15–20cm in depth but with at least one deeper area in each. Some pools which looked typical for *A. caerulea* but held no deeper water refuges, yielded no larvae and we assume these pools must occasionally (or regularly) dry out. Generally, pools that held *A. caerulea* larvae held few if any *A. juncea* larvae, but from one irregular and deeper 15 × 10m pool, 27 *A. juncea* and only three *A. caerulea* were obtained. At our visit in September the water level of the bog-pools had risen again following much drier weather during July/August. It would seem that the preferred habitat for *A. caerulea* egg-laying was similar to that further to the west but only in those bog-pools which had a deeper 'retreat' area could the larvae survive during drought periods. *A. juncea*, laying in generally deeper waters, did not encounter this difficulty.

## Sampling methods

From two bog-pool systems beside Loch Maree, nine pools suitable for *A. caerulea* were identified and marked. These were named Silver Loch (SL) and Grudie (G) and given a bog-pool number. From mid-1993 to mid-1996 the larvae were checked six times annually between May and October. Samples were taken with a pond net with a very small mesh, which retained all sizes of larvae, or a colander with a basin placed underneath to retain the small larvae (up to *c.* 8mm), which drained through the colander. Because all pools could be searched from the edge an attempt was made to catch maximum numbers and this usually included a sizeable proportion of the larger *Aeshna* larvae (>7mm) present. *A. caerulea* in particular seem to hang on to the emergent sedges above the level of the detritus substrate and can be extracted fairly easily. Other odonate species can be numerous and all were separated into small containers until the pool was searched again on the same day. The larger larvae were measured to the nearest mm in a minimal amount of water in a Petri dish placed on a plastic card graduated in mm. The length recorded was the distance between the anterior extremity of the head (excluding the antennae) and the distal tips of the paraprocts. Possible variations in measurement, due to stress *etc.* (see Clarke, 1994), were corrected where possible by allowing the larvae to relax. Identification of final instar larvae, with wing-buds extending on to segment four of the abdomen, is straightforward. In F-1 larvae the wing-buds were well over segment two and in F-2 apparently just under or touching segment two. All times are expressed in GMT.

Very small larvae were, at first, difficult to find. In 1996 a new technique of skimming a pond-net lightly across the surface of the vegetated water to a depth of 2–3cm proved effective. A similar procedure using a colander basin is perhaps even better. The larvae of length 2mm and upwards can be seen much more easily against the white basin than when on vegetation. Those under 5mm were measured to the nearest 0.5mm using a hand lens. After processing, all larvae were returned to the pool. Segregations of 1st- and 2nd-year larvae were based on discontinuities in the distribution of body lengths (see Fig. 2).

Trampling round the wet peaty edges and continual dredging through the thin emergent sedges, particularly during drought conditions when water levels were low, caused obvious habitat deterioration after a few years. This affected most of the pools, extending into the pools themselves. After the severe drought in 1995 several new pools were chosen in which to continue the sampling.

## Other odonate species of the bog-pool systems

*Libellula quadrimaculata* L. is the most numerous and widespread species. The larvae prefer the shallowest waters, living amongst the detritus substrate often at the edges of the pools.

*A. juncea* is regularly found in the same pools as *A. caerulea* but in much smaller numbers. The BDS 1994 meeting encountered 25 *A. juncea* compared to 325 *A. caerulea* larvae and this may represent a normal proportion in the small shallow pools. *A. juncea* is much more plentiful in larger deeper pools where there are surrounding rushes or sedges for egg-laying. Female *A. juncea* egg-laying in such sites in the main bog-pool system may deposit a few eggs in the shallow pools perhaps in a 'desultory' way but there *A. juncea* larvae are well outnumbered by *A. caerulea* larvae. It would appear that both *Aeshna* species have a different niche preference based on water depth, which might help to prevent competition between what are, in many ways, very similar species.

*Leucorrhinia dubia* (Vander Linden) is mainly found in deeper waters with some *Sphagnum* cover. Larvae have been seen on the underside of the floating *Sphagnum*. The 1994 BDS meeting total of 17 larvae from 19 pools gives a reasonable indication of its abundance in the shallower waters.

*Somatochlora arctica* (Zetterstedt) is not found in these bog-pools but in very shallow water, usually with a nearly complete cover of *Sphagnum*. Only one larva was found at the BDS meeting.

*Sympetrum danae* (Sulzer) flies in good numbers in September. The larvae, which hatch in spring, are not usually seen until late summer. They live in the shallower waters frequented by *L. quadrimaculata* and early instars are perhaps overlooked.

*Sympetrum striolatum* (Charpentier)/*nigrescens* Lucas is much less common than *S. danae* and prefers the deeper pools.

*Enallagma cyathigerum* (Charpentier), *Lestes sponsa* (Hansemann), and *Pyrrhosoma nymphula* (Sulzer) are present, keeping mainly to the deeper pools.

Each of the seven anisopteran species found in the bog-pools appears to have its own niche. The only one with which *A. caerulea* might be expected to compete is *A. juncea*. Larvae of both species are similar in size and grow at much the same rate during most of their development. The latter species becomes noticeably more bulky by its 3rd-year after hatching and, when held in a small container, appears more aggressive than *A. caerulea*. In such confined circumstances the larger *A. juncea* larvae will catch and devour smaller odonates whereas *A. caerulea* is more quiescent and usually disregards them. No aggression has been noted between similar sizes of the two species when closely confined together. In the field the definite habitat preferences probably assists their co-existence.

## Emergence and flight period

Precise emergence data are scarce. At mid-day on 25 June 1985, Gabb (1985) found a teneral female and associated exuvia on *Eriophorum angustifolium*. The wings were fully expanded and the first flight took place within an hour of discovery. A female emerging at 1300h on 21 May 1993 near Loch Maree is our only other record. The wings were closed. At 1445h the insect was in the same position but beginning to colour to the blue form. The exuvia was *c.* 0.7m from the water's edge and 15cm up on a *Calluna* stalk. On both occasions the weather was overcast; windy and cool in 1985 and mild, damp and fairly calm in 1993. Exuviae are difficult to find, perhaps because of genuine scarcity and because of wind-blow in the exposed terrain. They can be at a height of 5cm or more on heather or cotton-grass, or found where they have fallen on to the ground.

We made no systematic attempt to locate emerging *A. caerulea* or early flying adults but the following are our earliest records:

1992. On 4 June, on a mild, sunny, windless day, there were up to 10 males at the two study bog-pool systems and up to four females were egg-laying (when a cool north-east wind sprang up all disappeared). Assuming a 10–14 day maturation period, emergence must have started by the last week of May.

1993. A female emerging on 21 May and another exuvia found on 22nd.

1996. This may have been a late year: only an occasional territorial male was seen in hot weather over the bog-pools between 14 and 16 June. In a sheltered woodland glade at least six were flying and landing on rocks. Three or four showed the dull eyes of immatures suggesting that few would have emerged before early June.

1997. On 28 May, three adults were flying and on 29 May, three female exuviae were found.

1998. Two (male and female) teneral flying insects were noted on 27 May and five exuviae were found on 28 May.

1999. Two newly emerged adults were seen on 19 May. David Miller, Beinn Eighe NNR Manager, saw one on 18 May by his house, probably from an adjacent bog-pool, 8km SE of the study site.

The flight period extends well into August, one being noted on 11 August 1995 (there have been few August visits). On Rannoch Moor, C. E. Edwards saw one as late as 25 August 1996 (pers. comm.).

## Larvae – early instars

Table 1 gives dates and lengths of early instar larvae from the Loch Maree study pools. It was 1998 before we focused on the hatching date. On 27–29 May 1998 there were at least 12 at *c.* 2mm and four at *c.* 2.5mm. Of these, five at *c.* 2mm were sent to D. J. Clarke for captive rearing. The smallest larvae at 2mm were probably in their 2nd instar (the prolarva being considered as the 1st instar) and would have most likely hatched between

25 and 27 May. The 2.5mm larvae may have been 3rd instar and 3–5 days old suggesting a hatching date around 23–25 May. On 4 June, Pool SL13 yielded four larvae at 2mm.

Between 27 and 29 May the weather was rather wet and cold (the top 2.5cm of Pool G11 was 16.5°C on 28 May). On 4 June at 1000h it was cool and overcast with a north-east breeze and the temperature of the top layer of SL13 was 16.5°C. At 1400h, in bright sunshine, it was 25°C and at 1530h, 26°C.

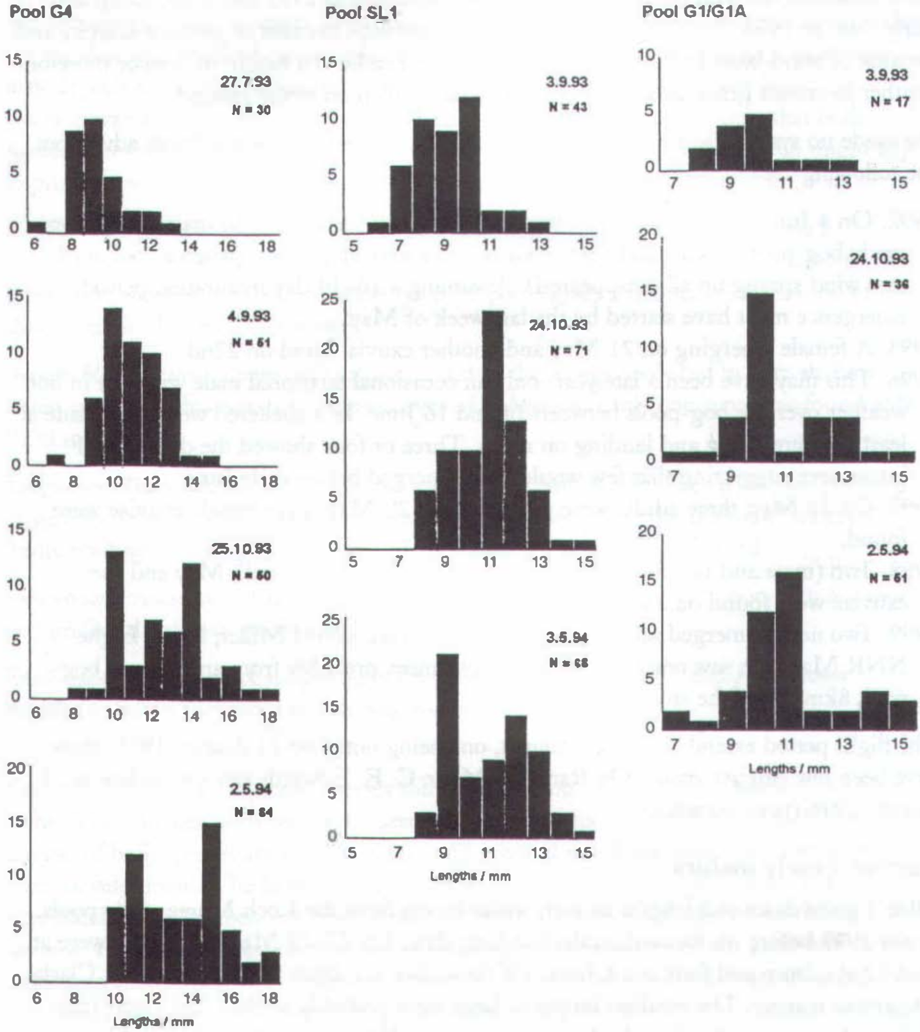


**Figure 1.** *Aeshna caerulea*: 1st-year larvae from several bog-pools.

On 29 June it was again cold and wet with the bog-pools overflowing and surface water temperatures of 16.5°C. On SL13 the small larvae were, as usual, at or very near the surface of the water but, in the more exposed G11 on the 30th, they were 7–8cm below the surface. By then, some 33 days after they had been first measured, the average size of larvae in SL13 had risen from *c.* 2.2mm to 3.5mm. On 22 July, the average size was 6mm, rising to *c.* 9mm by 1 September. The 15 June 1996 data and the two on 17 June

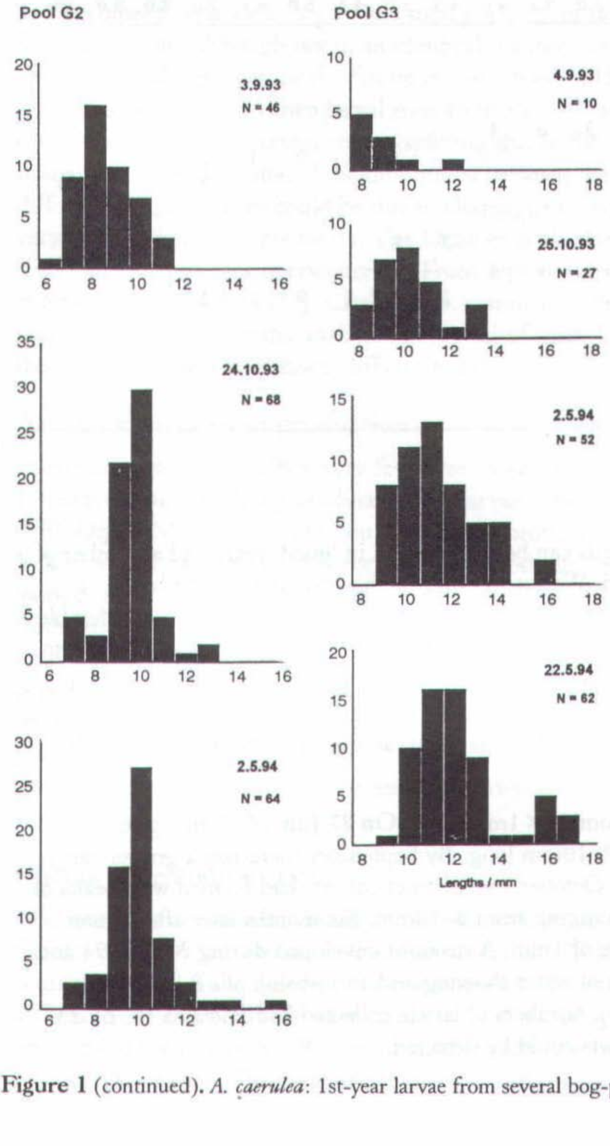


**Figure 1** (continued). *A. caerulea*: 1st-year larvae from several bog-pools.

1999 suggest similar hatching dates to those in 1998. The six from 1997 suggest that they may have hatched some 7–14 days later.

**Table 1.** *Aeshna caerulea*: frequency of early instars. Lengths of smallest *A. caerulea* larvae from various bog-pools at Loch Maree. Compare dates in SW Scotland at Silver Flowe (SF) and Ellergower (EG).

| Bog-pool | Date | Length (mm) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 8.0 | 9.0 | 10. |
| SL13/14 | 27.5.98 | 9 | | | | | | | | | | | | | |
| SL13 | 29.5.98 | 5 | 1 | | | | | | | | | | | | |
| SL13 | 4.6.98 | 4 | 1 | | | | | | | | | | | | |
| SL13 | 29.6.98 | | | 3 | 6 | 4 | | | | | | | | | |
| SL13 | 22.7.98 | | | | | | | 2 | 1 | 9 | 1 | 1 | | | |
| SL13 | 1.9.98 | | | | | | | | | | | 2 | 5 | 6 | 9 |
| G11 | 28.5.98 | 3 | 3 | | | | | | | | | | | | |
| G11 | 30.6.98 | | | 2 | 2 | | 3 | 1 | | | | | | | |
| G/SL | 15.6.96 | | 2 | 6 | 1 | 4 | | | | | | | | | |
| G/SL | 29.7.96 | | | | | | 2 | 2 | 5 | 9 | 1 | 2 | | | |
| G/SL | 18.6.97 | | 6 | | | | | | | | | | | | |
| SLY | 17.6.99 | | | 2 | | | | | | | | | | | |
| SF | 6.7.96 | 2 | 4 | | | | | | | | | | | | |
| EG | 6.7.96 | | 6 | | | | | | | | | | | | |

## 1st- and 2nd-year larvae

1st-year larvae of 7mm and upwards can be easily found in 'good' years and a number of pools have been regularly sampled. We suspect that catches may represent a large proportion of the *A. caerulea* present as no more larvae were detected after a considerable amount of collecting effort. Experience suggests that the smaller larvae generally tend to remain in their natal pool although there may be some movement to an adjacent lower one. Fig. 1 gives graphs for five of these pools (two very small adjacent pools are included as one) showing numbers and lengths of larvae from July/September to early May the following year.

G4 is a rather isolated oval pool some 5 × 1m in area. On 27 July 1993, in a group of 30 1st-year larvae, 80 per cent were 8–10mm long. By September there was a greater range of sizes peaking at 10mm. On 25 October, two distinct cohorts had formed with peaks of 10 and 14mm and larval lengths ranging from 8–18mm. Six months later after winter there was a general increase in size of 1mm. A drought developed during May 1994 and three weeks later, with only 2.5cm of water showing and an invasion of *c.* 8 full-grown Palmate Newts (*Triturus helveticus*), numbers of larvae collected had fallen to 18. By 23 July only three larvae and two newts could be detected.

The patterns of larval development in Pools SL1, G1/G1A (two very small adjacent pools) and G3 are not so clear-cut but all show a tendency to divide into cohorts by the following May. Pool G2 showed little evidence of divergence into cohorts or increase in size over the winter six months. In another four pools sampled, numbers were more erratic and revealed no obvious comparable pattern.

During the first year after hatching, each pool appears to develop its own larval structure and becomes a separate entity. Many such populations developed into two cohorts by the following spring although not in an identical manner nor in similar proportions. It may be that these differences, or the failure in some pools to develop a 'fast-lane' cohort, are related to food supply. When larval sizes from all pools are combined, the October and early May totals fail to reveal cohort-splitting due to the wide variation in larval lengths in the various pools. Some of the differences between the numbers of larvae sampled on different sampling dates could be due to chance, or to movement from adjacent pools in very wet weather, or to predation. The October peak of 9–11mm in most pools seems to be the minimal size for overwintering. From captive rearing these would appear to be in at least their 9th instar (D. J. Clarke, pers. comm.). Larger larvae, in their 2nd- and 3rd-years, show a much greater variation in spread of sizes due to differential growth, making the fate of any 1st-year cohorts difficult to follow.

## Annual variations in production

In our first searches in 1993, very few *A. caerulea* larvae were found. On 1–2 May, some 15 person-hours dredging produced eight larvae (three 1st-year, three 2nd-year and two F-0). On 22 May 1993, eight hours searching produced eight larvae (8–18mm) and one F-0 exuviae. It was not until September that good numbers of 1st-year larvae were located. Figs. 2 and 3 give the total numbers and lengths of *A. caerulea* larvae collected from nine bog-pools in early September of the years 1993–1998. The pattern of the graphs of 1st-year larvae is similar in five of these years showing a peak of 9–10mm and perhaps a tendency for differential growth (start of cohort-splitting) in some of the bigger larvae. The 1993 count of 170 larvae are practically all 1st-year. For 1994, the graph was comparable to that for 1993 with a total of *c.* 128 1st-year larvae. There was also a similar number of 2nd-year and *c.* 15 3rd-year larvae. There had obviously been a high survival of the 1993 hatching.

## Effects of drought in 1995

1995 was very dry. Regular monthly samples were made in the nine bog-pools except at the end of May when the water levels were very low. Table 2 gives the number of larvae counted on four visits. The larvae are separated by length into approximately three different year-groups. Heat-wave conditions during May/June were followed by rain, which filled the bog-pools. Between the May and June counts, the population declined by over 60 per cent. The greatest decline was in the 9–18mm larvae (hatched in 1994).

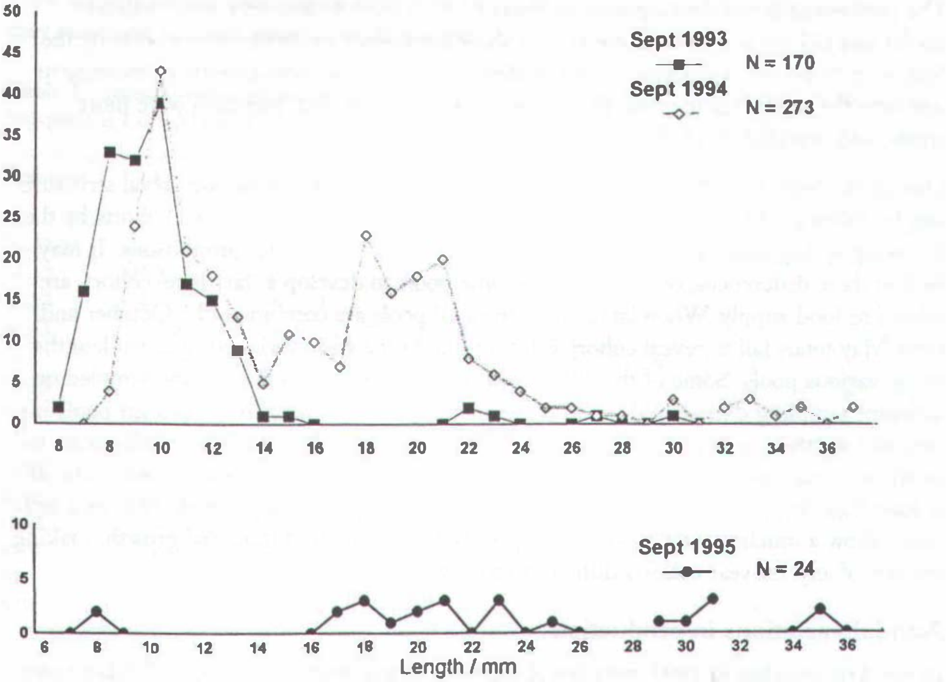


Figure 2. *A. caerulea*: Total larvae from nine study pools.

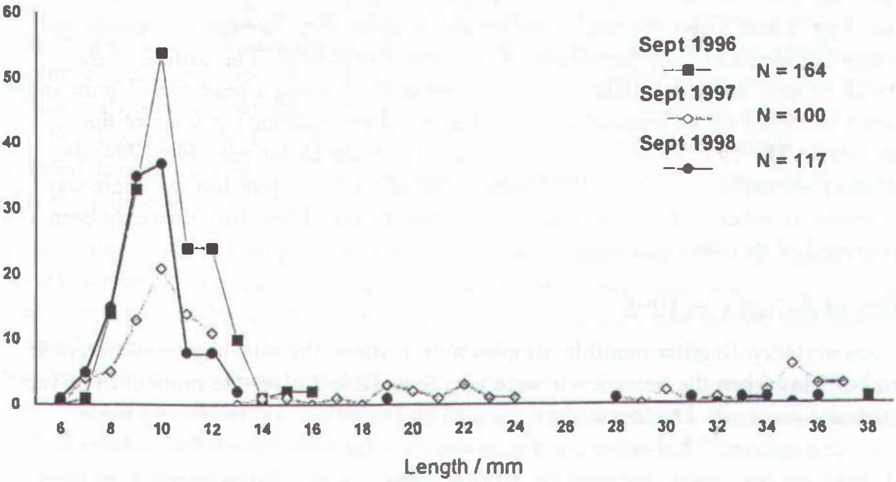


Figure 3. *A. caerulea*: Total larvae from three study pools 1996, and nine pools 1997 & 1998.

Due to the growth of the remaining larvae perhaps about 20 would be in the 19–27mm group by June. During the following four weeks, the water level in the bog-pools was maintained and numbers remained fairly stable. A more prolonged drought followed an intense heat-wave in August. By early September the pools had again filled but the larval population had apparently crashed to 24. Only two 1st-year larvae (see Fig. 2) were noted, compared to over 160 in 1993 and 128 in 1994. Seven of the remaining larvae were in their 3rd year. The largest larvae probably have a better ability to survive, perhaps helped by their greater mobility. Had the missing larvae really died or merely burrowed down into deep peat to re-emerge when the rains came? In 1996, sampling at the original nine pools and at three new ones (Fig. 3) supported the inference that they had died.

**Table 2.** Effect
at 9 bog-pools at Loch Maree during a period of intermittent droughts. the length groups correspond roughly to 1st-, 2nd- and 3rd-year larvae as at the beginning of May.

| Year 1995 | Total | Length | | |
|---|---|---|---|---|
| | | 9–18mm | 19–27mm | 28–39mm |
| 3–4 May | 463 | 240 | 97 | 9 |
| 24–26 June | 174 | 66 | 79 | 29 |
| 21–22 July | 167 | 47 | 69 | 51 |
| 5–6 September | 24 | 7 | 10 | 7 |

## 1996–1998 larvae

In Fig. 3 the 1996 graph of the three new pools is very similar to the 1993 one. The only non 1st-year larva was an F-0 of 38mm. 1997 was a year of low water levels with a low September larval count. From the three new pools, plus an additional compact group of six small pools to increase the available sample of sizes, only 100 larvae were collected. Just under half of these came from the original three pools, or around 30 per cent of the 1996 totals.

The September 1998 graph resembles that of 1993 with good numbers of 1st-year but only one 2nd- and five 3rd-year larvae. This was unexpected as it had been a very wet summer and one would have expected good survival of the September 1997 larvae. However regular monthly sampling of pools had been discontinued to prevent further deterioration of the habitat, so there are no data for larvae from then till spring. October and November 1997 were drier than usual (Scottish Natural Heritage data). Pools SL12 and SL13 were surveyed in May 1998 for newly hatched larvae. There was no sign of any larger larvae, although 18 (including one F-0) were caught from these two pools in the previous September, which suggests that the larvae had 'disappeared' sometime after this September survey. Summer drought is an annual hazard to a species that is confined to these very shallow waters but this is the only record of 'disappearance' of larvae in winter (or at least after September) during the nine years of the study. Is it possible that *A. caerulea* larvae may suffer mortality during the very rare winter drought?

## Comparison of summer drought years

Suitable bog-pools have a tremendous potential for *A. caerulea* larval growth. There was a high survival rate of the 1993 1st-year larvae into September 1994 and the expectation of good numbers of F-0 or F-1 larvae by September 1995 if the water levels had been maintained in the bog-pools. In the event very few seem to have survived. During summer 1992, the year before we started, rather unsuccessfully, to look for larvae, the water table on nearby Tansley Bog reached its lowest level of the period 1991–1997 (Scottish Natural Heritage records). There had apparently been a heavy loss of larvae in our study area with apparently few surviving into 1993.

A visit on 25–26 June 1995 demonstrated the effect of heat-wave conditions. In pool G2 a max./min. thermometer registered 24–31°C during a 26h period. The water level in this pool dropped *c.* 10mm during this 26h period and Tim Clifford, the SNH manager, reported that water levels in several bog-pools in the area had been falling rapidly during the previous four days of hot sunshine. Although water levels were high on 22 July, the numbers of larvae collected in G2 had dropped to 11 from the June count of 17. By 5 September, after the hot spell in August, no larvae were found. There were apparent losses of larvae during the summer of 1997 but not on the same scale as in 1995.

## 3rd-year larvae

Fig. 4 shows that, in early September, the usual divide between 2nd- and 3rd-year larvae is around 28mm although there may well be a small overlap of fast-growing 2nd-year and slow-growing 3rd-year larvae. In the 3rd-year cohort there are totals of 14 individuals in 1994 and 18 in 1997 from our September sampled pools (see Figs 2 and 3). In other years numbers of 3rd-year larvae were much lower and are consistent with the impression of the small numbers of annual emerging adults of this species.

Table 3 gives the months and measurements of F-1 and F-0 larvae examined between May 1994 and September 1998. As these larvae were obtained from regular sampling in selected bog-pools some of them will presumably have been measured on more than one occasion. September and October F-0 larvae tend to be smaller than the May ones which included many measured early in the month and which would be expected to emerge later in the summer. The two at 38mm on 16 June and perhaps the 36mm larva on 22 June may well have emerged later that same year, as a few adults remain on the wing into August. The 38mm larva of 28 July would probably not emerge until the following spring. Of the 69 F-0 handled, 63 were sexed giving a total of 32 females and 31 males.

Table 3 also gives measurement by months of F-1 larvae. Many of the September larvae will enter the final instar by the following spring and emerge that year. Perhaps some of those that were F-1 in May would emerge in June/July.

**Table 3.** *Aeshna caerulea*: length-frequency distributions in the final two larval instars.

| mm | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F-1 instars | | | | | | | | | | | | | | | |
| July | | 1 | | 1 | 1 | 1 | | | | | | | | | |
| August | | | 1 | | | 2 | | | | | | | | | |
| Sept | | | | | | 4 | | 1 | 1 | | | | | | |
| Oct | | | | 1 | | | | | | | | | | | |
| May | 1 | | | 1 | | | 2 | | 3 | | | | | | |
| June | | | | | | 1 | | 2 | | | | | | | |
| F-0 instars | | | | | | | | | | | | | | | |
| Sept | | | | | | | | 1 | 2 | 5 | 5 | 4 | 3 | 1 | |
| Oct | | | | | | | | 3 | 1 | 2 | 4 | 4 | 3 | | |
| May | | | | | | | | | | 5 | 5 | 7 | 4 | 2 | 4 |
| June | | | | | | | | | | | | 1 | | 2 | |
| July | | | | | | | | | | | | | | 1 | |

## Value of retreat areas

In Fig. 4 the larval measurements from SL2 show three different year-groups. On 3 September 1994, 1st-year larvae are from 8–13mm and 2nd-year from 15–24mm. By mid-October these two groups tend to overlap and this is more pronounced in May of the following year. Numbers of larvae collected in May 1995 showed an increase from the October 1994 figure perhaps due to an influx from Pool SL1 above. 1995 was a year of drought, particularly in August. Parts of Pool SL2 were slightly deeper than would normally be suitable for *A. caerulea* and, indeed, these areas were not frequented by larvae when water levels were high. By 5 September the 16 larvae netted from these deeper areas formed the bulk of the survivors from our study pools. It seems that slightly deeper parts of an occupied pool form a valuable retreat area during droughts.

## Discussion

From casual records it appears that *A. caerulea* emergence may start from around 20 May. Egg-laying has been noted on 4 June. By this time hatching of the previous year's eggs has started and may be completed in a very few weeks, perhaps by mid-June. Eggs continue to be laid through to late July/beginning of August and, after a period of development, go into diapause over the winter (Sternberg, 1990). There is no evidence that any eggs hatch in the year in which they are laid. No 2nd- or 3rd-instar *A. caerulea* larvae have been noted in July in the study area. At Silver Flowe/Ellergower in south-

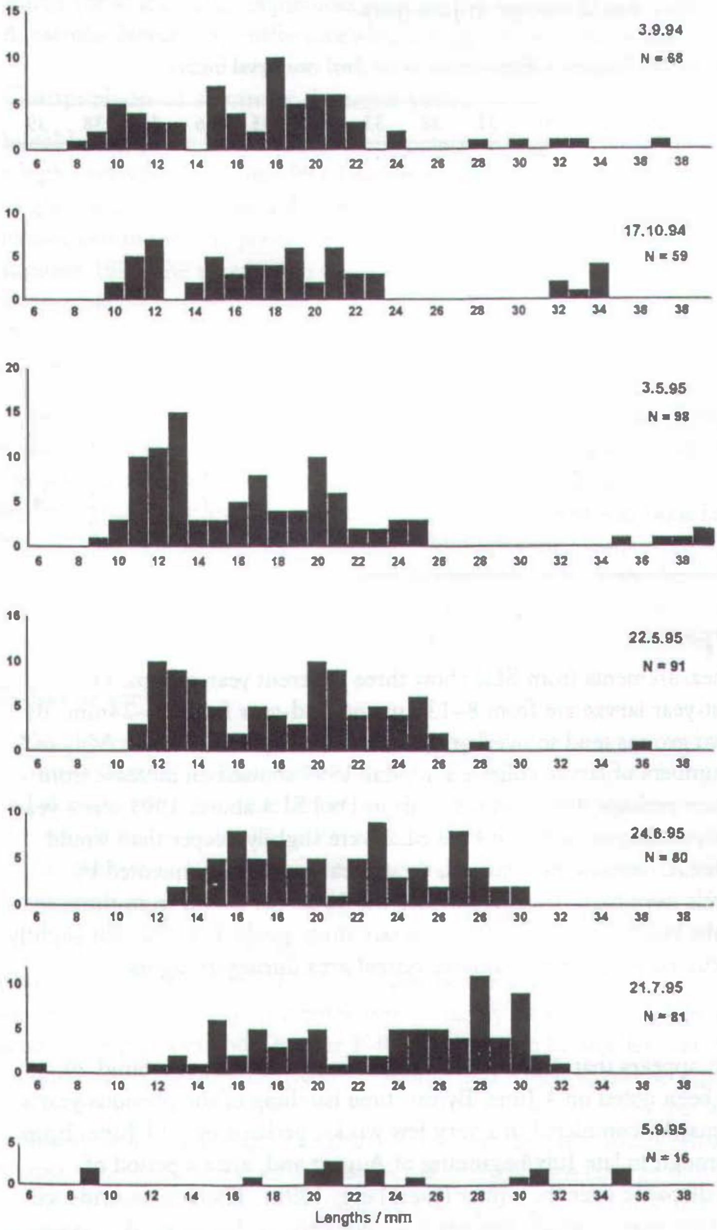


**Figure 4.** *A. caerulea*: Larval development in pool SL2.

west Scotland (250 and 280m a.s.l.) two larvae of 2mm and ten of 2.5mm were netted on 6 July (see Table 1). The hatching date of about one month later than at Loch Maree may be related to cooler surface water temperatures at the greater altitude.

Sternberg (1997) observes '... (1) at its lower distribution limits in central Europe ... where temperatures are thought to be too high for *A. caerulea* it shows a strong affinity with sphagnum bogs whose micro-climate generally is seen to be cold – continental, and (2) that this affinity becomes weaker with increasing altitudes.' In Norway, Pat Batty (pers. comm.) found *A. juncea* plentiful in one area at an altitude of 300m with no *A. caerulea*. Higher up the mountains, at 700m a.s.l., only *A. caerulea* was seen, in a much wider range of habitats than in Scotland. Larvae and F-0 exuviae were found in the small bog-pools and at the margins of deeper lochans and slow-flowing rivers. In Scotland, *A. caerulea* exists as an outlier at the western end of its Euroasian range. Its larvae are confined to very shallow *Sphagnum* bog-pools with an optimum depth of *c.* 20cm. This accords with Sternberg's statement.

Numbers can be surprisingly high in pools with a small surface area. From Pool SL2 with an area of 5–6m$^2$, we netted 60 *A. caerulea* larvae on 23 July 1994 and 98 on 3 May 1995. The only *A. juncea* noted among these catches was one on 23 July and two on 3 May. There is very obvious habitat segregation, which perhaps helps to prevent competition between these species.

Because of its restricted niche *A. caerulea* is very vulnerable during periods of extreme drought when apparently few larvae survive. In none of the seven years from 1993 to 1999 was there any evidence (numbers of F-0 exuviae or flying adults) that large numbers had emerged in the study areas.

The breeding bog-pools are entirely dependent on rain with only very local through-flow of water in very wet weather. This permits the water temperature in these shallow pools to become very high in the mid-summer sun (particularly at the surface of the pools). The eggs of *A. caerulea* are laid just below the surface of the water apparently into wet peat or vegetation. Sternberg (1990) states that the larvae '... are thermophilic ...' and '... need temperatures of about ... 20°C respectively which oscillate strongly within a day.' Our few records of surface-water temperatures range between 16.5°C and 26°C in normal weather conditions. During an exceptional heat-wave the maximum rose to 31°C. The larvae apparently all died; whether due to the extreme temperatures or to drying out of the pools is unknown, although the latter is perhaps more likely.

Soon after hatching the tiny larvae can be scooped out from near the water surface in sheltered corners. Very small *A. juncea* larvae are also found at surface level even in pools with much deeper water. On 30 July 1996 in the Culbin Forest area, 14 larvae of *Aeshna cyanea* (Müller), ranging in length from 4–8mm, were extracted from the surface of a filamentous algae (perhaps *Spirogyra*) floating in deep water. This is also the case with

*Anax imperator* Leach (Corbet, 1957) and perhaps many other species. This preference for the warm surface-waters does not seem to be restricted to the larvae of bog-pool species.

## Acknowledgements

We thank Keith Miller and Pat Batty for helpful comments; Tim Clifford and David Miller for useful local SNH records; Jonathan Kirby and Prof. Peter Vandome for help with the graphs; and Jacklyn Ryrie for help with field-work. We are grateful to David Clarke for regular discussions over many years and for checking the final draft and, in particular, to Prof. Philip Corbet for much helpful advice during the project and meticulous perusal of the final draft of the manuscript.

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# Discovery of a 'new' population of the Scarce Chaser *Libellula fulva* Müller on the River Stour in the Dedham Vale

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*Libellula fulva* Müller is reported to be a scarce dragonfly in Britain, restricted to six distinct areas (Merritt *et al.*, 1996). It breeds in slow-flowing rivers and associated dyke systems, with nearby ponds and lakes also utilized. The association with river systems renders it extremely vulnerable to pollution making conservation measures a high priority where it occurs. In the last four years it has been discovered at three additional river systems, suggesting that it may be expanding its range. In July 1996, it was recorded from the River Wey in Surrey (Follett, 1996) and more recently from the River Stour in Suffolk. It has also started to colonize the River Nene in Northamptonshire, which probably represents dispersal from the River Great Ouse populations in Cambridgeshire. The Suffolk records are particularly interesting as they are a considerable distance from other known sites (see Fig. 1).

The River Stour rises near Brinkley, Cambridgeshire, and flows east towards the sea. Along much of its length it forms the county boundary between Suffolk and Essex and, as such, has received the attentions of naturalists from both counties. The distribution of Odonata in both counties has been published in county atlases following extensive surveys (Benton, 1988; Mendel, 1992). The coverage for the Suffolk survey was especially thorough. The published distribution map for *Calopteryx splendens* (Harris) shows the species recorded in each tetrad along the full length of the river. With such thorough recording, it is likely that *L. fulva* was either not present in the area during the survey period, or present in only very small numbers.

In July 1997, Ian Johnson reported seeing two male *L. fulva* whilst leading a field trip to a small pond near Nayland in the Dedham Vale. This was especially interesting given the lack of records from the Essex and Suffolk surveys. Furthermore, no records from the area have been submitted to the national recording scheme. Following up on these sightings during July 1998, two males were observed by the author along the River Stour near Bures. At the time, the unfavourable weather conditions prevented an extensive search. However, during July 1999, further reconnaissance along much of the river revealed a sizeable population between Bures and Nayland. In addition, adult *L. fulva* were observed at Earls Colne on the nearby River Colne in North Essex during 1999. Such observations suggest that the River Stour population may have already started to

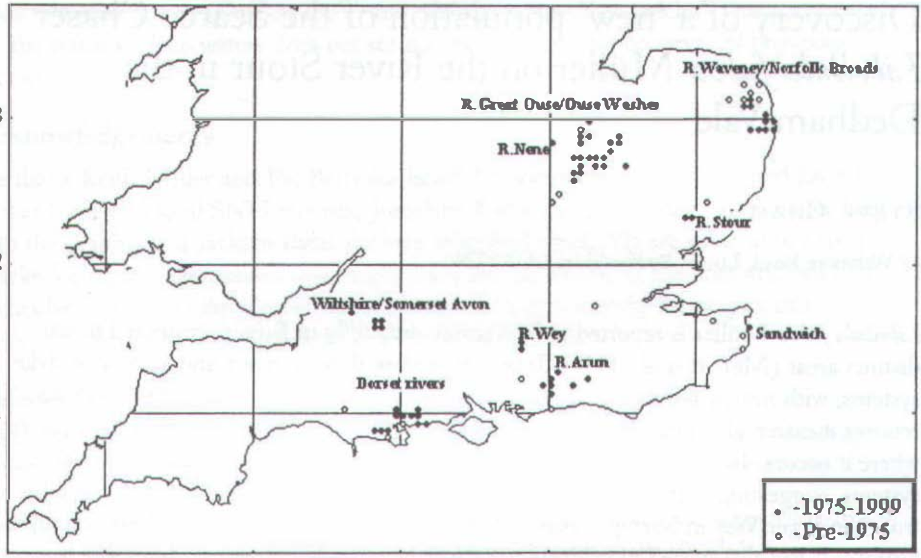


**Figure 1.** The distribution of the Scarce Chaser, *Libellula fulva*, in south-eastern England. Dots mapped at 5km resolution (cf. Merritt *et al.*, 1996).

colonize the River Colne. The question arises as to the origin of the River Stour population.

Mendel (1992) makes no mention of the species in the area, although he does refer to the increased populations of *Platycnemis pennipes* (Pallas) and *Erythromma najas* (Hansemann). He also refers to Longfield (1949) who mentions a colony as still present along 'the Suffolk Stour' and an additional record from Raydon Great Wood in 1956. Benton (1988) refers to a record from Colchester quoted by Lucas (1900) as collected by W. H. Harwood. Merritt *et al.* (1996) do not include any of these early records in the national atlas.

The recent (re-)discovery of the species reveals that its range is discontinuous along the river. Visits under favourable weather conditions have revealed sizeable colonies at various points along this stretch, with mating and oviposition observed. Strong breeding populations of *P. pennipes* are also present in the same areas. Benton (1988) quotes some Suffolk records for *P. pennipes* along the Stour near Nayland made by Sam Beaufoy between 1949 and 1960. He goes on to conclude that it had already been lost from the Stour. Mendel (1992) quotes that *P. pennipes* was present along the Stour in small numbers between Stratford St. Mary and Bures between 1988 and 1992. The present day situation has greatly improved for this species. The bankside vegetation is particularly luxuriant, with a predominance of Reed Sweet-grass (*Glyceria maxima*) in the key areas. Searches show that *L. fulva* is apparently absent upstream of Bures at present.

Whilst the present Stour valley population may have originated through natural colonization, it is possible that a small colony of *L. fulva* may have been overlooked in the area for over fifty years. Mendel (1992) speculates on other possible reasons for the recent increase of *E. najas* along the Stour valley. Large volumes of water, which could contain dragonfly eggs or larvae, are now pumped underground from the Ouse Washes into the upper reaches of the Stour. The lack of chlorination of the water in recent years would enhance the chances of survival of any eggs or larvae dispersed by this means and offers a plausible explanation for the observed increases of both *P. pennipes* and *E. najas*. The Ouse Washes also has a strong population of *L. fulva* that might have dispersed to the Stour in the same way. Whatever the reason, this 'new' population will provide a means of monitoring the fortune of this species in years to come.

## Acknowledgements

I would like to thank Ian Johnson for informing me of the first Stour valley sighting; Steve Covey for providing details of recent Wiltshire records; and J. A. Cowlin for the sightings on the River Colne. The distribution map was produced using Alan Morton's DMAP software (32bit version) and is based on all records in the Dragonfly Recording Network Biobase database.

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# First proof of successful breeding by the Lesser Emperor *Anax parthenope* (Sélys) in Britain

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The Lesser Emperor *Anax parthenope* (Sélys) is a resident of northern Africa, Asia, the Middle East and the Mediterranean regions of southern Europe (Askew, 1988). In recent years it has become a more frequent immigrant to northern Europe, notably Britain, Belgium and the Netherlands (Parr *et al.*, in press).

*A. parthenope* was first recorded as an immigrant to Britain on 13 June 1996 at Cinderford Linear Park, Gloucestershire (Phillips, 1997). A second British record, another male, followed less than a year later, photographed at Gear Sands in Cornwall on 25 May 1997 (Jones, 1998), quickly followed by sightings in Cambridgeshire (Thomas, 1997) and East Sussex (Parr, 1999).

Remarkably, despite *A. parthenope* having been recorded from Britain for the first time only two years earlier, 1998 produced 21 sightings in Cornwall alone. These observations covered five different sites, occurred in every month from May through to September, and involved a minimum of six adults, including two females. This fuelled speculation that the relatively high numbers observed within the county might be the result of successful local breeding.

On 31 July 1999, a hot and sunny day, I visited a site on the Lizard peninsula (SW61) to monitor the resident dragonfly populations. The site is on private land just over 5km north of the most southerly point on the British mainland and forms part of a Site of Special Scientific Interest. At the core of the site is a series of three shallow ponds, with a combined surface area of 2.3ha of water during winter, that stand at a point where an extensive area of Lizard heathland gives way to an area of rough grazing. A drainage ditch runs along the northwest boundary of the site providing added odonatological interest. The vegetation in and around the pools is typified by Common Spike-rush (*Eleocharis palustris*), which totally dominates the main water body, giving it a 'paddy field' like appearance. Other vegetation includes Common Cottongrass (*Eriophorum angustifolium*), Marsh St John's-wort (*Hypericum elodes*), Amphibious Bistort (*Polygonum amphibium*), Water Mint (*Mentha aquatica*) and Marsh Pennywort (*Hydrocotyle vulgaris*). Rushes (*Juncus* spp.) dominate the drier margins, where other vegetation includes Purple-loosestrife (*Lythrum salicaria*), Hemp Agrimony (*Eupatorium cannabinum*), Common Fleabane (*Pulicaria dysenterica*), Devil's-bit Scabious (*Succisa pratensis*) and Ragged-Robin (*Lychnis flos-cuculi*). The main pool does not completely dry up, even in the driest summers, though the water area shrinks to less than 25 per cent of its winter coverage by late August each year.

At the eastern-most margin of the main pool my attention was drawn to a very pale *Anax* exuvia attached to a small stand of *Juncus*. A casual comparison of this specimen and known *A. imperator* Leach present at the site suggested that this was not an exuvia of the latter species. Close examination of the male projection at the base of the epiproct and the length of the cercus (Askew, 1988) confirmed that this pale exuvia was a male *A. parthenope*. It is interesting to note that, although an adult female was observed at a site just 3km to the north in May 1998, there had been no previous confirmed records from this more southerly habitat.

Shortly after my discovery, further probable *A. parthenope* exuviae came to my attention via Keith Pellow who had collected four specimens from Bake Farm Pools (SX318587) in August 1999, two of which he had sent to me for advice on their identification. Both male and female adult *A. parthenope* had been noted at this site during July 1999.

In the Lizard specimen, both Bake Farm specimens and an Algerian *A. parthenope* of known identity (collected by Dr Boudjéma Samraoui), the male projection measured 2mm wide and 1mm long, while the cercus measured 3mm long (Fig. 1). This conformed well to the description of *A. parthenope* given by Askew (1988: 203): 'male projection only about half as long as broad, about one-third the length of a cercus.' *A. imperator* is described as having 'male projection at base of epiproct as long as broad, half the length of a cercus.'

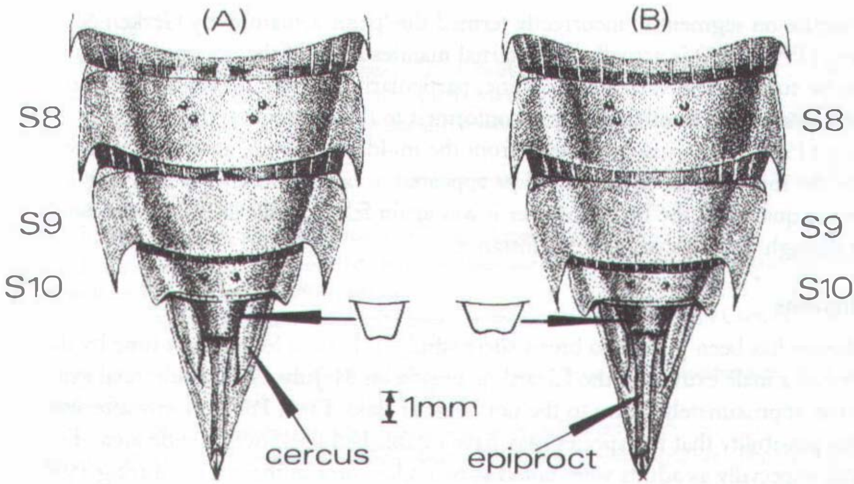


**Figure 1.** Abdominal apices of (A) *Anax imperator* and (B) *Anax parthenope* in dorsal view, with separate outlines of the male projection.

Aware of the significance of these records, I sought both a second opinion and additional features to determine the specimens' identity. Professor Philip Corbet very kindly undertook to examine the Lizard and Bake Farm material with me and brought to my attention the recently published book by Gerken & Sternberg (1999). This excellent work mentioned three additional features for separating the two *Anax* species, including the medial length of the prementum (apex to hinge), 'the penis armature' (*sic*) on segment 9 of the abdomen, and the reach of the hind margin of the postmentum/prementum hinge. All of the suspected *A. parthenope* material available and several *A. imperator* of known identity were examined in order to test their compliance with these features.

Of the *A. parthenope* material, only the Lizard and Algerian specimens had the head intact and in both cases the medial length of the prementum (apex to hinge) was approximately 8.5mm, which falls within the range of 8.0 to 8.7mm given by Gerken & Sternberg (1999: 208) for the species. However, examining *A. imperator* specimens for the same feature produced measurements as low as 8.9mm. This value is somewhat lower than Gerken & Sternberg's range of 9.2 to 9.9mm, suggesting that in this character the potential may exist for some overlap between the two species.

The reach of the hind margin of the postmentum/prementum hinge depends on the angle that the head of the exuvia sets in comparison to the thorax. It was therefore felt that this character, which Gerken & Sternberg describe as reaching the anterior margin of the third coxae in *A. imperator* and the posterior margin of the second coxae in *A. parthenope*, was not clear enough to be useful in this instance.

The structure on segment 9, incorrectly termed the 'penis armature' by Gerken & Sternberg (1999: 208) is actually the external manifestation of the gonopore. It was found to be surprisingly variable in outline, particularly in the *A. imperator* material examined, and only a small proportion conformed to the description by Gerken & Sternberg (1999): 'tapering proximally from the middle to the tip, anteriorly pointed'. Three of the four exuviae of *A. parthenope* appeared to be anteriorly rounded 'only from the anterior quarter to the tip'. However it was again felt that this character was not distinct enough to be decisive in this instance.

## Conclusions

*A. parthenope* has been proven to breed successfully in Britain for the first time by the discovery of a male exuvia on the Lizard peninsula on 31 July 1999. Additional exuviae discovered approximately 75km to the northeast at Bake Farm Pools shortly afterwards allow the possibility that the species may have established itself over a wide area of Cornwall, especially as adults were noted at two other sites in the county during 1999.

Current knowledge of the larval development time for *A. parthenope* indicates that, in Europe, larval development is likely to take two years (Robert, 1958), suggesting that the original oviposition would have occurred during the summer of 1997. However it is not inconceivable that in the right conditions, such as the shallow pools of the Lizard site where there is a high degree of exposure to sunshine, *A. parthenope* could complete its larval development in one year (P. S. Corbet, pers. comm.). If so, it is possible that oviposition could have occurred during the summer of 1998, when there were numerous sightings of adult *A. parthenope* in Cornwall.

The shape of the male projection (Fig. 1) appears to be the most reliable feature for separating male *A. parthenope* and *A. imperator* exuviae in Britain. Both the Lizard and Bake Farm exuviae are conclusively identified as *A. parthenope* using measurements of the male projection at the base of the epiproct and the length of the cercus. It may be usefil to note that Bellmann (1987) recognizes the length of the female genital armature (legeröhre) relative to that of segment 9 as serving to distinguish the two species.

It remains to be seen whether these new populations persist in future years, although at Bake Farm Pools, at least, this would seem a distinct possibility (Pellow, 2000).

## Acknowledgements

I would like to extend my thanks to Dr. Boudjéma Samraoui who provided the Algerian *A. parthenope* exuvia, Keith Pellow for the Bake Farm material, and Mr. H. Bosustow for allowing access to the Lizard site (which is private property and therefore is not named here). I would also like to thank Prof. Philip Corbet, not only for the loan of the Algerian specimen and bringing the relevant literature to my attention, but also for his generosity in freely giving of his valuable time, support and encouragement.

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# Flight characteristics of the Brilliant Emerald *Somatochlora metallica* (Vander Linden) in south-east England

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## Introduction

Hammond (1983) describes the flying habits of the Brilliant Emerald *Somatochlora metallica* as similar to those of the Downy Emerald *Cordulia aenea* (L.), which is described as 'a fast flier, keeping low above the surface of the water at the edge of a pond or canal, making a short but regular patrol'. More recently, the flight characteristics of the Brilliant Emerald have been described by Vick (1997): 'As with the Downy Emerald, males fly around edges of lakes and ponds, but the Brilliant Emerald flies faster and pauses less frequently to investigate shady nooks. Typically, they cruise at 0.8–1.3m above water, keeping 1–2m from the edge, and flying as much as possible under overhanging trees'. d'Aguilar *et al.* (1986), whose observations were probably made outside of the UK, note that 'in fine weather, the adults fly strongly and "sail", moving constantly between the water and tree-tops'. The purpose of the present paper is to describe the flight patterns we have observed in the Brilliant Emerald, demonstrating that its behaviour is quite distinct from that of the Downy Emerald.

## Background to the present study

The study originated following observations during the early 1990s by the first two authors at sites near Bracknell in South-east Berkshire (Grid ref. SU86 and SU96). Here there are areas of open water in the form of ponds and small lakes of markedly different sizes, widely scattered amongst plantation pine forest. In these conditions, *S. metallica* behaves as an adventurer, an opportunist, moving between one area of water and another. This behaviour renders it a very elusive species and, despite the fact that it has a broadly similar local distribution and has been recorded at a greater number of sites, it is seen far less often than the *C. aenea.* The study was extended in recent years to take in observations by all three authors at woodland ponds distributed through southern England: in Berkshire, Hampshire, Surrey and Sussex. Observations of the species on slow-flowing waterways, including sections of the Basingstoke Canal and Wey Navigation in Surrey, and the River Blackwater along the Berkshire/ Hampshire border, have extended the scope of the survey still further.

## Descriptions of flight styles

We have observed that, when encountered at woodland ponds, the male *S. metallica* normally adopts one of three different forms of flight style.

**Flight style I (FS I).** This flight style is typically at a height of about 1m above the water and close to the edge. It takes the dragonfly beneath overhanging vegetation, where it is prone to loiter with spells of hovering, and into regions of shade. It is broadly similar to the flight style adopted by *C. aenea*, although *S. metallica* is generally slower and more purposeful in flight. This style is also used by *Aeshna cyanea* (Müller), which, with intervals of hovering, gives it an inquisitive manner.

**Flight style II (FS II).** In this style the male patrols back and forth along a regular beat in the sunshine with a slow, controlled flight, occasionally punctuated by hovering. In most respects it is similar to the patrolling flight of *Anax imperator* Leach. Typically the flight is about 2–3m above the water, but where the pond has steeply sloping banks the dragonfly will occupy airspace as high as 6m above the water level. Over small ponds (up to about 20m diameter) the dragonfly occupies an area above the centre of the pond, but in larger ponds the flight is typically within an airspace about 4–6m from the edge. When several males are present, as happens on rare occasions, they space out, each patrolling over different parts of the pool.

**Flight style III (FS III).** In this style the dragonfly upon visiting a site flies around it on an irregular flight path. These visits typically last 1–2 minutes, but may be as short as 20 seconds, sometimes longer than 2 minutes. During this brief period *S. metallica* maintains a sense of urgency, flying faster than in the first two flight styles. Its height above the water varies.

The above descriptions of the three styles may be classified as the typical or normal modes, but departures from the styles have been observed. As with other dragonflies, *S. metallica* is capable of flight with a wide range of speeds. *S. metallica* is capable of fast forward flight, can hover in still air, and has been seen flying into a wind of sufficient strength to carry the dragonfly backwards relative to the ground. All of these flight conditions have been observed on different occasions whilst the dragonfly was adopting FS I, but most frequently *S. metallica* travels forward through the air with a deliberate, controlled rate of advance.

## General comments

When adopting FS I, the male *S. metallica* appears to be searching for ovipositing females that use water margins for egg-laying. In contrast, FS II may represent general territorial behaviour, allowing the dragonfly to maintain an overview of a site for an extended period of time, and providing it with the opportunity to observe the entry to, or departure from, the site by any females. When adopting FS III, *S. metallica* appears to be carrying out a general reconnaissance of a site. Whilst FS I and II involve systematic, orderly flight paths, FS III is characterized by a flight path with no apparent pattern. The following description provides an example of the erratic behaviour observed. At Oval Pond, Padworth, a single male *S. metallica* appeared in the middle of the lake flying very purposefully. It was seen to touch the water several times before flying at high speed towards the bank. Its behaviour was very different from that of the many *C. aenea* on the wing. It flew at high speed towards the dam end of the lake and then began to patrol the margins. This it did for several minutes before leaving the pond. It returned a second time *c*.30 minutes later and repeated this behaviour. This is the only record for *S. metallica* at this site from many visits, suggesting that it was exploratory.

Feeding activity rarely takes place over water, though it has been observed on one occasion at Chobham Common Fish Pool (SU9963) during a fine day with plenty of flying insect prey. This male was continually 'mobbed' by two male *Aeshna grandis* (L.). Away from water, *S. metallica* has been seen hawking for prey along the tree-lined margins of valley bogs and over bracken on the edge of a forest ride.

*S. metallica* has been observed on tree-lined sections of slow-flowing waterways, including the Basingstoke Canal (at Frimley Green, Brookwood and Sheerwater), the Wey Navigation (between Walsham Meadows and the Anchor Inn) and the River Blackwater (at Sandhurst and near Bramshill). Here, particularly along the man-made waterways, there is little apparent variation of the habitat and one stretch of water is like another. Under these conditions the males can establish a regular pattern of territories. In some places the territories are closely packed, so that neighbouring males interact, whilst elsewhere, large gaps separate the territories. Given sufficient space, males appear to operate in a territory extending some 25m along the axis of the waterway. They fly roughly 1m above the surface of the water, and move about over the middle of the waterway, along the margins and from side-to-side, without restriction. This flight style appears to be a combination of FS I and II. Initially, it was thought that the different behaviours over woodland ponds and over waterways could be explained simply in terms of the different habitats. Further observations suggest another explanation depending upon the presence or absence of other species of flying Anisoptera.

In southern England, *S. metallica* is on the wing from late May. Its main flight season corresponds to the months of June and July, and by early August it has disappeared. During much of its flight season, on many of the woodland ponds it frequents, *S. metallica* is outnumbered by *C. aenea* and/or *Libellula quadrimaculata* L. *L. depressa* L. and *Orthetrum cancellatum* (L.) may also be on the wing at the same time. Observations indicate that if any of these other species are active at a woodland pond, *S. metallica* will normally adopt FS II to minimize aerial interactions. Conversely, if no other species are flying, *S. metallica* will normally adopt FS I. These observations are reinforced by sightings towards the end of the *S. metallica* flight season, when the darters start to take to the wing. *Sympetrum sanguineum* (Müller) has been observed rising aggressively from its perch to interact with an *S. metallica* flying in FS II. In very hot conditions, *S. sanguineum* and *S. danae* (Sulzer) have been seen perching lethargically on one sunny bank of a pond, whilst opposite, in conditions of shade, an *S. metallica* was searching along a margin, adopting FS I. *S. metallica* appears to take evasive action to avoid close encounters with the *A. imperator* and *A. grandis*.

The distinct flight patterns observed at woodland ponds and on slow-flowing waterways can be reconciled in the following way. It appears, in the absence of other species of Anisoptera on the wing, that the single flight pattern found on slow-flowing waterways is a convergence of FS I and II. Expressed another way, the flight styles FS I and II are manifestations of a divergence in behaviour to minimize interactions with other dragonflies. It is not clear whether *S. metallica* uses shaded and obscure sites as a strategy deliberately to minimize potential competition/interactions with other Anisoptera, or whether it favours this microhabitat *per se*.

We have seen *S. metallica* at several small sites where *C. aenea* does not occur. The smallest water body in the Bracknell area at which any Emerald has been recorded is the pond at Gormoor Heath constructed by a conservation team during the winter 1996/97. This pond measures about 3m by 8m. On 17 June 1997, a male *S. metallica* flew over this tiny pond for 3 minutes using FS II. Whereas our observations confirm that *C. aenea* is a poor disperser, *S. metallica* in the Bracknell area moves from one woodland pond to another. Hence *S. metallica* is encountered at sites where *C. aenea* is rarely or never seen, including some sites that are well concealed within mature blocks of trees. The woodland ponds are vulnerable to diverse threats. Several of the larger ponds monitored have experienced large falls in water level in recent years, threatening the survival of the aquatic wildlife. Ponds in valley bogs and wet heath are subject to loss through succession caused by the growth of birch, pine and sallow. In the face of these threats, the dispersal behaviour of *S. metallica* may be interpreted as increasing its chances of long-term survival.

For a full understanding of the flight of all creatures, including birds, bats and insects, it is becoming increasingly recognized that consideration should be given to the subject of energetics. To meet the high energy demands of flight, a dragonfly must take in sufficient supplies of food. During perching little energy is used. Some dragonflies spend periods of time perched; the darters and chasers use this energy-conservation strategy. In the air, a dragonfly will consume substantial amounts of energy, at one extreme, whilst hovering, and at the other extreme under conditions of fast forward flight. Between these extremes the dragonfly uses less energy and there is a particular flight speed at which the rate of energy consumption is a minimum. This corresponds with the minimum-power speed of aircraft flight (Ward-Smith, 1984). It is conjectured that the slow, controlled flight adopted by *S. metallica* during FS I and FS II is the equivalent of the minimum-power speed of aircraft flight. At this flight speed, the dragonfly is able to remain airborne whilst adopting an energy-conservation strategy.

## Outstanding considerations requiring further investigation

Although occasionally the male *S. metallica* will spend up to 1 hour or more at a woodland pond site on a single visit, more generally the visit is for a shorter period, often under 10 minutes. Females are particularly elusive and have been observed far less often than the males. Only once has oviposition been observed at these sites around Bracknell and copulation not at all (our observations on rivers and canals have occupied perhaps only 5 per cent of the total time spent watching *S. metallica*, yet we have observed both copulation and oviposition at such sites). Since the bulk of our observations have been made between 1000h and 1600h, the question arises as to whether mating activity occurs mainly early in the day or in the evening. Are encounters between males and females mainly away from water? If they are, there still has to be some justification for the male spending time over water. Why are sightings of *S. metallica* less frequent than those for *C. aenea*, despite their similar flying seasons? Why does *S. metallica* appear to be more noticeable in the absence of *C. aenea*?

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# Observations of the Red-veined Darter *Sympetrum fonscolombei* (Sélys) at Bake Lakes in Cornwall during 1999

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Following the highly successful breeding of *Sympetrum fonscolombei* (Sélys) during 1998 at Bake Farm Fishing Lakes in south-east Cornwall (Pellow, 1999), the 1999 flight season was eagerly awaited. Between 1 May and 28 October 1999, a total of 42 visits were made to the site and during June and July the site was visited more frequently than in 1998. In comparison to 1998, fewer individuals were encountered during the summer of 1999. This short paper presents further observations on the persistence of a population of an immigrant species of dragonfly that may be in the early stages of colonizing Britain.

As in 1998, successful emergence and the presence of exuviae were observed only from the two main pools, Mirage and Dune. The first adult was observed on 13 June, when 4 teneral adults were present and 6 exuviae were collected. This compares with the first observation of an adult on 5 June in 1998. The emergence of the first generation continued through to 26 June after which no teneral adults were seen and no exuviae collected. A lone immature adult was sighted on 7 July, suggesting that newly emerging individuals might have been missed. *S. striolatum* (Charpentier) had a highly successful season in 1999 at the site and high numbers of this species emerged from the two main pools during the same period (Fig. 1). The first period of emergence covers a minimum period of 14 days. Emergence of *S. fonscolombei* was earlier than the more numerous *S. striolatum* and was completed well before the emergence of the latter species peaked during July.

Apart from the immature seen on 7 July, the only adult *S. fonscolombei* seen were single adult males observed on 5 July, 30 July and 4 September. These sightings may have been of the same male, as on each occasion the individual was observed patrolling the same 10m section of bank on Mirage Pool. Assuming that these sightings were all of first-generation adults, the flight period of 83 days is similar to the 87 days observed in 1998.

No females were seen, so no oviposition was observed and a second generation was not expected. Therefore, it was surprising to discover 4 teneral adults and 11 exuviae on 19 September as well as a further exuvia on 24 September. It is not clear whether these individuals were the result of successful breeding of individuals from the first generation or the result of delayed development of larvae from the previous year. If the latter, then this may be an indication of a further breeding strategy of this highly migratory species.

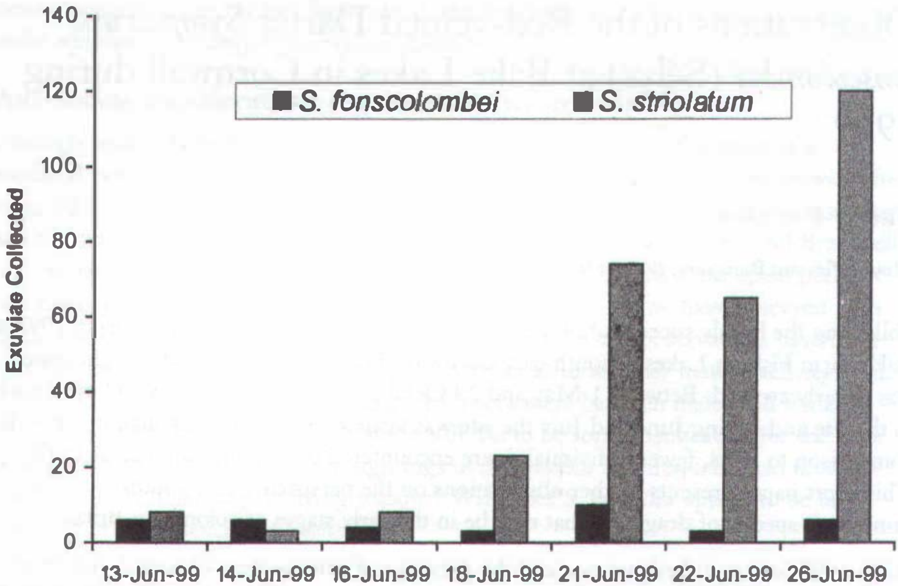


**Figure 1.** Collections of exuviae of *Sympetrum fonscolombei* and *S. striolatum* at Bake Lakes during June 1999.

The size of the 1999 adult population was very much reduced from the exceptional numbers recorded in the previous year. However, the data presented clearly show that following colonization of the site in 1997 (Bake Farm Fishing Lakes were created in 1996), this population of *S. fonscolombei* has persisted through to at least 1999. The total of 38 exuviae collected during June 1999 is considered likely to be close to the actual number of adults emerging during this period, as is the total of 12 emerging adults during September 1999. It remains to be seen whether this colony of *S. fonscolombei* can sustain itself in subsequent years.

## Acknowledgements

Thanks are due to Tony Lister and the managers of Bake Lakes for their support, patience and allowing unlimited access to the site.

## Reference

Pellow, K., 1999. Some observations of a breeding population of Red-veined Darter *Sympetrum fonscolombei* (Sélys) in Cornwall during 1998. *Journal of the British Dragonfly Society* 15: 23–30.

# Book review

*A Guide to the Dragonflies of Great Britain*

Arlequin Press, Chelmsford, Essex CM1 1SW, England (1999) 21 x 15cm, 128pp.
£15.95 incl. post and packing (softback). ISBN 1 900159 01 5

Illustrated by Dan Powell; with text by Dan Powell and Colin Twist; edited by Colin Twist

The strength of this book lies in its beautiful paintings of dragonflies and their habitats. By producing these illustrations, Dan Powell has made a uniquely valuable contribution to the genre. The colour paintings of adult dragonflies, portraying posture and behaviour in nature, are (in my experience) unrivalled for their realism and beauty; and their impact is further enhanced by an enviable economy of line. Likewise the sepia paintings of habitats are eloquent and simple. Many readers will be grateful also for the inclusion of sketches that capture skilfully the first impression, or 'jizz', of different species. Wildlife artists have seldom managed to illustrate living dragonflies convincingly, but Dan Powell has done so with consummate success. I cannot imagine a set of illustrations better able to arouse an interest in dragonflies among field naturalists.

Each species account includes a simple distribution map for Great Britain and Ireland, and brief information regarding similar species, 'jizz', size, flight period, abundance and salient features of behaviour and ecology. Illustrations include magnified details of some characters used for determining adults to species. General introductory sections touch on anatomy, life cycle, information sources, fieldcraft, distribution and conservation. Tables summarize flight periods and habitat types, and a 'Quick reference guide' leads the reader to a likely determination on the basis of colour pattern. Certain habitats are cross-referenced by number to the inventory in the useful site guide by Hill & Twist (1998), a fact that needs to be made clearer in the text.

Despite its admirable qualities, this book is not a stand-alone identification guide for all the species it encompasses. For reliable species determinations it should be used in conjunction with Miller (1995) and Brooks (1997), or with the older but still useful Hammond (1983). The need (by conservation bodies and record centres) for secure identifications should be stressed in the book but isn't. On the contrary, one reads on page 32 that a net was dispensed with 'in order to prove (*sic*) that dragonflies can be identified purely by fieldcraft.' How such a 'proof' could be obtained is not explained! One cannot confirm the identity of some species without examining them in the hand, and it is scientifically inadmissible to imply otherwise. There is probably no record centre in Britain that would regard all dragonfly determinations as secure if based on fieldcraft alone. It may be fashionable nowadays to dispense with a net, but to do so cannot guarantee reliable identifications. For example, the account (on page 122) of the Green Darner (known to visit Britain from North America) makes no mention of the vertex pattern or the shape of the male superior abdominal appendages, two characters needed to distinguish it reliably from other species of *Anax*. Likewise there is no mention of the possibility of mistaking the Scarlet Darter, *Crocothemis erythraea*, for *C. servilia*, probably introduced intermittently to Britain as eggs or larvae on aquatic plants imported for aquarists (see Brooks, 1988). Failure to respect these and other caveats, or to secure a voucher specimen, could result in potentially valuable records having to be disregarded.

Neither the text, nor the editing, of this book matches the quality of the artwork. Because I expect a second edition to appear before long, I illustrate this statement with a few examples.

Some facts given are incorrect or misleading; and there are obvious omissions. Brown Hawker eggs do not spend three years in diapause, and larvae of the Azure Hawker and Downy Emerald usually, probably always, require more than two years to develop. The Common Hawker certainly does not 'court', and it is stretching the meaning of the term to say that the White-Legged Damselfly does so; and a generation of the Large Red Damselfly is normally completed in two years, sometimes in one, but not in '2–3'. Anisoptera sometimes perform intramale sperm transfer *before* adopting the tandem position (page 56). It would have been useful to mention for all resident aeshnids which species do and do not have diapause eggs. No dimensions are included for the 'vagrants' listed on pages 122–125.

In the text, vocabulary, syntax and punctuation fall short of accepted standards. The singular of 'larvae' is 'larva' (page 12); adjacent sentences should be separated by a full stop or semicolon; apostrophes should be conventionally placed (pages 32, 88, 119); and spelling of 'affected' and 'effected' (page 83) and conjugation of the verb 'to set' (pages 72, 97, 108, 117) should be correctly rendered.

This book contains illustrations outstanding for their realism and beauty, and it provides information of interest. Its value is diminished by poor editing and by failure to make the text authoritative. One hopes that a second edition will soon enable these deficiencies to be rectified.

## References

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**Philip Corbet**

## INSTRUCTIONS TO AUTHORS

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

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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.

Use of these terms is acceptable: 'exuviae' for cast skin or skins (singular and plural); '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.

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

Titles of journals should be written out in full.

Tables should be typed, each on a separate, unnumbered page.

Legends for illustrations should be typed together in sequence on a single unnumbered page.

Illustrations (figures) should be prepared in black ink, and scaled to allow a reduction of 1.5 to 3 times. Lettering should be neat and uniform.

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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