J. Br. Dragonfly Society, Volume 41 No. 1, April 2025

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Journal of the British Dragonfly Society

Volume 41 Number 1 April 2025

British Dragonfly Society

The aims of the **British Dragonfly Society** (BDS) are to promote and encourage the study and conservation of Odonata and their natural habitats, especially in the United Kingdom, and to raise public awareness of dragonflies.

The Journal of the British Dragonfly Society, published twice a year, contains articles on Odonata that have been recorded from the United Kingdom and articles on European Odonata written by members of the Society.

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ISSN 1357-2342

Back numbers of the Journal can be purchased from the BDS Shop at £2.00 per copy to members or £5.50 per copy to non-members.
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Cover illustration: Final larval instar of a female Coenagrion pulchellum. Photograph by Steve Cham.

The Journal of the British Dragonfly Society is printed by Artisan Litho, Abingdon, Oxford.
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    - The following terms are used: `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 2020'.
    - References cited in the text should be in the form '(Longfield, 1949)' or '... as noted by Longfield (1949)'.
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Species Review 13: *Coenagrion pulchellum* (Vander Linden) (Variable Damselfly)

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Summary

This species review provides a synopsis of the natural history and conservation of *Coenagrion pulchellum* (Variable Damselfly) in Great Britain and Ireland, examining its habitat requirements and distribution, insights into its life cycle and behaviour and variation in morphology, markings and colour. The colouration and markings on the head, thorax and abdomen are described and compared with those of the closely related *Coenagrion puella* (Azure Damselfly) with which it is often confused.

Introduction

Coenagrion pulchellum (Variable Damselfly) is one of seven species of the genus *Coenagrion* that have been recorded in Britain and Ireland. It is listed as 'Near Threatened' in the British Odonata Red List (Daguet *et al*., 2008) and, due to its relative scarcity in Britain, it is of high conservation concern, thus needing to be correctly identified and carefully monitored wherever it occurs. In the Irish Red List it is listed as a species of 'Least Concern', but due to declines in some areas it is regarded as a priority species for monitoring (Nelson *et al*., 2011). Of the extant *Coenagrion* species in Britain and Ireland *C. pulchellum* is the only one currently showing a negative occupancy trend (Taylor *et al*., 2021). It favours high quality habitat, comprising clean standing water and luxuriant aquatic and emergent vegetation. Male and females present different challenges to distinguish individuals from the closely related and more common and widespread *Coenagrion puella* (Azure Damselfly).

Coenagrion pulchellum was originally described and named as *Agrion pulchella* by Vander Linden (1825), though there has been discussion of the exact date and nomenclature used in the original description (Jödicke, 2016). Old specimens in the Grosvenor Museum in Chester are labelled as *Agrion pulchellum* and were given the English name of Beautiful Fay (Gabb, 1988). Lucas (1900) also used *A. pulchellum* but made reference to *Coenagrion pulchellum* as a synonym. The species' specific epithet *pulchellum* derives from the Latin word *pulchellus*,

which means pretty, and has been adopted in the French vernacular name of Pretty Dancer (meslibellules.fr., 2024).

Vernacular names currently in use in the UK, Ireland and the rest of Europe refer to *Coenagrion* species as Eurasian Bluets and the closely related *Enallagma* species as American Bluets (Dijkstra *et al*., 2020) (Table 1).

Table 1. The scientific names of the blue and black damselflies found in Britain. Along with their corresponding British/Irish and European vernacular names.

	Vernacular name	
Scientific name	**British/Irish**	**European**
Coenagrion armatum	Norfolk Damselfly	Dark Bluet
Coenagrion hastulatum	Northern Damselfly	Spearhead Bluet
Coenagrion lunulatum	Irish Damselfly	Crescent Bluet
Coenagrion mercuriale	Southern Damselfly	Mercury Bluet
Coenagrion puella	Azure Damselfly	Azure Bluet
Coenagrion pulchellum	**Variable Damselfly**	**Variable Bluet**
Coenagrion scitulum	Dainty Damselfly	Dainty Bluet
Enallagma cyathigerum	Common Blue Damselfly	Common Bluet

As the vernacular names suggest, the markings and colouration of *C. pulchellum* are highly variable. Being one of several similar blue and black damselflies recorded in Britain and Ireland it can be challenging to distinguish it from the other species. It is most likely to be confused with the more common and widespread *C. puella* and *Enallagma cyathigerum* (Common Blue Damselfly) with both of which it is often syntopic. Due to their similarities, blue and black damselflies have sometimes been referred to as the 'Little Blue Jobs of Odonatology' (LBJ's) and for convenience have been lumped together in transect surveys. Females are more variable than males yet have received less attention in describing the observed colour variants (Cham, 2024). Due to the difficulties in distinguishing some individuals to species level without close examination there is a possibility that *C. pulchellum* may be overlooked in some areas, especially when present at low population density in amongst other more abundant 'blue and black' species.

Current status

Throughout Europe *Coenagrion pulchellum* is not threatened, although some localised declines have been observed (Boudot & Kalkman, 2015). Askew (1988)

drew attention to regional differences in form across Europe, with two forms described in north-west Europe (f. *pulchellum* and f. *interruptum* Charpentier 1840), and another form in the Mediterranean regions (f. *mediterranean* Schmidt 1964). He considered that, although there is considerable variation within individual populations, the value of subdividing it into subspecies is debatable. This is endorsed by Boudot & Kalkman (2015), who also highlight that populations in southern and eastern Europe appear darker than those in central and western Europe, but noted that this does not warrant them being described as a subspecies. They concluded that there are insufficiently well-defined characters or range differences and therefore *C. pulchellum* is currently regarded as monotypic.

Of the seven *Coenagrion* species recorded in Britain and Ireland, *C. puella* is the most widespread and abundant species, yet at some sites where it is sympatric *C. pulchellum* can be more abundant. *Coenagrion armatum* (Norfolk Damselfly) was last recorded in 1957 and is now extinct in the region. *Coenagrion hastulatum* (Northern Damselfly), *C. mercuriale (*Southern Damselfly) and *C. scitulum* (Dainty Damselfly) currently have highly restricted distributions. *Coenagrion scitulum* has recently re-colonised Britain after being last recorded in 1953, when its sites were flooded by seawater. It is currently restricted to a few colonies in Kent yet can be sympatric with *C. pulchellum* at some sites, albeit in differing habitat. *Coenagrion hastulatum* is listed as 'Endangered' in the British Odonata Red List (2008) and is restricted in the UK to the Scottish Highlands. *Coenagrion lunulatum* is restricted to Ireland and has never been recorded in Britain, despite also being present in The Netherlands. *Coenagrion mercuriale* is listed as 'Endangered' in the British Odonata Red List (2008) and is legally protected under the Wildlife and Countryside Act (1981). It is restricted to a small number of areas where it favours shallows runnels and streams with high quality water. Its main strongholds are in the New Forest, Hampshire, and the Preseli mountains, Pembrokeshire. Smaller colonies are found in Devon, Dorset, Anglesey, Gower, Oxfordshire and on the flood plains of the Test and Itchen rivers in Hampshire. It is unlikely to occur at the same habitat as *C. pulchellum.* While being more common than the other *Coenagrion* species, with the exception of *C. puella*, *C. pulchellum* is experiencing a decline in Britain, the underlying reasons for which are poorly understood, and therefore its future trend in Britain is difficult to predict (Taylor *et al*., 2021).

Distribution

Coenagrion pulchellum is widespread across Central Europe and northern parts of Central Asia, yet it is absent from Iberia and parts of Fennoscandia (Boudot & Kalkman, 2015). Sites where it occurs are standing waters and slow

flowing rivers and canals, which are largely unshaded with well-developed bankside and aquatic vegetation. Fox (1991) stated “This species represents a considerable enigma. It is very widespread throughout the Palearctic but is nowhere anything other than local, despite being very abundant at some sites”. It is common and widespread across Ireland where it is more abundant than *Coenagrion puella* (Nelson & Thompson, 2004). In the UK it has a scattered and patchy distribution but can be locally abundant where found. *Coenagrion pulchellum* is regarded as a species prone to site gains and losses over time, with sites becoming unsuitable due to eutrophication, succession, or a lack of management (Taylor *et al*., 2021).

Long standing populations of *C. pulchellum* have been recorded from a number of counties of Britain for many years, yet there have been substantial losses from some of these over the last century (denoted*). Lucas (1900) listed Argyllshire, Yorkshire, Warwickshire*, Cambridgeshire, Norfolk, Essex*, Kent, Sussex, Surrey*, Dorset*, Ulster and Guernsey* as counties where it was recorded and notes that it “does not appear to be as common as generally supposed”. He went on to make specific mention of it as abundant in Cambridgeshire and common in Sussex and Guernsey*. Longfield (1937) stated it was very common at several sites in Yorkshire, Stafford*, Huntingdon, Cambridge, Norfolk, Oxford, Berkshire, Somerset, Hampshire and Surrey*. She also listed counties where it is exceedingly local, restricted to just one site: Cheshire, Nottingham, Lincoln, Warwick*, Devon*, Isle of Wight*, Sussex and Kent. Waring (1996, 1998) raised concern about the loss of sites from a number of vice-counties, over the period since records began. Based on a desktop survey and input from local recorders, he noted all known *C. pulchellum* sites across England, Scotland and Wales between 1991 and 1997 and recorded sites with high abundance and, where it outnumbered *C. puella*. He also noted that it favoured good quality habitat with shelter from trees, and presence of hedges and grasses.

Whilst it was formerly recorded from the Channel Islands and reported as common at Grand Mare on Guernsey (Luff, 1982), records from other sites were found to be in error and later correctly identified as *C. scitulum* (Le Quesne, 1946). The current status of *C. pulchellum* in the Channel Islands is regarded by Parr & Long (2015) as uncertain and probably a former resident.

The current distribution and abundance of *C. pulchellum* in Scotland, Wales and England between 2013-2023, shows a scattered spread with major populations concentrated in widely separated areas (Plate 1). The majority of records for this period, submitted since the last national atlas (Cham *et al*., 2014), include an estimate of abundance (verified by the BDS and downloaded from NBN Atlas accessed 04/08/24), indicating where the major populations occur (Plate 1 A-R). The habitat conditions for these are described by region below. For Ireland and Northern Ireland abundance data was not available.

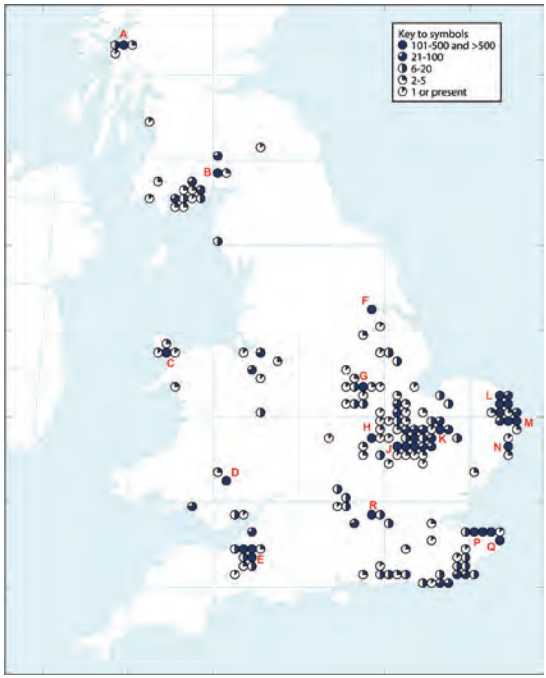

Plate 1. Distribution of *Coenagrion pulchellum* in Great Britain 2013-2023. Key to sites where abundance is recorded as >100 (101-500 and >500 combined):

Scotland

A	NM93	Argyll - Black Lochs near Oban
B	NY08	Dumfries and Galloway - Castle Loch nr Lockerbie

Wales

C	SH47	Anglesey - Cors Ddyga / Malltraeth Marsh, *
D	SO12	Breconshire - Llangorse Lake, Brecon Beacons National Park****

England

E	ST34,43,44	Somerset Levels, including Ham Wall*, Shapwick****, South Drain and Westhay Moor**
F	SE82	Yorkshire - Broomfleet Washlands
G	SK73	Leicestershire - Grantham Canal
H	SP87	Northamptonshire - Wickstead Park
J	TL16,26,36,37,57	Cambridgeshire - Fen Drayton Lakes*, Paxton Pits****Wicken Fen****
K	TL68	Suffolk - Lakenheath Fen*
L	TG30,31,32,41	Norfolk Broads, including Cantley Marshes*, Ludham Marshes**, Strumpshaw Fen*, Sutton Fen*, Upton Fen****
M	TM49,59	Suffolk - Carlton Marshes***, Fritton Decoy
N	TM46	Suffolk - Minsmere*
P	TR06,16,26	North Kent Marshes, including Grove Ferry**, Seasalter**** and Westbere*
Q	TR35	Kent - Sandwich Bay****
R	SU88	Berkshire - Widbrook Common****

* RSPB reserve; **National Nature Reserve; ***Wildlife Trust Reserve; ****other nature reserve

Habitat Requirements

The habitat and micro-habitat conditions favoured by *Coenagrion pulchellum* are not well understood and in many of the areas where it is present it occurs at some sites, often in high abundance, but is absent from other seemingly suitable sites in close proximity. Drake (1987) noted it as widespread across the Somerset and Gwent levels, favouring ditches with botanically rich emergent-dominated sites. Askew (1988) stated that it occurs at sites with a complex of standing water bodies and rich flora. Most of the sites with the largest populations of *C. pulchellum* occur on nature reserves or sites with a high degree of protection and management for wildlife diversity (Plate 1 A-R). Pickess (1995) highlighted that RSPB reserves in Somerset and Cambridgeshire are especially important sites for *C. pulchellum*, where active management benefits the habitat and water quality. It appears that the species is well able to disperse from established sites. Records of individuals submitted on iRecord and confirmed with photographs (iRecord, 2024a), indicate that they are dispersing and being seen in new areas and could potentially colonise suitable sites.

An important yet often overlooked factor in habitat selection is the hinterland and area adjacent to the breeding sites that provide suitably sheltered areas for maturation, feeding and roosting, away from water. During periods of sub-optimal weather or overnight, meadows, grassland and hedgerows sheltered from the wind are favoured areas for roosting.

East Anglia and surrounding counties

The low-lying Fenland of East Anglia and its surroundings represent the largest region with long-established and large populations of C*oenagrion pulchellum*. Lucas (1900) noted it as abundant in Fenland, near Ely and Wicken and Corbet *et al*. (1960) make reference to the species as a “fen dweller” and “may often be swarming in the Fenlands”. The Rivers Great Ouse and Nene flow through The Fens towards The Wash and both have provided a conduit for dispersal into new areas, with sites in these river catchments progressively colonised by *C. pulchellum*. Notable sites with large populations (Plate 1 J, K) include Fen Drayton, Lakenheath, Kings Dyke near Peterborough, Ouse Washes, Paxton Pits, St. Ives gravel pits and Wicken Fen. Most of these sites are protected as nature reserves with a rich assemblage of aquatic plants reflecting the high-quality water conditions.

The history of gravel extraction along the River Great Ouse valley in Cambridgeshire (VC29/31) serves to illustrate the capability of *C. pulchellum* to disperse and colonise new sites, as suitable habitat became available (Milne, 1974). River gravels had been dug in the area on a small, local scale since the

18th and 19th Centuries and was scaled up in the 20th Century. Amongst the River Great Ouse valley, gravel pits, the older flooded workings and mature pits around St. Ives now support important populations of both *C. pulchellum* and *C. puella* (Milne, 1984). At the time of Lucas (1900) these quarries did not exist. Upstream the colonisation of mature gravel pits at Fen Drayton and Little Paxton followed, and also now have strong populations. Similarly in Bedfordshire (VC30), former gravel pits at Felmersham NR and Willington are further upstream and have been colonised more recently with the first records in 2017. In neighbouring Northamptonshire (VC32), sites for *C. pulchellum* within the River Nene catchment were discovered around the same time. Tyrrell (2019) reported its preferred habitat at three sites in Northamptonshire (at Maxey Pits, Weldon Woodland Park and Wickstead Park), where a common factor was the presence of flowering water-lilies *Nymphaea* spp and *Nuphar* spp. At Maxey Pits it was highly localised to just one lake in a complex of fishing lakes. Although no water quality data was included, the accompanying Google Earth satellite image shows the one lake where it was recorded to be different to the others, appearing to have less turbid water. The site at Wickstead Park in Kettering is a fishing lake within a few km of the River Nene and now has a notable population (Plate 1 H). It has also recently been found nearby at other former gravel pits along the Nene (Mark Tyrrell pers.com.).

At the sites with strong populations around Fenstanton and St. Ives in Cambridgeshire the habitat requirements present an enigma (Perrin 2015) – Val Perrin (pers.com.) recalls that in one area of old flooded gravel pits the relative abundance of the three species (*C. pulchellum*, *C. puella* and *E. cyathigerum*) differed markedly, although the habitats themselves appeared superficially very similar.

Norman Moore recorded the Odonata that colonised his medium sized pond (38 x 13 m) at Swavesey, Cambridgeshire, over a period of 17 years (Moore, 2002a, 2002b). Of the 19 species recorded, *C. puella* was abundant in all the years of surveying the pond, yet only single male *C. pulchellum* were recorded in just three of the years. This pond is within 3 km of the large populations at Fen Drayton Lakes and Meadow Lane GP at St. Ives. The relatively small size of the pond was considered to be a limiting factor here, which may provide some insight into its habitat requirements in other areas. This is supported by similar observations at Woodwalton Fen, where in an earlier 27-year study of twenty small ponds, *C. pulchellum* was not recorded at any of them, despite being present in the area (Moore 1991).

In the low-lying land of Lincolnshire (VC53/54), the populations of *C. pulchellum* represent an extension of those in the Cambridgeshire Fenland. Deeping Lakes Nature Reserve, adjacent to the River Welland, which also flows into The

Wash, comprises a number of flooded gravel pits of varying ages and maturity, managed by the Lincolnshire Wildlife Trust, supports a notable population. Others are at Baston Fen and further north at Haxey Grange Fen.

The Norfolk Broads in East Norfolk (VC27) includes wetland sites of international importance, designated under the Ramsar Convention. The area has a diversity of habitats that support a wide range of aquatic plants and rare invertebrates that are dependent on high quality water, including sizable populations of *C. pulchellum*. The mosaic of wetland habitats includes open water, reed fen, carr or wet woodland and grazing marsh with each providing different habitats. The main focus of the Broads Authority's conservation strategy since its creation in 1989 has been on improving water quality. *Coenagrion pulchellum* is abundant in Broadland (Plate 1 L) at How Hill, Ormesby Little Broad, Upton Broad, Ludham, Hickling and Strumpshaw Fen. The Broads mega-population extends into East Suffolk (VC25) at Carlton and Castle Marshes (Plate 1 M) and Minsmere (Plate 1 N). Each of these sites have dykes with good quality water and a rich aquatic flora including *Hydrocharis morsus*-ranae (Frogbit) and *Stratiotes aloides* (Water Soldier) (Mendel, 1992). In Suffolk the distribution is fragmented with large populations in some areas of the county and none in others, despite no obvious differences between the sites (Mason & Parr, 2016). The relatively recently created RSPB reserve at Lakenheath (Plate 1 K) in West Suffolk (VC26) is closer to populations in the Cambridgeshire Fens and has a significant population.

In Hertfordshire (VC20) a single male *C. pulchellum* was recorded on 3 June 2023 at Admiral's Walk Lake, Hoddesdon. There are currently no known populations in the county, and this was only the fourth verified record. This area of the Lea valley, which has many former earth extraction sites, has potentially suitable habitat for further colonisation.

South-west England

The flat low-lying land of the Somerset Levels and Moors (VC5/6) is internationally renowned for its biodiversity that includes botanically rich wetlands and important invertebrate communities. *Coenagrion pulchellum* is abundant in exceptionally high numbers in many of the pools, ditches and rhynes (drainage ditches) (Plate 1 E). The intricate managed landscape has developed over centuries from the drainage and irrigation of the land for agriculture and to manage flood risk. The Levels were formerly exploited for salt and dug for peat and have been transformed into a mosaic of land combining agriculture and extensive wetland nature reserves (including Catcott, Ham Wall, Shapwick and Westhay). Due to its height above sea level, the area is potentially vulnerable to climate change, and ongoing water management is essential to maintain the quality of the water

and range of habitats. At the northern part of the Levels in the Bristol Region (VC6) *C. pulchellum* is more scattered and uncommon, confined to SSSIs and NNRs such as Puxton Moor and at the BDS Hotspot at Steart Marshes. It is restricted to a small number of rhynes with suitable micro-habitat where there are shallowly sloping banks with a gentle 'U' shaped profile (Barnett *et al*., 2013). It occurs in rhynes on both peaty and clay soils but only those that are species-rich with abundant emergent and submerged aquatic plants. In these areas it does not occur in the more eutrophic ditches where algal mats are dominant.

There have been few records of *C. pulchellum* in Dorset (VC9), the last verified one being in 1996 (Brown, 2023), although there was a record of a single male reported on social media in 2024. Records, in 2005 and one from 2016, appear to be errors, highlighting the need for care and correct identification during the verification process. Similarly, a single record of a male in Gloucestershire (VC33/34) also highlights the caution needed before identification can be confirmed (Phillips & Phillips, 1999), especially when some distance from known populations.

South-east and central southern England

In Kent (VC15/16) *C. pulchellum* favours the low-lying marshes and levels in the north-east of the county where there is dense aquatic and marginal vegetation (Brook & Brook, 2009). Sites include the River Stour, East Kent, Sandwich, Stodmarsh, Fordwich, Deal and Westbeare (Plate 1 P, Q). The area around Sandwich is the only location in Britain where it occurs in close proximity to *Coenagrion scitulum*.

In East and West Sussex (VC13/14), the main population is centred on the Pevensey Levels, with other notable sites around Rye Harbour, Pett Level, Amberley Wildbrooks and the Adur Valley, with scattered records elsewhere (Beldon *et al*., 2004, Martin *et al*., 2024). Some of these are managed grazing pastures with associated ditches, where the water level is high and there is a good range of aquatic and marginal plants. A key habitat requirement is considered to be a dense and wide emergent vegetation margin, dominated by Iris and Reedmace (Beldon *et al*., 2004).

In Berkshire (VC22) a sizeable population of *C. pulchellum* is present at Widbrook Common, near Cookham (Plate 1 R), where the White Brook (Widbrook) flows through pastureland that has been grazed by commoners since time immemorial, creating a diverse wetland habitat for a wide diversity of invertebrates. A large complex of wetlands between Burghfield and Reading, comprising the River Kennet, Kennet and Avon canal and mature gravel pits, also supports a smaller population of *C. pulchellum*.

In Oxfordshire (VC23), Brownett (1996) considered *C. pulchellum* to be decidedly local, occurring at low abundance. There have been intermittent records comprising small numbers from Cothill Fen NNR for many years, but it appears to have declined with no records since 2017, despite regular transects by the Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust (BBOWT) (Burch, 2022). Over the years the habitat has changed and appears unsuitable for *C. pulchellum*, with much of the area a shallow calcareous fen that supports *Ceriagrion tenellum* (Small Red Damselfly) and *Orthetrum coerulescens* (Keeled Skimmer). *Coenagrion pulchellum* has been seen emerging at deeper pools, which were more open, at this site in 2002 (pers.obs.). At the adjacent Parsonage Moor and Dry Sandford nature reserves *C. mercuriale* occurs on the small streams and runnels. It remains to be seen if recent management work in 2024, to open up some of the original pools, will attract *C. pulchellum* to recolonise this site. On the boundary of Berkshire and Oxfordshire a small colony is present at pools by the River Thames at Barton Fields, near Abingdon. This colony has been present for a few years in low numbers. It has also been recorded nearby at Radley Lakes and at Iffley Meadows (Burch, 2022).

On the North Hampshire/Surrey border (VC12/17) it was previously recorded along the Basingstoke Canal, with records dating back to the time of Lucas (1900). Longfield (1937) regarded it as very common in Surrey but does not give details of locations. There have been records from the Canal in past times cited as “swarms of damselflies especially Variable and Large Red Damselflies, on the canal near Odiham” (Taverner *et al*., 2004). In 1995 it was still recorded at Ash Embankment on the Canal. In previous times the Canal was botanically rich and regarded to be one of the best sites for aquatic plants in Britain (Byfield, 1990). Since being re-opened to boat traffic the water quality has deteriorated and records of *C. pulchellum* and other notable species of Odonata have diminished. *Coenagrion pulchellum* was previously recorded at Langham’s Pond at Runnymede, Surrey where it was regarded as common by Follett (1996). There have been no recent records for either Surrey or North Hampshire and these former colonies appear to have declined to the point of extinction.

The only known colony of *C. pulchellum* in south Hampshire (VC11) has been at Sowley Pond where it was previously abundant. Sowley Pond is the largest lake in the New Forest and is private with limited access. Very little work on Odonata has been possible, although in 1988 a survey of the Odonata was permitted (Goodyear, 1989; Winsland, 1994). Goodyear recorded it as abundant, mainly on the west and south-west sides with many tandems and ovipositing observed. Whilst the habitat still looks suitable, when viewed from a distance (pers.obs.), access to this private site is difficult and although it may still be present its current status is uncertain.

Northern England and the Midlands

In Leicestershire and Rutland (VC55) *C. pulchellum* is recorded in large numbers on part of the Grantham Canal (Plate 1 G). The canal was closed in 1936 and has gradually been reclaimed by nature over much of its length. Many sections have no visible standing water, but those which remain have clear water and abundant aquatic and emergent vegetation (Merrill, 2022, 2023). *Coenagrion pulchellum* can often be the most abundant species during its peak flight season. Over the last twenty years it has also been discovered at a number of other localities in the north and east of VC 55 (Merrill, 2022, 2023). From 2007 onwards it has been recorded at the complex of lakes in the Wreake Valley where it seems to be thriving. There have also been recent records from other isolated sites in the northeast of VC55, which may relate to wandering individuals rather than established colonies. It remains unclear why it is not present at other apparently suitable sites in the county, although it is acknowledged that it may have been overlooked due to its similarity with other blue and black damselfly species.

In Nottinghamshire (VC56) it has been recorded at the Skylarks Nature Reserve, at Holme Pierrepoint and at Netherfield and Colwick Country Park (Bradbury, 2023). All the mature gravel pits along the River Trent provide potential for further dispersal and colonisation and there are signs that it is expanding out from Nottinghamshire into Derbyshire (VC57), with the first record for that county in 2024 (iRecord, 2024b).

In Shropshire (VC40) there have been intermittent records at a number of the counties' meres with the majority of recent records come from Berrington Pool and Shomere (Shropshire Dragonflies, 2024). These private sites have both adult and exuviae records. Whixall Moss and other parts of Shropshire have had sporadic records between 1932 and 2012, but the majority of these sites are privately owned and difficult to gain access. It is possible that *C. pulchellum* is present in low numbers at other sites across Shropshire but remains undiscovered due to its similarity in appearance to other more abundant blue and black damselflies (Sue Rees-Evans, pers.com.).

In Cheshire (VC58), *C. pulchellum* has been known from its main site at Hatchmere for many years (Cheshire Dragonflies, 2024). This mere is part of the Northwest Midlands Meres and Mosses Ramsar site, a wetland site of international importance. It has also been recorded at several marl pits of man-made origin across the county. Gabb & Kitching (1992) noted that there are other apparently ideal sites in the county where only *C. puella* is recorded. Judd (1986) reported that *C. pulchellum* was historically far more widely distributed in Cheshire and its adjacent counties than it appears to be today.

The damselfly's disappearance from many of these localities was attributed in part, to the combined environmental pressures of urbanisation and agricultural intensification.

Records in Yorkshire date back to the time of Lucas (1900) but currently it appears to be restricted to the area at Broomfleet Washlands (Plate 1 F) and the nearby North Cave Wetlands in East Yorkshire (VC61). Broomfleet Washlands is fenland type habitat with a series of fishing ponds that provides flood relief to the adjacent Market Weighton Canal. These sites support a sizeable population of *C. pulchellum* (Yorkshire Dragonfly Group, 2024).

In Cumbria (VC70) it occurs at only one site, having been lost from several sites pre-1950 (Clarke & Eweda, 2020). A small population is present at Low Church Moss in the west of the county, a tarn with rare neutral fen habitat, where it was the most abundant *Coenagrion* species in June 2023. This site is potentially threatened by development. Natural England have been advised about the site's condition and the species' status and it remains to be seen if it will survive here.

Wales

In North Wales it occurs in large numbers at several sites on Anglesey (VC52). Malltraeth Marsh on the floodplain of the Afon Cefni is a Site of Special Scientific Interest (SSSI), with the northeastern part comprising an RSPB reserve (Plate 1 C). The wetland habitats comprise lakes, and pools with extensive reedbed and system of marshes, which support a diverse flora and rich assemblage of dragonflies and damselflies, including notable populations of *C. pulchellum*. It is also reported to be abundant at Llyn Rhos Ddu near Newborough, Anglesey.

Llangorse Lake, Breconshire (VC42) is the largest natural lake in mid-Wales and a BDS Hotspot (Plate 1 D) where *C. pulchellum* is one of the most abundant species (BDS, 2024; Noble & Mullen, 2024). Noble recalled a huge emergence of damselflies in May 2024 where "Of the uncountable thousands I estimated that 90% were Variable Damselflies" (Noble, 2024). This site is renowned for its rich flora and fauna and high quality water (Natural Resources Wales, 2024).

It is currently only found at a small number of sites on the Gwent Levels in Monmouthshire (VC35), where it is recorded in relatively low numbers among the large populations of *C. puella.* Increased recording activity in 2023 confirmed its continued presence at four sites on the levels (Preddy, 2023).

The disused Tennant Canal in Neath Port Talbot (VC41) supports a rich diversity of aquatic and emergent vegetation and provides connectivity between a number

of notable fen, swamp and marsh habitats in the county (e.g. Crymlyn Bog, Pant y Sais Fen). It is notable for the occurrence of *Dolomedes plantarius* (Fen Raft Spider) at its only site in Wales, along with a population of *C. pulchellum*.

Scotland

Coenagrion pulchellum has a highly localised distribution in Scotland with strongholds in Dumfries and Galloway (VC72-74) (Plate 1 B) and further north around Oban, North Argyll (VC98) (Plate 1 A), where it occurs at mesotrophic lochs. It has been present in the area of the Black Lochs, Argyll dating back to 1845 (Smith & Smith, 1984). Survey work in south-west Scotland has recorded it at a number of new sites across several counties, with important and established populations at Loch Fern, near Dalbeattie, and Castle Loch, Lochmaben (Mearns, 2019). Recent records away from these locations suggest that it may be under-recorded and present in low density in other areas (Pat Batty pers.com.).

Ireland and Northern Ireland

In Ireland *C. pulchellum* is widespread and locally abundant but considered to be declining in some areas (Nelson *et al*., 2011; Thompson & Nelson, 2014). It occurs across much of the lowland areas of central Ireland from the Shannon estuary in the south-west to Lough Neagh in the north-east (Nelson & Thompson, 2014), where it favours lowland cut-over bogs, small lakes, ponds and especially natural fens and unenriched water. Merritt *et al*. (1996) regarded it to be more tolerant of acidic conditions and found on peaty moorland pools. In Northern Ireland it was reported to be the most abundant species favouring cut-over bogs and some lakes in the south of the province (Rippey & Nelson, 1988).

Habitat overview

The observed habitat conditions of *C. pulchellum* across all regions indicate that high water quality that promotes a rich diversity and high abundance of aquatic and emergent plants is a common and important feature of the sites where it occurs. These characteristics are associated with extensive lowland habitats, with surrounding sheltered areas and still waters such as fenland, grazing marshes and old mature gravel pits especially favoured. Such sites are also havens for other rare and notable wildlife biodiversity. Where these lie in river valleys there appears to be the potential for further dispersal. These habitat conditions have also been reported in the Upper Rhine Valley in Germany, where *C. pulchellum* favours older still waters with well-developed aquatic vegetation (Rademacher, 1998). In the Netherlands it favours well-vegetated,

still water habitat, being especially abundant in fenlands, and is reported to decline at sites that become eutrophic (de Groot, 2002).

The question remains as to why it is absent from apparently 'suitable' sites in close proximity to known populations. Further study is needed to answer this and analysis of water quality combined with assessing the abundance and types of aquatic plant species may further contribute to our understanding of its habitat requirements.

Description and Identification

There are few other Zygoptera species in Britain and Ireland that present the same challenges to identify as *Coenagrion pulchellum*. The colour and markings of most *Coenagrion* species are variable with *C. pulchellum* more variable than that of most (Askew, 1988). Attaining correct identification can be problematic due to the wide variation of distinguishing features of both males and females. This can be particularly difficult with some individuals, especially as *Coenagrion puella* also shows some degree of variation of the same features (Parr, 2017). It is possible that *C. pulchellum* may be overlooked in some areas, particularly where there are large populations of *C. puella*. One therefore needs to progress with care when identifying in the field and from photographs where key features are not clearly visible.

The increased interest in Odonata through citizen science and greater recording activity has driven a growing demand for confirmation of identification using photographs, especially those posted on social media. Postings, requesting confirmation of ID, clearly demonstrate that blue and black damselfly species have caused more confusion over identification than most other damselfly genera, with females of *C. pulchellum/C. puella* often featuring (e.g. Aspen, 2022; Curd, 2021; Procter, 2021; Pryke ,2023).

The number of incorrectly identified records submitted with photographs through iRecord, and therefore rejected, suggests that recorders particularly have difficulties identifying females (iRecord, 2024b). Furthermore, a photograph incorrectly identified as *C. pulchellum* is shown on the species section of NBN Atlas (NBN Atlas image gallery, accessed 03/11/24) yet clearly shows a male *C. puella*. This photograph was flagged as being incorrect by an experienced observer, but in a subsequent response it was still incorrectly verified as *C. pulchellum* and remains on the website (NBN Atlas accessed 12/12/24), highlighting the issues relating to identification. Correct identification is possible from good quality photographs taken from the correct angles, but a combination of distinguishing features is often required. Photographs taken

in the field can be magnified in camera or computer and enhanced digitally to enable key diagnostic features to be more clearly visible. Whenever possible it is recommended to take a photograph dorsally and one laterally.

When identifying the adults of *C. pulchellum* and other blue and black damselflies, one needs to consider size, colouration, distinctive body markings and morphology.

Size

The typical dimensions of *Coenagrion pulchellum* are: total length 34-38 mm, abdomen length 23-32mm and hind wing length 16-23mm.

Colouration

Mature males are predominantly a combination of blue and black colouration. The markings on different parts of the body are highly variable (described below). Newly emerged (teneral) males appear pink or grey on the sides of the thorax and develop the blue colouration within a few days.

Colouration of females is more variable than that of males. Females occur in two forms; a variegated form and a dark form, both of which go through age-related transitional colour phases. This results in several mature colour variants of each form (Cham, 2024). The relative percentages of each form and associated variants in a population vary from site to site. For example, in May 2024 the variegated form-blue variant was predominant at Ham Wall on the Somerset Levels, with other variants in lower numbers, whereas, in Cambridgeshire, females of the variegated form-green variant predominated, with other variants in lower numbers (pers. obs.). Nelson & Thompson (2004) noted that the dark form is less numerous in most populations in Ireland.

Female variants exhibiting what has previously been regarded as immature colouration have been observed *in-copula* and ovipositing, indicating that transitional colour phases continue to develop throughout the adult lifetime and are not directly related to maturation (Cham, 2024). It should be noted that guides to identification tend to place more emphasis on mature colouration and give less attention to describing the immature colouration or transitional phases.

Morphology

Each part of the body has markings and structural features that can be used for identification of adults of both sexes, which help to distinguish *C. pulchellum* from *C. puella* (Plate 2). Due to their variable nature, it is recommended that a combination of features is used to confirm identification.

Plate 2. Male and female *Coenagrion pulchellum* showing the key features used for identification: AHS, antehumeral stripes; An, shape of anal appendages of males; IOB, inter-ocular bar; Pr, shape of hind margin of pronotum; S2, black marking on segment 2 of male abdomen; S4 & S5, extent of colour on abdominal segments 4 and 5 of females; S9, shape and extent of black marking on segment 9 of males; S10, shape and width of pale blue marking of males.

Head Two pale postocular spots are present on the dorsal surface of the head of both sexes and of all other *Coenagrion* species. Between the spots is a similarly pale inter-ocular bar which is present in a large proportion of both sexes of *C. pulchellum*. This feature is a strong indicator for this species and helps to initially distinguish most individuals from *C. puella*, in which the bar is usually absent. The bar, however, is highly variable in *C. pulchellum* (Plate 3), especially in males, and may be complete, reduced, broken or absent and needs to be used in combination with other features to ensure correct identification.

Pronotum The pronotum is the prominent plate-like structure that covers the dorsal surface of the prothorax (first segment of the thorax) in damselflies. As a precursor to copulation the male grips the female's pronotum with its anal appendages to form a tandem, which is maintained during the process of copulation. The shape of the hind margin is species-specific and serves to prevent, or at least minimise, inter-specific coupling (see also anal appendages

Plate 3. Head and thorax of male *Coenagrion pulchellum* showing the combination of features and their variation from left to right:
Antehumeral stripes - complete, exclamation mark, broken, partial, almost absent.
Black marking on S2 - bold with stem, bold no stem, bold and thick stem, weak no stem, bold no stem.
Inter-ocular bar - broken, complete, absent, weak, partial.

Plate 4. Shape of the female pronotum in *Coenagrion pulchellum* and *C. puella*: (A) *C. pulchellum* with pale coloured rim; (B) *C. pulchellum* with pale coloured middle lobe; (C) *C. puella* for comparison.

below). The shape of the hind (posterior/distal) margin of the pronotum is one of the definitive features to distinguish both sexes of *C. pulchellum* from *C. puella*, the differences being more pronounced in females.

In *C. pulchellum* the hind margin is indented when viewed from above, giving it a characteristic tri-lobed appearance (Plates 3 & 4a, b). When viewed from the side it appears slightly raised with the middle lobe particularly prominent. The rim of the hind margin is normally black with no pale markings and is less pronounced in males. Females have deeper indentations where the central lobe has a pale rim or occasionally is pale along the length of the margin (Plate 4a,b). In contrast, the hind margin of the pronotum of *C. puella* forms a gentler curve, typically delineated by a pale rim (Plate 4c), although there is some variation in the extent of the pale colour on the rim.

Whilst the shape of the pronotum is a definitive feature it may not show clearly in photographs taken at an angle. It is therefore recommended that every effort is made to take photographs from a dorsal viewpoint.

Thorax The markings on the thorax are useful features for the identification of species of Zygoptera and to distinguish *Coenagrion* species from other similar genera. The two short black lines on either side of the thorax (interpleural and metapleural stripes, often referred to as '*Coenagrion* spurs'), distinguish *Coenagrion* species from *E. cyathigerum*, which has one very short stripe.

On either side, on the latero-dorsal surface of the thorax, are the pale antehumeral stripes. These stripes are prominent features, the colouration and extent of which influence the overall appearance ('jizz') of an individual and are useful indicators for identification to species level. Antehumeral stripes in *C. pulchellum* males are highly variable and can be complete, broken, much reduced or almost absent (Plate 3). The broken antehumeral stripes of males often comprise a short line separated from a dot to form a ! (exclamation) mark. This is a strong identification feature, especially in males. In the majority of females, the antehumeral stripes are mainly complete with a small number of individuals showing a broken stripe. Reduced or absent stripes accentuate the black background colouration of the top of the thorax, making individuals appear darker than *C. puella*. The darker 'jizz' of *C. pulchellum* is sometimes the first indication of this species' presence when at low density in amongst large populations of *C. puella*. Rarely, *C. puella* males and females also have broken antehumeral stripes (e.g. Parr, 2017) so care needs to be taken, or a combination of features may be needed for identification.

As described above, the background colour of the sides of the thorax of *C. pulchellum* exhibits age-related variation. In newly emerged and immature

individuals it ranges from orangey-pink to pale grey and then goes through further colour transition during maturation. In mature males the sides of the thorax and the antehumeral stripes are typically blue. Mature females vary, with yellowy-green, green, orangey-brown or blue on the sides of the thorax (Cham, 2024).

Abdomen The abdomen of damselflies comprises 10 segments (S1-S10) of varying lengths. The fine black markings present on the sides of the abdomen distinguish *C. pulchellum* and *C. puella* from other *Coenagrion* species, which lack these markings. These markings appear as thin lines that are drawn out into long spikes, running forwards from the posterior black markings on S3-6 (Plate 5).

The extent of the black markings on the dorsal surface of the abdomen are very useful features to distinguish the males of *Coenagrion* species, although unhelpful for distinguishing females. In males, the black marking on the dorsal surface of S2 and the extent of black on the dorsal surface of S9 are especially useful to aid identification and distinguish between *C. puella* and *C. pulchellum*. When viewed from above, the black marking on S2 of male *C. pulchellum* typically forms a thick wine goblet shape, the U part with a stem linking it to the black inter-segmental ring between S2 and S3. This marking varies considerably in its thickness and can either lack the stem or be particularly overthickened (Plate 3). Male *C. puella* typically have a thinner U marking with no stem. In most populations this feature can distinguish the two species although in a small number of *C. puella* males the U mark is stronger and sometimes has a stem present.

The extent of black on S9 of males is a useful feature yet is highly variable and there is a degree of overlap between *C.pulchellum* and *C. puella*. In *C. pulchellum* the black extends forwards from the inter-segmental ring between segments S9 and S10, often taking up more than 50% of the segment in a large proportion of individuals. The shape of the black marking has been described as being ‘bat-like’ or like a ‘batman cape’ yet this analogy can be misleading due to its high variability in both species (Plate 6). In *C. puella* males the extent of black is much reduced, typically taking up less than 50% of the segment, although in some individuals the extent of black is greater (Plate 6 lower row). A small proportion of *C. pulchellum* males can also show a much reduced amount of black (Plate 6 upper row), so this needs to be used in combination with other features.

A small, pale blue marking is present in the centre of the distal margin of S10 of males, close to the anal appendages, which is often overlooked for identification purposes. This feature is rarely if ever mentioned in recent guides yet was

Plate 5. Male and female *Coenagrion pulchellum* in tandem (side view), showing the lateral thin black lines on S4-6 that distinguish *C. pulchellum* and *C. puella* from other *Coenagrion* spp.

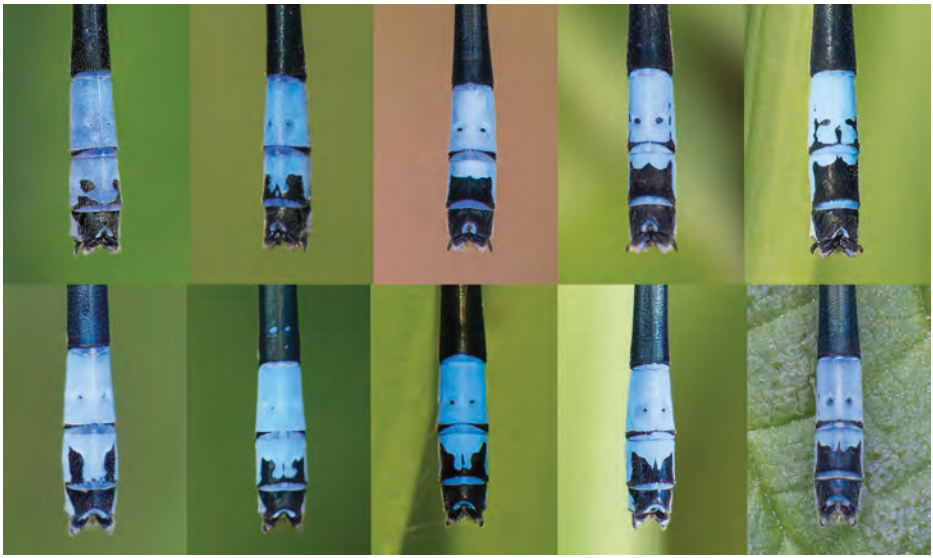

Plate 6. Variation of the black marking on S9 of male *Coenagrion pulchellum* (upper row) and *C. puella* (lower row). Note the shape and width of the blue marking on S10 which is characteristic and consistent for each species.

reasonably accurately depicted by Lucas (1900) and can be diagnostic in distinguishing males of *C. pulchellum* and *C. puella* when visible in dorsal view (Plate 6). This feature appears to be consistent in males of the two species:

- semi-circular and wide in *C. puella* males, with a span of >50% of the width of S10.
- narrower and more angular (~90°) in *C. pulchellum* with a span of 32-39% of the width of S10.

In a small number of *C. pulchellum* males the marking is reduced to two small pale specks on either side of the centre, but still recognisable as being narrow and angular. No variation has been observed in *C. puella* males. It can therefore be useful in distinguishing the males of the two species at times when other features are not clearly visible in photographs or when unusual aberrations are encountered. An aberrant male *Coenagrion puella* resembling *C. pulchellum* and exhibiting a confusing mix of the characteristics, is shown and discussed by Parr (2017). Although the marking on S10 is not mentioned in the text the photograph of this individual clearly shows the semi-circular and wider marking that is typical of *C. puella*, which would have assisted in making an identification in this case.

Females occur in two forms, each with various colour variants, distinguished

by the extent of black on the dorsum of the abdominal segments and overall colouration (Cham, 2024). In the dark form-colour variants the segments are all black with a coloured ring at the inter-segmental joints, which is either blue or green. In females of the variegated form-colour variants the abdominal segments have a coloured portion that varies in colour and its coverage. Previously, this form has misleadingly been referred to as the 'blue form'. The extent of colour relative to the amount of black on S4 and S5 has been suggested as a means to distinguish *C. pulchellum* from *C. puella,* where it takes up more than a third in *C. pulchellum,* compared to less than a third in the latter (Smallshire & Swash, 2018). The coloured portion on S4 and S5 is, however, variable in both species and ranges from 21-56% of the segment length in *C. pulchellum* (Plate 7) and 11-40% in *C. puella* and therefore due to the overlap cannot reliably be used to separate all females of the two species.

Plate 7. Variation and extent of the coloured portion of abdominal segments S4 and S5 of female *Coenagrion pulchellum*; (left to right) range of 21-56% of segment length.

Anal appendages The anal appendages of male Zygoptera serve to form a tandem with conspecific females and prevent, or lessen, the possibility of inter-species couplings. All *Coenagrion* species have distinctive shapes and sizes of these appendages, which comprise a pair of superior or upper appendages (cerci) and a pair of inferior or lower appendages (paraprocts). In *C. pulchellum* the male's superior anal appendages engage with the deeply indented (tri-lobed) posterior margin of the female's pronotum during tandem formation (Plate 8). The inferior appendages complete the gripping mechanism. In addition, just above each inferior appendage there is a black lateral projection pointing outwards. These projections, which are placed on the sides of the females pronotum during tandem, are covered in hairs, that may fulfil a sensory function during copulation (Plate 8). The process of tandem formation is difficult to observe or study in detail and any attempt to control a mating pair for closer viewing usually results in them separating.

Close examination of the blue marking on S10 and the geometry of the appendages can be used to distinguish *C. pulchellum* males from *C. puella*. In *C. pulchellum* the superior appendages typically meet in the centre (Plates 6 upper row & Plate 8) when viewed from above, whereas in *C. puella* there is a clear gap between them. The black lateral projection splays outwards in *C. pulchellum*, whereas they are more incurved in *C. puella* (Plate 6 lower row). In the field these can prove difficult to see; good quality photographs taken from above and magnified in camera or on a computer screen can show the

Plate 8. Anal appendages of male *Coenagrion pulchellum*. (A) anal appendages in dorsal view. Note the superior appendages touch in the centre; (B) anal appendages connected with the female pronotum while in tandem. INF, Inferior (lower) appendages; PRO, lateral projection; SUP, superior (upper) appendages.

detail needed for identification. Some field guides show line drawings of anal appendages in lateral view to distinguish species. These are less useful and, judging from high magnification photographs of live specimens in the field, the dimensions and orientation of the appendages can differ from those shown in drawings (pers.obs.).

Life Cycle

Egg and larval stages

Studies in captivity have shown the duration of the egg stage in *C. pulchellum* to be around 28 days, with subsequent larval development of one year (Gardner, 1954). In France, hatching of the eggs is reported to occur two to six weeks after laying and the larval phase lasts one year, or two if conditions are unfavourable. *Coenagrion pulchellum* is thought to have 10 to 13 instars/ stadia (meslibellules.fr, 2024).

Larval development is typically one year in southern regions of Britain, although at higher latitudes in Scottish populations and possibly in Ireland it may take two years (Nelson & Thompson, 2014). At the only site in Cumbria, larvae found late in the season were quite large, with small wing buds, suggesting a two-year cycle (Clarke, 2017). In comparison, *C. puella* usually has a one-year life cycle. However, at the northern edge of its range, or when food is scarce or its density is very high, a proportion of the population has a two-year life cycle (Thompson in Brooks & Cham, 2014).

Larvae of *C. pulchellum* can be found in expanses of lush aquatic and emergent plants in areas where females have been observed ovipositing in the previous year. They are often brown and darker compared to *C. puella* (Cham, 2012; Nelson & Thompson, 2014) (Plate 9). This varies depending on the habitat conditions and both species can have brown or green larvae. In most populations there is insufficient distinction for identification to species based on larval colouration. At Paxton Pits, final stadia larvae have been observed moving amongst the underwater leaf rosettes of Water Soldier, which are subsequently utilised for emergence (pers.obs.).

Like the adults, larvae also exhibit high levels of variation and therefore present a challenge to identify, especially where they are syntopic with *C. puella*. Various characteristic features have been examined in an attempt to distinguish *C. pulchellum* from *C. puella* larvae leading Norling & Sahlen (1997) to conclude that “these two species cannot be reliably separated” and Askew (1988) found that the separation seems to be unreliable. Seidenbusch (1996) examined

Plate 9. Female final stadia of *Coenagrion pulchellum* larva showing dark brown colouration. Note the rounded caudal lamellae with dark nodal band. Spots can be seen on the hind margin of the head.

microscopic features to separate *C. pulchellum* exuviae from those of *C. puella* from sites in Bavaria but indicated that more material from other populations would need to be examined before they could be reliably used. Cham (2010) proposed a matrix, based on a combination of features, which increased the success rate of identifying a proportion of larvae and exuviae. The degree of variation results in some individuals overlapping with *C. puella*, so some larvae or exuviae could not be identified with confidence. In some studies of larval abundance, the larvae of *C. pulchellum* and *C. puella* have been treated as one taxon (*Coenagrion puella*/*pulchellum*) due to these difficulties (e.g. Granath *et al*., 2024).

The caudal lamellae of larvae and exuviae of *C. pulchellum* can be distinctive, having an oblique and often dark nodal line and broad rounded tips which helps to distinguish the more obvious ones from the pointed tips of *C. puella*. However, there are individuals of both species that have caudal lamellae that fall in a 'mid' area where they cannot clearly be described as rounded or pointed (Cham, 2012). Larvae of *C. pulchellum* have distinctive dark spotting on the upper hind margins of the head which persists through to the exuviae. This again is very similar to the spotting on the head of *C. puella* and will not distinguish the two species. It does, however, separate *Coenagrion* species and suspected *C. pulchellum* from those of *Enallagma. cyathigerum* and *Ischnura elegans* (Blue-tailed Damselfly) larvae which lack these spots and often occur in the same habitat.

Plate 10. Prementum removed from an exuvia of *Coenagrion pulchellum* to show the angle (>90°) between the two rows of premental setae.

The prementum, which forms part of the labial mask is useful for identifying exuviae. The prementum can be removed from an exuvia so that the two rows of premental setae, which are at an angle to each other, are visible on the underside (Cham, 2012). The included angle between the two rows of setae is greater in *C. pulchellum* than it is in *C. puella*, being >90° in *C. pulchellum* (Plate 10) and <90° in *C. puella*. In a small percentage of individuals, the angle is close to 90° making it difficult to identify to species with confidence. If this feature is used in combination with the shape of the caudal lamellae one can be more confident in the identification (Cham, 2010).

Emergence and flight period

Emergence takes place during daylight hours on emergent plants, either over water (including the upturned leaves of *Nymphaea* and *Nuphar* water-lilies and the leaf rosettes of *Stratiotes aloides*) or within 1.5m of the water's edge (including on *Iris pseudacorus* (Yellow Flag Iris), *Typha* spp (Reedmace) and *Juncus* spp).

Emergence commences from mid-April and large numbers can build up to a

peak over a period of a few weeks. The early emergence of *C. pulchellum* at some sites means that for a period of up to two weeks it can be the only blue and black damselfly on the wing, before the first *C. puella* and *E. cyathigerum* start to appear (pers.obs.). Following the initial peak, emergence then continues for several months in lower numbers. Emergence is also a time when they are prone to predation, especially in high density populations (see below).

The flight period of *C. pulchellum* has changed in recent decades with it now emerging nearly one month earlier than it did prior to 1996, likely in response to ongoing climate warming (Cham *et al.*, 2014). Merritt *et al.* (1996) cited that adults are on the wing from mid-May to the beginning of August. In Ireland the absolute flight period is reported to be from 2 May through to 27 September with a peak in June and early July (Nelson and Thompson 2014).

British Odonata have been classified into spring and summer species depending on whether or not they have a synchronised emergence when the bulk of the population emerges early in the year (i.e. a 'spring species'). *Coenagrion pulchellum* is regarded as a summer species (Corbet, 1999; Corbet *et al*., 1960), in which there is an extended emergence period throughout most of the warm season. However, *C. pulchellum* appears to be increasingly showing signs of a more concentrated emergence through April and May at many sites across England, with adult numbers declining during late June and being absent by mid-July (pers.obs.). In some areas a small number of late individuals can still be on the wing in August (iRecord 2024).

Maturation

The maiden flight of most Odonata is directed away from water to avoid aggression from mature males already at the breeding site. Teneral adults of *C. pulchellum* move away from the breeding site to spend time in the surrounding hinterland. It is during this time that they require a plentiful supply of insect prey as they mature. Adjacent meadows and hedgerows are favoured places, and large numbers can be seen in these areas. Areas sheltered from wind are often reported to be favoured. During inclement weather *C. pulchellum* and *C. puella* are often concentrated in sheltered areas of meadows and along hedgerows, whereas *E. cyathigerum* and *I. elegans* appear to be tolerant of more open and exposed areas (pers. obs.).

During maturation, *C. pulchellum* goes through transitional colour changes, resulting in a number of colour variants, especially in females. The exact timing of maturity is difficult to determine, as transitional colour changes continue throughout the lifetime of individuals and after they have become sexually active (Cham, 2024).

Feeding

Small invertebrates make up the main food items of adult *C. pulchellum*. The prey will be determined by the local conditions and availability. Adults have been observed catching prey in flight as well as gleaning from leaf surfaces. These include non-biting midges (Chironomidae), small Crane Flies (Tipuloidea), micro-lepidoptera, Leaf Hoppers (Cicadellidae) and small Spiders (arachnids) (Plate 11).

Roosting behaviour

The sheltered areas in the immediate hinterland to the breeding site are important for roosting overnight. When temperatures are too cool for activity, damselflies need to minimise the risk of predation by selecting suitable resting/roosting sites. Rough grassland appears to be attractive to *C. pulchellum* with individuals selecting, where possible, grass, rush or reed stems with a particular thickness, so that their interocular distance enables them to have all around vision (Askew, 1982) (Plate 12). They typically roost low down in clumps of grass and *Juncus* spp and, in early morning, have been observed climbing up the stems to gain warmth from the early morning sun (pers.obs.). If disturbed while roosting and during periods of inclement weather they will drop into the vegetation and remain still until the danger passes (Nelson & Thompson, 2014; pers.obs.).

Males and females roost individually, but when tandem pairs have formed during the previous evening they will sometimes stay in tandem overnight. Rarely reported, these tandem pairs cool down and get covered with droplets of dew overnight (Plate 13) and, by the following morning, they need to warm up before they can recommence copulation. Jaeckel *et al.* (2014) reported finding *C. pulchellum* roosting in male biased clusters, with males representing approximately 75% of individuals, at two sites in Germany, which reflected the sex ratio they had observed during the day.

In the early morning, large numbers of individual and tandem pairs of *C. pulchellum* can be observed in sheltered areas sunning on large leaves, such as *Alisma plantago-aquatica* (Water Plantain) and *Rumex hydrolapathum* (Great Water Dock) as well as other surfaces, to warm up in direct sun (Plate 14). This represents a good time of day for monitoring the species composition of various populations before they become too active.

Plate 11. *Coenagrion pulchellum* catching prey. (A) Female feeding on a non-biting midge caught in flight; (B) Male feeding on a leafhopper caught by gleaning off a leaf.

Plate 12. Male *Coenagrion pulchellum* roosting on a grass stem where the inter-ocular distance provides all around vision.

Plate 13. Tandem pairs of C*oenagrion pulchellum* occasionally remain together overnight and become covered in dew.

Plate 14. Tandem pairs of *Coenagrion pulchellum* warming up on nettle leaves in the early morning sun.

Copulation

Tandem formation and copulation are initiated in sheltered areas adjacent to the breeding site. Observations at various sites, including the large populations at Paxton Pits NR and Ham Wall NR indicate a sequence of mating behaviour (pers. obs.). On days with favourable weather conditions, tandems are formed from around 06.30 BST onwards in areas that are in sunlight and sheltered from the wind. After tandem formation the males seem reluctant to progress with copulation and pairs remain in tandem for some time before copulation is initiated. A timed observation typifies the sequence.

Early morning observations of *Coenagrion pulchellum* at Paxton Pits NR, meadow adjacent to Rudd Lake. 20 June 2024.

05.30 Start of observations at meadow and search for roosting damselflies. Cool morning with slight dew.
05.55 Individuals found roosting in long grass. No pairings yet.
06.15 Some individuals active and flying to, and resting on, objects now in full sun.
06.30 Males flying and encountering females and forming tandems.
07.05 Tandems flying and landing on grass stems. Single males flying in search of females.
07.29 Tandem pair singled out after landing on grass stem and observation started.
07.31 Tandem female freely hanging from male.
07.47 Tandem female grasps grass stem but no attempt by male to initiate copulation.
07.51 Tandem disturbed by rival conspecific male but pair remains perched.
08.27 Male transfers sperm to secondary genitalia while in tandem.
08.29 Copulation starts – arching movements of bodies indicates sperm removal and transfer by male.
08.47 Copulation ends and pair remain in tandem.
08.59 Pair fly off in tandem and observation ended.

Early morning tandem formation followed by a delay before commencing copulation, as well as some pairs remaining in tandem overnight, serves as a guarding function to acquire and hold on to a female before the pair are sufficiently warmed up to start mating. This precopulatory tandem guarding behaviour prevents rival males acquiring females and has also been observed in other species (Corbet, 1999). During this time, and while in tandem, males have been observed transferring sperm from their primary genitalia to the secondary genitalia, under abdominal segment S2 (Plate 15) which then subsequently initiates copulation. The female is encouraged by the male to arch her abdomen forward so that her genitalia make contact with the males'

Plate 15. Male and female *Coenagrion pulchellum* in tandem while the male transfers sperm to the secondary genitalia under S2.

secondary genitalia. Copulation then goes through a series of phases as the male removes sperm from previous matings before transferring his own. Copulation takes approximately 15-20 minutes before the pair fly off in tandem. Tandem pairs arrive at water to start oviposition with a peak of activity in the early afternoon. Further copulation has also been observed to continue at the breeding site.

In the surrounding areas, where tandem and copulating pairs have been observed in the morning, there appear to be predominantly single males later in the morning and into the afternoon. Successful males, which have formed tandem pairs in the morning, have moved on to the breeding site with a female to oviposit. In the absence of females, the remaining single males will engage with any damselfly moving in the area. They appear increasingly eager to mate, resulting in heterospecific tandems. Single *C. pulchellum* males have been observed on a number of occasions attempting to form tandem with the larger females of *Erythromma najas* (Plate 16) and with both males and females of *I. elegans* (pers. obs.). Martens (1989) also observed unmated male *C. pulchellum* repeatedly attacking the male in conspecific tandems as well as the males of other Zygoptera.

Plate 16. Unpaired males of *Coenagrion pulchellum* attempt to form a tandem with females of other species such as this *Erythromma najas* (Red-eyed Damselfly).

With the wide range of variable characters of *C. pulchellum*, and the somewhat lesser variability of *C. puella*, researchers have investigated the possibility of hybridisation between the two species. One instance of a possible cross between *C. puella* and *C. pulchellum* has been reported (Miller & Fincke, 2004). Freeland & Conrad (2002) explored the hypothesis that the decline in *C. pulchellum* may be a result of hybridisation with *C. puella*, especially with the considerable overlap of their respective distributions. They regarded the potential implications to be important in future conservation management strategies for the species. Lowe *et al.* (2008) investigated the genetic relationships among populations of *C. puella* and *C. pulchellum* using mitochondrial sequence data collected from five different sites across central England. These revealed three haplotypes with high overall similarity and they found that *C. puella* and *C. pulchellum* were highly genetically divergent, and that there was no evidence of hybridisation between any of the populations examined, even where *C. puella* and *C. pulchellum* were syntopic. These studies concluded that there is no evidence that hybridisation between *C. puella* and *C. pulchellum* could be responsible for the on-going demographic decline in *C. pulchellum*. Although hybridisation between *C. puella* and *C. pulchellum* remains a possibility (Parr, 2017), further research is required before it can be determined. More genetic studies will be needed to provide estimates of diversity, population structure and dispersal capacity that might prove invaluable in future conservation management strategies for these damselflies.

Male *C. pulchellum* occasionally form tandem with *C. puella* females, (noted where the female has subsequently been positively identified), yet have separated after failed attempts at copulation and a short period of inactivity (pers.obs.).

In contrast to possible hybridisation, Van Noordwijk (1978) investigated the possibility for competitive exclusion of *C. pulchellum* or *C. puella* by the other species at a study site in Belgium. There was some indication that *C. puella* moved away to small ponds in the presence of *C. pulchellum* as these smaller ponds were not populated by the latter. These observations fit with those of Moore (1991) at Woodwalton Fen where both *C. puella* and *C. pulchellum* are present in the area. *C. pulchellum* was not observed at small ponds over a study period of 27 years.

Oviposition

Oviposition takes place in tandem over water. The pair arrive at the breeding site where they initially settle on aquatic plants at the water's surface or on those with floating leaves before commencing oviposition.

The oviposition of *Coenagrion pulchellum* was first described by Wesenberg-Lund (1913) and Robert (1958) who noted that the undersides or submerged parts of floating leaves of aquatic plants needed to be within reach of the female's abdomen and ovipositor. They observed that the tandems settled at the edge of the big floating leaves of *Nymphaea* and *Nuphar* water-Lilies to gain access to the underside. On leaves that were infested by *Donacia crassipes* (Water-Lily Reed Beetle), the pairs would prefer to land at the holes in the leaf created by the beetle. In an experimental setup, the holes on intact, fresh leaves were imitated and this induced landing and testing by tandems of *C. pulchellum* (Martens, 1989) and it was suggested that eggs are probably not deposited, because the underside of the leaf was still too hard and smooth and concluded that females never try to oviposit if the ovipositor cannot reach the underside of the leaf. Matushkina & Gorb (2007) demonstrated that the stiffness of the ovipositor of Zygoptera species correlates with the hardness of preferred plant substrates, with *C. pulchellum* suited to oviposit in a range of plants in the mid-range of hardness of those measured.

Oviposition has been cited to be into the undersurfaces of floating leaves with the eggs being arranged in a spiral formation (Askew, 1988). Corbet (1962) mentioned that the spacing of eggs is created by being laid in a circular fashion under the leaves of *Nymphaea,* and the regular pattern of incisions, as observed by Wesenberg-Lund (1913), was measured by the styli. Tyrrell (2019) observed that water-lily species were a common factor at breeding sites in Northamptonshire and tandem pairs exclusively used the underside of lily pads for oviposition. Other abundant submerged aquatic plants such as *Elodea canadensis* (Canadian Pondweed) and *Ceratophyllum demersum* (Rigid Hornwort) were seemingly ignored.

At Ham Wall RSPB reserve on the Somerset levels many tandem pairs oviposit, often in groups, into *Ceratophyllum demersum*, which is abundant in many of the pools and ditches (pers.obs.). *Hydrocharis morsus-ranae* (Frogbit), which is an indicator species for good quality water, is also utilised. This is a favoured plant for oviposition in the ditch systems at Woodwalton Fen in Cambridgeshire and is also used at Wickstead Park in Northamptonshire, where eggs are laid on the underside of the floating leaves (pers.obs.). At Rudd Lake at Paxton Pits NR, an area of water lily is utilised for ovipositing and expanses of *Ceratophyllum demersum* in an adjacent part of the same lake are also used (pers.obs.) (Plate 17). On the nearby Hayling Lake, many tandem pairs can be observed ovipositing into the upper surfaces of *S. aloides*. The underside of water-lilies is also used at this site with the tandem pair typically landing on the edge of the pads so the female can bend her abdomen underneath. Females in-tandem appear to favour the softer, brown leaves of the Stratiotes aloides rosettes for oviposition rather than the new fresh green growth (pers. obs.),

Plate 17. Group oviposition by three tandem pairs of *Coenagrion pulchellum* (left to right 2,5,6) alongside three pairs of *C. puella* (left to right 1,3,4).

which may be too hard for the ovipositor to penetrate, as suggested by Martens (1989). At Felmersham NR most ovipositing is in the areas of *Stratiotes aloides* whereas, at Willington gravel pits, tandem pairs have been observed ovipositing into *Crassula helmsii* (New Zealand Pigmyweed) (pers.obs.).

Tandem pairs settle at the oviposition site with the male contact guarding in an upright position. The male will sometimes lean forward to rest on the substrate. Females occasionally fully submerge to continue ovipositing underwater, with the attending male moving down until just its head and the top of its thorax are above water. During underwater oviposition, females have been observed progressively moving down a submerged leaf rosette of *Stratiotes aloides* laying eggs into the upper surface of the leaves (pers.obs.) (Plate 18). These tandem pairs were not under any aggression from rival males that might force the need to oviposit underwater. This behaviour suggests that access to the underside of plants (referred to above) may only be required at sites with the large floating leaves of water-lilies. Underwater oviposition occurs in a number of Zygoptera species (Corbet *et al*., 1960) and whilst known to also occur in *C. mercuriale*, it has not been reported for *C. puella*.

In summary, *Coenagrion pulchellum* utilises a range of aquatic plants for oviposition, ranging from water-lilies with large floating leaves through to submerged plants such as *Ceratophyllum* with much finer stem and leaf structure. In each case it appears to be attracted to areas with extensive areas of aquatic plant growth at the water's surface. Tandem pairs of *C. pulchellum* are frequently observed ovipositing in groups, including in close association with tandem pairs and groups of *C. puella* (Plate 17). Large expanses of aquatic

Plate 18. The female of a tandem pair of *Coenagrion pulchellum* will occasionally fully submerge to oviposit while the male stays contact-guarding.

plants are more likely to be attractive for group oviposition, where one tandem pair attracts more pairs to oviposit in areas which they regard as 'safe' from potential predators. Group oviposition has long been known to be a characteristic of *C. pulchellum* (Martens, 1989) and is regarded to serve as an anti-predation function, where the males can detect potential threats and assist the females' escape (Corbet, 1999). This may be a key requirement for site selection for the species and partly explain why large populations of *C. pulchellum* favour larger scale, botanically rich sites. Further study is needed to establish the factors attracting the species to oviposit and why they are absent from other sites in close proximity.

Predators and parasites

Damselflies, including *Coenagrion pulchellum,* face many predators during each stage of their life cycle. Predators and parasites of the adult stage have been better studied than the underwater egg and larval stages.

Larvae are predated by fish and a range of carnivorous invertebrates. *Ranatra linearis* (Water Stick Insect) and *Dytiscus marginalis* (Great Diving Beetle have been observed catching unidentified zygopteran larvae in areas where *C. pulchellum* larvae are abundant (pers.obs.). Diving birds are also likely to take them.

The predators of adults include:

Anisoptera (Dragonflies) – *Anax imperator* (Emperor Dragonfly), B*rachytron pratense* (Hairy Dragonfly), *Libellula quadrimaculata* (Four-spotted Chaser) and *Orthetrum cancellatum* (Black-tailed Skimmer) have all been observed catching and consuming both males and females of *C. pulchellum*. Tandem pairs are preyed upon, sometimes leaving one of the sexes with part of the other still attached (Plate 19).

Robberflies (Asilidae) – These are known to catch damselflies and Clements (1999) referred to a report in Sweden of *Neoitamus cyanurus* (Common Awl Robberfly), a species also recorded in Britain, taking *C. pulchellum*.

Birds – Zygoptera are especially vulnerable to predation during emergence. *Coenagrion pulchellum* often emerges in large numbers, presenting a significant food resource for birds feeding their young. *Gallinula chloropus* (Moorhen) and *Fulica atra* (Coot) have been regularly observed picking damselflies from emergent vegetation in prime areas where *C. pulchellum* was emerging e.g. at Paxton Pits NR (pers.obs.). At the same site *Passer domesticus* (House Sparrow) form small colonies in bushes close to water where damselflies are emerging. Here they are regularly observed flying over water to take newly emerged *C. pulchellum* and *E. najas* from the upright rosettes of *Stratiotes aloides*, returning with beaks full of damselflies (pers.obs. - identifiable from photographs).

Spiders (Arachnida) – a range of species have been observed building webs close to areas where damselflies emerge, rest and roost. Adult *C. pulchellum* have been frequently recorded in spiders' webs (pers.obs.).

Fish - Species that oviposit underwater are more susceptible to predation by fish, which have been observed preying on females of Zygoptera. Tandem

Plate 19. Female *Coenagrion pulchellum* with the remnants of a male abdomen still attached following its predation by *Libellula quadrimaculata.*

pairs of *C. pulchellum* have been observed flying up from the water surface when *Scardinius erythrophthalmus* (Rudd) were detected (pers. obs.) but no specific predation has been proven. Group oviposition by *C. pulchellum* in dense expanses of aquatic plants such as *Stratiotes aloides* and *Ceratophyllum demersum* may offer some degree of protection from predatory fish. Mühlenhaupt *et al.* (2022) cited that the caudal lamellae of *C. pulchellum* larvae are larger than in other *Coenagrion* species, which makes them more suited to relatively fish free habitat.

Mites - Individuals of *C. pulchellum* can carry a heavy burden of mites of two (possibly three) species of the genus Arrenurus: *A. tricuspidator* (*A. cuspidifer*) and *A. maculator* (Baker *et al.,* 2007; Stolbov *et al.*, 2020). High density populations of *C. pulchellum* are particularly prone to mite burdens (pers.obs.) where mites (unidentified) have been observed on the underside of S6, 7, 8 and 9 and on the dorsal inter-segmental joint of S7-8 of males (Plate 20). On females, mites concentrate on the underside of the thorax at the leg attachment points and at the junctions of S1/S2 and S4/S5 (pers.obs.) (Plate 21). A full review of the affects of mite loads and site selection on Zygoptera species was carried out by Baker (2011). Hughes *et al.* (2016) found that water mite prevalence and abundance were higher on females compared to males of *C. pulchellum* and

Plate 20. Male *Coenagrion pulchellum* with a mite burden concentrated under the distal part of the abdomen. One mite is also visible under the thorax.

Plate 21. Female *Coenagrion pulchellum* with a heavy mite burden concentrated under the thorax.

proposed that this was due to different behaviour and life-history strategies. They also found that the prevalence and abundance of water mites was lower on the larger males of *C.pulchellum* than on smaller ones, suggesting that male body size is a sign of good condition, with sufficient resources available for strengthening their immune systems.

Conservation

The greatest threat to *Coenagrion pulchellum* is a decline in water quality due to enrichment, pollution and turbidity that reduces the lush growth of aquatic plants. The effects of eutrophication caused by farming activities and wastewater are recognised as a major threat to the Somerset Levels, where very large populations of *C. pulchellum* occur (Natural England, 2021). On the North Somerset Levels a buffer zone designed to reduce run-off of fertilisers and chemicals from adjacent agriculture on each side of ditches has been implemented in an attempt to maintain the good water quality important for a range of scarce plants and invertebrates that includes *C. pulchellum* (Barnett *et al.* 2013). Here the species does not occur on the heavily managed ditches and rhynes. Lowering of the water table and drying out of the ditches can also have a negative effect. Excessive clearance of dykes and ditches will reduce populations and lead to their loss. On low-lying grazing marshes in Sussex, and similarly on RSPB reserves, the key conservation measure that benefits Odonata, including *C. pulchellum*, is sympathetic rotational ditch management (Pickess, 1995; Beldon *et al.* 2004).

Many of the areas with strong populations of *C. pulchellum* are low-lying grazing marshes and the Broads of Norfolk and Suffolk are at particular risk from rising sea levels (Barkham, 2024). The Gwent Levels in South Wales is low-lying land rich in wildlife, including *C. pulchellum*, and was formerly reclaimed from the sea. Despite being protected in law the Gwent Levels and its surroundings are also under pressure from developers. Multiple planning applications to develop this important area have been made in recent years (Gwent Wildlife Trust, 2024).

In some of the regions described above, disused canals support notable populations of *C. pulchellum*. In Leicestershire, the future of the sizable population of *C. pulchellum* along the Grantham Canal depends on the future use of the canal, which currently is one of the finest Odonata sites in VC 55 and of particular local importance (Merrill, 2023). The demise of the Basingstoke Canal in North Hampshire and Surrey is a reminder of how quickly fauna and flora can diminish when canals are reopened to leisure boat traffic.

On a smaller scale, the overshading of favoured breeding sites can impact

the species. Areas of aquatic plants that become increasingly shaded by trees result in *C. pulchellum* moving to other areas. At Paxton Pits NR the growth of *Salix* spp (Sallow/Willow) has shaded areas of aquatic plants previously used by *C. pulchellum* (pers.obs.). Lack of ongoing management to remove excessive shading can ultimately result in the loss or movement of the species if it continues. The loss of *C. pulchellum* at Langham's Pond at Runnymede in Surrey may be due to changes in water chemistry promoting the growth of *Lemna minor* (Common Duckweed) and the invasive alien *Lemna minuta* (Least Duckweed) that completely cover the water surface, shading out other aquatic plants used for oviposition (pers.obs.).

Large scale habitat creation has proven benefits for the species, with one of the best examples being the RSPB reserve at Lakenheath Fen in Suffolk. Once a stretch of farmland, this wetland reserve is now a rich mix of reedbeds, marshes and woodlands. Previously unrecorded in an earlier recording period (Mendel, 1992), *C. pulchellum* is now present in high numbers (Mason & Parr, 2016). Further extension to this reserve is currently in progress. The Great Fen Project in Cambridgeshire also aims to extend the existing Fenland National Nature Reserves at Holme and Woodwalton to form one vast continuous area of wetland (The Great Fen, 2024). This area already supports notable populations of *C. pulchellum* which should benefit from further large-scale wetland habitat creation.

Conclusions

Coenagrion pulchellum is a threatened species and declining in some areas and therefore is of high conservation value. To be able to actively conserve it, site managers need to be sympathetic to its habitat requirements both at the breeding site and in the surrounding areas. There are encouraging signs that it is colonising new sites, especially nature reserves and other protected areas, where water quality and a rich aquatic flora are actively maintained. Every effort needs to be made to protect its wetland sites from agricultural and industrial runoff.

Coenagrion pulchellum appears to favour more extensive habitat than *Coenagrion puella*. The highest concentrations occur at sites with a complex of larger water bodies with abundant aquatic plants. These botanically rich areas reflect the high water quality in these areas. Small ponds appear to be avoided. Further study is still needed to establish why some sites have *C. pulchellum* only in specific areas and why they are absent from apparently suitable habitat close by. Comparative water quality analyses and aquatic plant surveys may go some way to answering this question.

Monitoring and recording work need to take into account aspects of the breeding behaviour of *C. pulchellum*. Suitable areas used for oviposition need to be determined, by monitoring these areas when tandem pairs visit water to oviposit from late morning and into the afternoon (Plate 17). Extensive botanically-rich areas utilised for group oviposition need to be carefully managed and maintained.

At low population densities *C. pulchellum* can go undetected due to the difficulties in distinguishing it from the more abundant *C. puella*. Learning and understanding the 'jizz' of this species, particularly the darker appearance of males when compared with *C. puella*, will help recorders to distinguish individuals in the field. Further study is still required to establish the sequence of colour transitions and the various forms of females, and how this can reliably distinguish them from *C. puella* when the pronotal lobe is not visible.

Acknowledgements

Thanks go to all the field recorders and Vice County recorders that submit and verify records. Without their valued input this species review would not be as comprehensive. Also, to those authors that have produced county atlases, reports and websites. These publications provide valuable snapshots of the state of dragonflies under local conditions, enabling trends to be assessed that are not apparent in analyses at a national level. I would also like to thank the referee for constructive feedback and suggestions on the initial draft.

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Received 5 November 2024, accepted 27 November 2024

First occurrence and behaviour of *Aeshna affinis* Vander Linden (Southern Migrant Hawker) in Worcestershire.

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Summary

Aeshna affinis (Southern Migrant Hawker) has recently increased its breeding range in the UK and it seemed only a matter of time before the species arrived in Worcestershire. This paper documents the first occurrence in the county and details the field observations of adult male behaviour and habitat selection, together with the use of photography to determine the minimum number of males present; also an individual's approximate duration spent on the site.

Introduction

Aeshna affinis occurs throughout continental Europe south of the Scandinavian countries. It is rarely abundant but is known to migrate in large numbers (Dijkstra *et al.*, 2020). It was first recorded in England in Kent in 1952 and then in Sussex and Hampshire in 2006. More recently, oviposition has been recorded at Hadleigh Country Park, Essex and at Cliffe, Kent (Smallshire & Swash, 2018). Currently there are breeding colonies in parts of south-east England with outlying colonies in Oxfordshire and Gloucestershire (Parr, 2024). However, individuals have been recorded from as far north as Spurn Point in Yorkshire and as far south-west as Dale Airfield in Pembrokeshire (Parr, 2024).

Aeshna affinis (Southern Migrant Hawker) does not require permanent water all year round to breed and tends to choose areas which dry out during the summer months. Unusually for an aeshnid, oviposition is carried out with the pair in tandem, often directly into damp ground, which may eventually dry out completely, then flood again during the winter and spring. It is thought that eggs laid the previous year hatch early in the spring following a winter diapause, and that the larvae develop rapidly to emerge later that year (Chelmick, 2020)

Methods

Observations were carried out at Ryall Concrete Plant and Quarry (Ryall Pits) (British National Grid Reference SO868398) (Plate 1), a private site managed by Cemex UK situated just south of Ryall village over a 25 day period in August 2024. Numerous photographs were taken, mostly of perched individuals but some in flight. Males in all the photographs were closely scrutinised and individuals identified, predominantly using the pattern and shape of blue markings on the abdomen, and then assigned an individual number. Details of the structure of the wing cells were then examined, especially the region around the pterostigma, to determine any differences between individuals.

Observations

On 2 August 2024, whilst searching suitable habitat at Ryall Pits (Plate 1) for *Sympetrum fonscolombii* (Red-veined Darter) (a sporadic visitor here, but one that had successfully bred in 2023), one of the old silt beds created in the mid-1990s, which retained shallow water levels during the spring and early summer after winter flooding, was checked. The high vegetation there was reasonably sparse, but no standing water was visible. However, there was a small open area fringed with *Phragmites australis* (Common Reed) which held a tiny patch of water a few centimetres deep, predominately surrounded by a sodden carpet of moss, *Veronica catenata* (Pink Water Speedwell) and *Juncus effusus* (Soft Rush).

A blue dragonfly shot past and disappeared into the reedbed, but reappeared a couple of minutes later and began patrolling, back and forth over the boggy ground, just a few metres from the observer. A brief hover, revealed strikingly vivid blue eyes and it was clear that this was a male *Aeshna affinis* (Southern Migrant Hawker) (Plate 2A, B), a first record for Worcestershire. The old silt beds at Ryall Pits appeared to match the habitat requirements of *A. affinis* noted by Chelmick (2020), making it a potential breeding location for this species.

Other local Odonata enthusiasts, including county dragonfly recorder Mike Averill, recorded a second male on the same day, and additional perched views of this stunning insect were obtained. Both males were still present the next day and were joined by a third, though close scrutiny of photographs taken over the two days revealed all three individuals were present on the first day. The occurrence of fourth and fifth males on the second day (3 August), was established when the author analysed a series of photographs taken by Mike Fletcher.

Plate 1. The old silt bed at Ryall Pits (British Grid Reference SO868398) on 2 August 2024.

Each male patrolled an area approximately five by ten metres in diameter, at varying heights between 10 cm and 2 m above ground level, for periods as short as a few minutes to half an hour, before disappearing into the reedbed. The patrolling male would not tolerate a second incoming male, which would be swiftly chased away, although it was oblivious to the presence of male *Sympetrum sanguineum* (Ruddy Darter) or *Sympetrum striolatum* (Common Darter). Photographic evidence revealed that it was only once this small area was vacated, that a different male would occupy the territory, and this switching continued throughout the day, though sometimes males were absent from the patch for quite long periods. When at rest, males perched on vertical plant stems (Plates 2B, 3A) such as *P. australis* (Plate 3A), *Typha latifolia* (Great Reedmace) and *Salix sp*. (Willow), often at the edge of the territory but sometimes much deeper inside the reedbed; they also favoured resting along a narrow, man-made path through the reeds (Plate 3B). No sightings of a female were confirmed, though a male pursued an unidentified female hawker into the territory on the second day, both briefly dropping to the ground before continuing high over the reedbed still unattached.

A B

Plate 2. Male *Aeshna affinis* at Ryall Pits on 2 August 2024. (A) in flight; (B) at rest.

A B

Plate 3. (A) *Aeshna affinis* on *Phragmites australis*; (B) The path through the reedbed used by *A. affinis* as a resting site.

By the third day (4 August), the once boggy area had dried out considerably, and there were predominately cloudy skies and a stronger breeze than on previous days, making conditions slightly less favourable for dragonflies, and no males were found either here or in the surrounding area. The fourth day was the same. Then on the fifth day (6 August), by which time the site was completely dry, two males reappeared, one of which had been previously sighted on day two; the other was a new individual. Sightings continued up to 26 August, with additional observations at two other ponds in the Ryall Pits complex (Plate 4). Site visits on 4, 9, 19, 25 and 30 August produced no sightings, though cooler and windier conditions may have played a factor on some dates, with fewer dragonflies on the wing, though a thorough search of the area was made on the 30 August in good weather.

For the majority of males, the average duration of stay was two to three days, though the original males may have been present before observations started. Three males were only observed on a single day, whilst male number five was recorded on three occasions over an 11-day period and was probably one of the two individuals reported on 11 August.

Over the 25-day period, hundreds of good quality photographs were taken of perched individuals, plus a smaller selection of flight shots obtained by the author, Mike Fletcher, Mike Averill and Des Jennings, which proved essential in determining the minimum number of males present, together with an individual's approximate duration spent on the site (Table 1).

Eleven individuals were identified using the pattern and shape of blue markings on the abdomen and a photographic montage produced for each, depicting as many body positions as possible and the date each shot was taken. The most complete profiles were recorded for seven individual males (Plate 5), the left side and dorsal surface for two and just the left side for one, whilst the eleventh individual was identified by flight views only. Once all the montages had been completed, the left hindwing was selected from the ten individual males which had been photographed when perched, and a segment from around the pterostigma to the wing tip for each of these was cropped and compared. Close examination of the wing-cell structure revealed uniquely shaped and positioned cross-veins for each individual (Plate 6), backing up the initial criteria used to separate the males.

Just four other species of Odonata were recorded at the old silt bed whilst male *Aeshna affinis* held territory. These were *Ischnura elegans* (Blue-tailed Damselfly), *Ischnura pumilio* (Scarce Blue-tailed Damselfly), *S. striolatum* and *S. sanguineum*. A visit to the still dried out silt bed on 6th September found a male *Aeshna mixta* (Migrant Hawker) patrolling the exact same five by ten metre patch the *A. affinis* males once frequented.

Plate 4. One of the other ponds at which *Aeshna affinis* was recorded in the Ryall Pits complex. 24 August 2024.

Plate 5. Montage of number 9 male *Aeshna affinis* at Ryall Pits, showing the individual from six different angles.

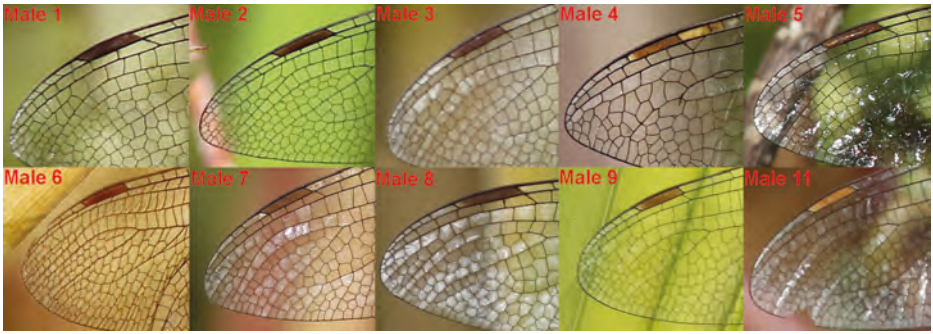

Plate 6. The wing tips of ten different male *Aeshna affinis* at Ryall Pits, showing differences between individuals in the cells and the cross veins. Photographs by A. Warr and M. Fletcher.

Table 1. Dates in 2024 on which individual numbered males and unknown recorded males of *Aeshna affinis* were seen at Ryall Pits.

	Male Number											
Date	1	2	3	4	5	6	7	8	9	10	11	Not identified
2 Aug	■	■	■									
3 Aug	■	■	■	■		■						
6 Aug				■	■							
11 Aug												■
12 Aug					■							■
16 Aug					■		■	■				
17 Aug							■	■		■		
18 Aug							■		■			
24 Aug											■	
26 Aug											■	

Discussion

The first question must be, from where had these individuals originated? After days of a hot southerly airflow, it was initially thought migrants from Continental Europe the most likely answer, or dispersal from colonies elsewhere in the UK. Over the first few days, this seemed a plausible explanation but, as sightings continued, with older males being replaced by new arrivals at the exact same

locality, another possible option is that they bred here in the summer of 2023. However, no females were recorded.

After emergence, the adults depart to become sexually mature in areas of dry scrub and woodland, sometimes many miles from water, then return weeks later to breed. This behaviour could certainly explain this series of occurrences at Ryall, with adults emerging here during July, then returning once matured to find a female and breed. Some time was spent searching for their exuviae, but it was probably a little late in the season and none were found. The author saw four or five presumed *Aeshna mixta* exuviae at Ryall on 28 July, but understandably did not consider the possibility that they might be *Aeshna affinis* exuviae as adults of the latter species had not yet been recorded at the site; the exuviae of the two species are very similar. Obviously the true origin of the males cannot be confirmed but evidence of breeding will be checked in 2025.

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Warr, A. (in press) Occurrence of Southern Migrant Hawker *Aeshna affinis* at Ryall Pits in 2024. Worcestershire Record **54.**

Received 22 October 2024, revised and accepted 1 December 2024.

Long term population trends in *Sympetum danae* (Sulzer) (Black Darter) compared with other heathland dragonfly species and some generalist species in the south of England

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Summary

All heathland species of Odonata have shown a decline in Southern England, more so than in the whole of England. *Sympetrum danae* (Black Darter) has shown a strong decline while *Aeshna juncea* (Moorland/Common Hawker) has been largely lost in Southern England. *Orthetrum coerulescens* (Keeled Skimmer) and *Ceriagrion tenellum* (Small Red Damselfly) are also in decline in Southern England. *Lestes sponsa* (Emerald Damselfly) has suffered a loss of sites rather than decline at surviving sites. However, both *S. danae* and *A. juncea* have extended their ranges northward.

Habitat loss has affected all odonate species but has particularly impacted those species subject to additional environmental constraints. *Sympetrum danae*, for example, being in the south of its range, has been additionally impacted due to increasing temperatures, drought and unstable water levels, whereas *S. striolatum,* which has no diapause at the egg stage, is at a competitive advantage. *Sympetrum danae* has extended its oviposition period more than *S. striolatum* and *S. sanguineum*.

Introduction

Sympetrum danae (Black Darter) is Britain's smallest dragonfly. Its distribution, while covering heathland habitats throughout the UK, has a northly emphasis, being very strong in the Scottish Highlands, while *Sympetrum sanguineum* (Ruddy Darter) is restricted largely to England. *Sympetrum danae* has a more northerly distribution in Europe than *Sympetrum striolatum* (Common Darter) and *S. sanguineum*. In mainland Europe, *S. danae* is only found in cooler, montane areas such as the foothills of the Alps. Similarly, in North America, the species extends as far south as Arizona and New Mexico, but here is found in cooler areas of higher elevation.

The State of Dragonflies report (Taylor, *et al*. 2021) shows *S. danae* to be the second most strongly decreasing odonate species nationally after *Lestes sponsa* (Emerald Damselfly).

Similarly, in Germany, *S. danae* has gone from being "the most common dragonfly in Lower Saxony" (Jödicke & Pix, 2021 based on 1976-1995 data), to showing a clear, continuous decline in the period since 1985. Termaat (2023) described it as stable in the Netherlands at the beginning of his study period 1990 -2015, but "recently showing strong declines" (p150). He considered that "Climate warming is likely to be the culprit, rather than other environmental issues such as nitrogen deposition." (p170). Even in the agricultural areas of Southern Scandinavia it is suffering habitat loss through fragmentation, waterbodies becoming overgrown and drought, and is at risk (Billqvist *et. al* 2023) It is now listed as Endangered in Europe by the IUCN. (Billqvist *et al*., 2024) commenting, "The distribution trends as well as its occupancy is severe almost throughout its European distribution with dramatic population losses in Flanders and Wallonia, Germany, the Netherlands, France, and the UK. There is no proof of the species' presence in Slovenia in this millennium. In two of the species' real strongholds, Finland and Sweden, it is also declining. Only in Denmark and Lithuania the situation seems to be positive."

Situation in the East Berkshire / Northern Hampshire / West Surrey area

Historically, *Sympetrum danae* was much more common in the area of East Berkshire, Northern Hampshire and West Surrey (Fig.1). For example, in 1938 it was reported as "plentiful" at Fleet Pond and "fairly so" at the Bourley reservoirs (now overgrown) (Richards, 1939). "On 28 Aug., literally hundreds were ovipositing at Elstead, Surrey." (Richards, 1940). In the early 1990's it may have been breeding on the "Frimley Green/Pirbright part of the Basingstoke canal, where some of the flashes look suitable" (Hall, 1993. The Dragonfly Fauna of the Basingstoke Canal. 25 p unpublished manuscript C. Hall *pers.com*.) but, as always with *S. danae*, they may have been "strays from the adjacent heaths". In Germany the species is known to breed on river meanders (Jödicke & Pix 2021), so breeding on the Canal was not impossible.

In recent times, the species has been lost from both The Ridges/Simons Wood in Finchampstead, Berkshire (101-500 recorded in 1995, with the last record in 1997) and Yateley Common in Hampshire (the last record being in 1996).

The aim of the research presented here was to make comparisons between southern English heathland species and generalist species and between southern England heathland species and the same species across the whole country, in order to investigate the long-term change in populations in the regions over time.

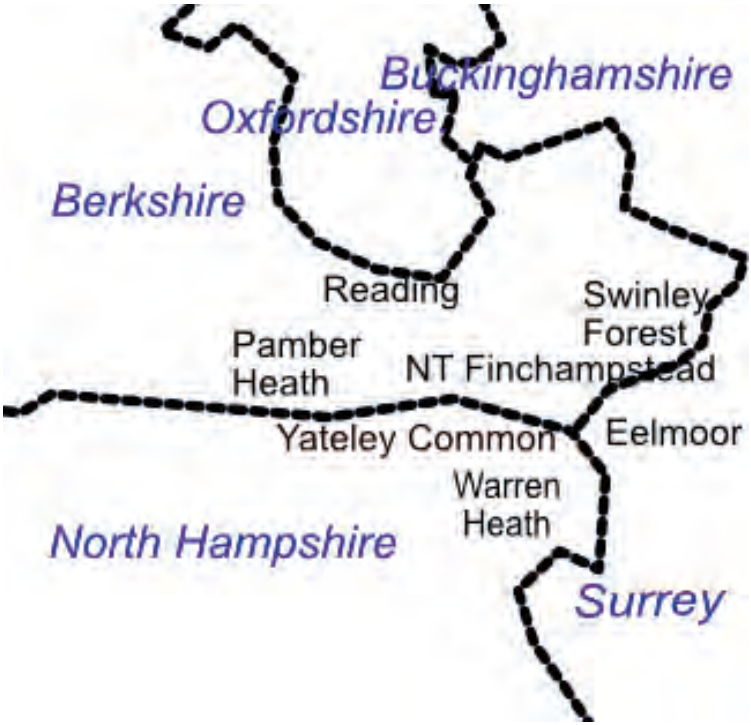

Figure 1. Places mentioned in the text overlaid on Vice Counties.

Methods

Data were analysed for *Sympetrum danae* and compared with data for four other heathland specialists: *Aeshna juncea* (Moorland/Common Hawker), *Orthetrum coerulescens* (Keeled Skimmer), *Ceriagrion tenellum* (Small Red Damselfly) and *Lestes sponsa* (Emerald Damselfly).

Comparison was also made between this moorland species and seven generalist species in southern England: *Aeshna cyanea* (Southern Hawker), *A. grandis* (Brown Hawker), *A. mixta* (Migrant Hawker), *Anax imperator* (Emperor Dragonfly), *Sympetrum striolatum* (Common Darter), *S. sanguineum* (Ruddy Darter) and *Orthetrum cancellatum* (Black-tailed Skimmer).

Records from the NBN database (and approved by the British Dragonfly Society) for the region south of a line from approximately the Severn estuary to London were used to provide a quantified, long-term perspective in the south of the species range (Fig. 2). This covers some of the most species-rich sites in the country.

Changes in Occupancy

To allow for observer effort, for each species the chance of it being recorded for each 1 km square, on a date when any odonate species was recorded, was calculated for its main flight season. MsExcel was used to filter out, firstly records of all larvae and then records of adults outside the main flight season of the specific species as recorded in Cham *et al.* (2014). The results for the 1km squares and day of the year were concatenated to give a unique identification number for what was considered a recording visit. The number of unique visits was then counted. This was calculated for all Odonata species for each year and then for the specific species. The latter figure was then divided into the former to give a measure of the chance of the specific species being reported.

To reduce the risk of including records of vagrants, the *S. danae* data were reanalysed using only stages indicating probable or successful breeding (larvae, emergent or exuviae). Little difference was seen in the trends with those of the adult records.

Applying the analysis based on records in 1km squares for the whole country introduced a bias since the South is far more data-rich than the North, especially the far North. To overcome this and to identify where the declines are occurring, the country was divided into five 200 km latitude bands except for the Scottish Highlands. In the latter case the few records from Orkney and Shetland were included within this band. These data were then analysed based on occupancy rather than abundance. (Abundance data can provide more local resolution information than occupancy but must be used with great caution owing to the difficulties in physically counting dragonflies and differences in the method and area of each observation and the intent of the observer).

Results

Heathland Species

Southern England *Sympetrum danae* populations remained fairly steady from 1983 to 1989 with about an 8% chance of being seen. After this they showed a steady decline to just over a 1% chance of being seen by 2020 (Fig. 2).

A clear decline in *S. danae* abundance was seen in the Swinley Forest at the Millpond (13 records of 20-100 up to 2013 and 28 records of only 6-20 up to 2020) and the Buttersteep Brickpits (with eight records of 101-500 up to 2002 and 16 records of only 20-100 up to 2012).

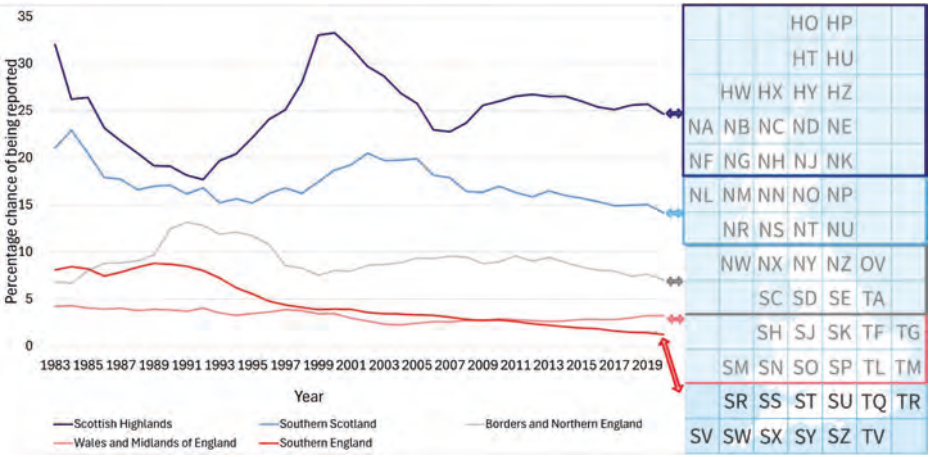

Figure 2. *Sympetrum danae*: For each of five latitude bands, the percentage chance of this species being reported in a 1km square on a day when any other dragonfly or damselfly species was reported. Data from 1980- 2023 in flight period from 1 July to 1 September. 7-year moving-average. Data based on 2334 squares & days (= 'visits'), with records for all Odonata that flight season in 1983 rising to 3,510 in 2000 and 9,434 in 2020. NBN download 13 April 2024.

A reduction in the high counts of *S. danae* was seen throughout the heathlands of Berkshire, North Hampshire and Surrey. (The only 501+ records were the Thursley 1992 records. There were 90 records of 101-500, which level was last seen at Holt Heath in 2010 and at both Warren Heath and Thursley in 2009).

All typically heathland species showed a decline in Southern England, but only *Aeshna juncea* showed a steeper decline than *S. danae.* In Southern England, *Lestes sponsa*, *O. coerulescens*, and *C. tenellum* (Small Red Damselfly) are all in decline where the heathlands seem particularly badly affected. This decline was seen both when Southern England heathland species were compared with those of the whole country (see below) (Fig. 3) and when the within Southern England heathland species were compared with comparator generalist species (Fig. 4). Bowler *et al.* (2022) reported a similar decline in moorland species in Germany, especially in those species which were cold-adapted.

At Eelmoor SSSI, Chris Hall, working for Marwell Wildlife, produced a very useful long-term data set showing rising populations of *Orthetrum coerulescens* (Keeled Skimmer), and *Ceriagrion tenellum* (Small Red Damselfly). Also stable, if not rising, numbers of *Lestes sponsa* (Emerald Damselfly), and stable but fluctuating counts of *S. danae* (Fig. 5).

National Situation Both *Sympetrum danae* and *Aeshna juncea* showed declines in the southern 200 km of the country (Figs. 2, 6). The occupancy in

the North remained stable, but both species showed steeper declines as one moves south.

Orthetrum coerulescens showed a slight decline in Southern England but a rise in Southern Scotland, with the first records for the Scottish Highlands in 2014. *Sympetrum sanguineum* showed a slight decline in Southern England but was stable in Wales and the Midlands. *Sympetrum striolatum* experienced a smooth decline in Southern England compensated for by a range expansion north in the late 1990s and with a stable population since. *Ceriagrion tenellum* remained a southern species but showed a clear decline in Southern England, with a steady but small representation in Wales and the Midlands of England.

A small rise in *L. sponsa* occupancy can be seen in the North. In the South the population seems stable, but when observer effort is allowed for, it is clear that here too a decline was taking place. Interestingly *L. sponsa*, like *S. danae* is also declining in Germany as well as in the UK.

Comparison with other species in southern England

Aeshna juncea *Aeshna juncea* now has only isolated records in the Thames valley and no confirmed records in Berkshire in recent years (D. Sussex, *pers. comm*.). The last records for Swinley Brickpits and Swinley Millpond were both in 2006 and at Warren Heath in 2009. There has been only one record at Thursley (in August 2020) after the fire on the site in June 2020.

Approximately 10% of the records held nationally on the NBN database are unconfirmed, presumably caused by confusion over the name. Already in 2014, Clarke argued for a change and it is time to correct this anomaly. A change in the name from ‘Common’ to the IUCN designation of ‘Moorland’ would probably cause less frustration among both observers and verifiers.

Orthetrum coerulescens Populations of *Orthetrum coerulescens*, another typically heathland species (with a few unusual non-heathland sites), have been stable in recent times in Southern England. There are signs of increase in Eelmoor (Fig 5). However, as it has a niche of small seeps and bog pools rather than major lakes, trends might escape the comprehensive analysis by abundance data given to large sites. There is evidence of attempted colonisation at Simons Wood, Berkshire, with new colonisation in 2014 and then intermittent records with oviposition across the site into 2023. The species has low but stable populations at the Swinley Brickpits and Millpond.

Burch (2022) reported a rise in *Orthetrum coerulescens* numbers at two Cothill BBOWT Reserves in Oxfordshire and attributed this to grazing and other

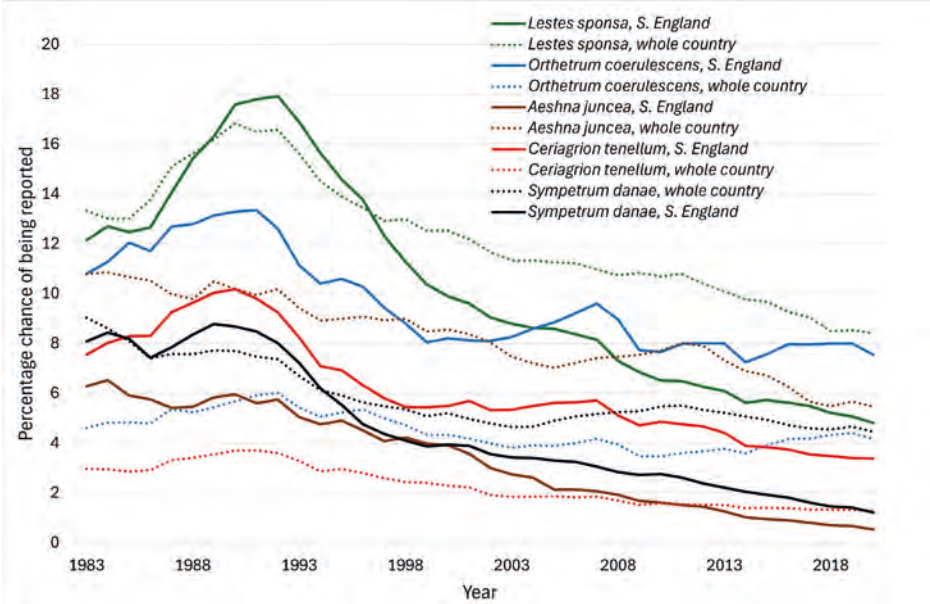

Figure 3. The percentage chance of a specific heathland species being reported for each year from 1980 to 2023 in each 1km square in Southern England (solid lines) and in the whole country (broken lines) on a day when any odonate species was reported. Adult and peak flight season records only. NBN download 13 April 2024. 7-year moving average.

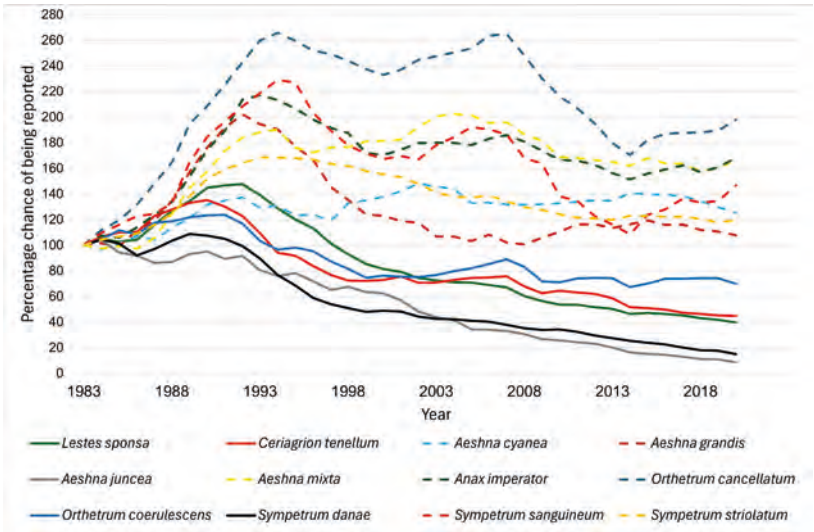

Figure 4. The percentage chance of a specific dragonfly or damselfly species being reported during a visit to a 1 km square in Southern England on a day when any dragonfly or damselfly species was reported. Flight season records only. Solid lines, heathland species; dotted lines, generalist species. 7-year moving average with 1983 normalised to100.

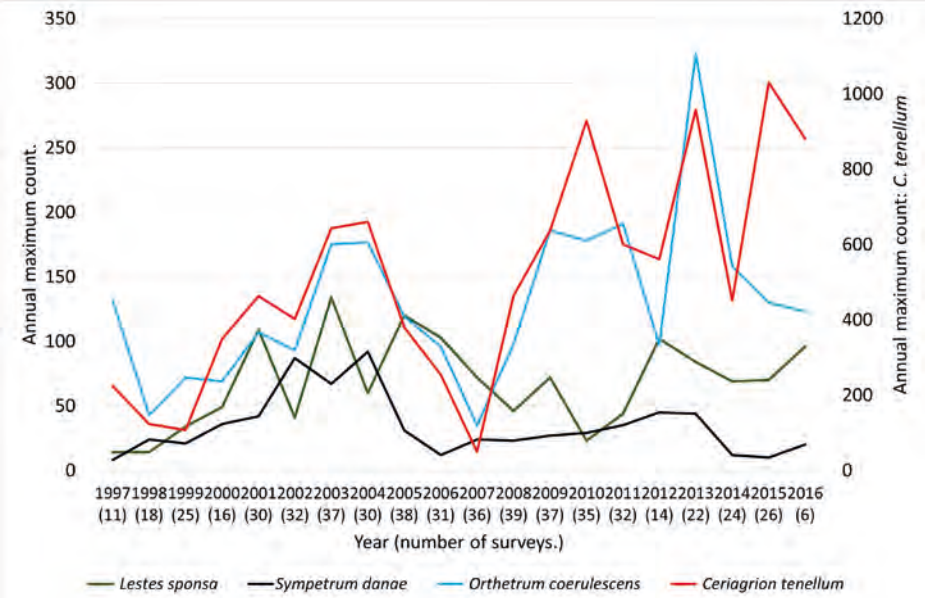

Figure 5. Maximum counts of *Lestes sponsa*, *Sympetrum danae* and *Orthetrum coerulescens* (left-hand axis) and *Ceriagrion tenellum* (right-hand axis) at Eelmoor SSSI, Hampshire 1997 to 2016, with the number of surveys in parentheses. In 2014 surveying started late in the season, missing the beginning.

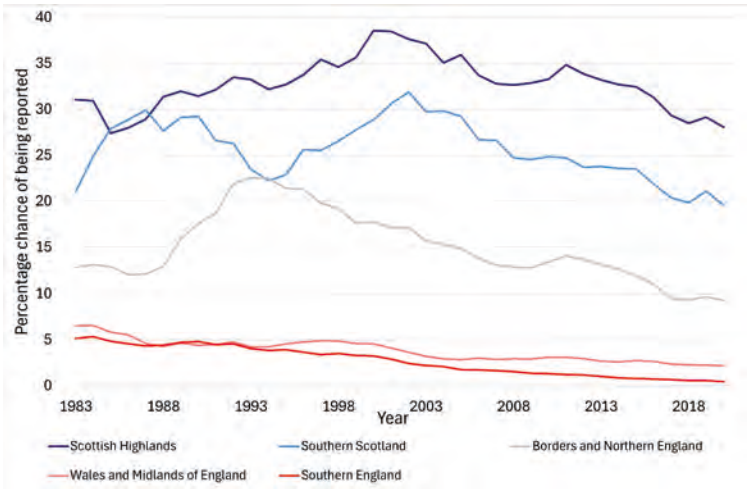

Figure 6. *Aeshna juncea*. For each latitude band, the percentage chance of this species being reported in a 1km square on each day when another dragonfly or damselfly species was reported. Data from 1980 to 2023. Flight period from 16 June to 1 September. 7-year moving average. Data based on 2,798 total number of squares & days (= 'visits'), with records for all Odonata that flight season in 1983, ranging from 4,593 in 2000 to 12,323 in 2020. NBN download 13 April 2024.

management practices to keep runnels from being overgrown. Eelmoor also has grazing as part of the management practices. Biggs & Williams (2024) expressed concern about open heath ponds becoming scrubbed over due to loss of traditional grazing. White (2006) reported that management that removal of vegetation with intermittent grazing at Holt Lowes SSSI, Norfolk, at that time the only colony in East Anglia, had improved the number of territories on ponds of pH 6-7. The species showed no preference for flowing or still water. The suggestion was that peat substrate or poor nutrient conditions rather than pH alone might favour the species, while shallower ponds would warm faster to speed larval development and a seep that did not dry out like other shallow ponds was beneficial to the species.

Lestes sponsa *Lestes sponsa* was the only species found to have reduced its occurrence nationally more than *Sympetrum danae* (State of Dragonflies Report 2021). However, in contrast to *S. danae* there have been strong populations in the Swinley Forest, consistently with counts of 21-100 since 1993 and 101-500 in 2023 at Swinley Buttersteep Brickpits. Only at Simons Wood/The Ridges was there unequivocal signs of decline, with eight consecutive years of reports of 6-20 in the 1990's to it now being considered lost from the site. The simplest explanation of the situation regarding *L. sponsa* is that there has been a loss of sites rather than decline at surviving sites.

Ceriagrion tenellum *Ceriagrion tenellum* is an important heathland species considered Nationally Scarce. Hope (2009) reviewed the historical distribution and found it to have very specific habitat requirements in a restricted range in southern England. However, there was no strong signal of decline on favourable sites and indeed colonisation and establishment of a seemingly self-sustaining colony at The Ridges. There were counts of 500+ locally from 1993 to 2016 and one count of 101 to 500 at Swinley Buttersteep Brickpits in 2023. One pond previously notable for the species is now overgrown with *Rhododendron*, suggesting that the species is influenced by a change of habitat management of the site.

In the data set presented by Burch (2002) from Cothill BBOWT Reserve, Oxfordshire, the species was fluctuating at low levels, but was apparently stable. The simplest explanation for *C. tenellum* is like that for *L. sponsa*, *i.e.* loss of sites rather than decline at surviving sites causes population change.

Discussion

Changes in Abundance of *Sympetrum danae*

There are a number of possible explanations for a large-scale change in abundance of these Moorland species.

One potential explanation for the decline in large counts is that there has been a change in observer focus. For the 2014 Atlas, a location of 1 km^2 was used, possibly leading to high counts, as recorders were possibly estimating over a larger area. Later records might have a focus on smaller locations and so yield lower counts. However, if this were true, the effect should be seen in all species but it seems to be a particularly *Sympetrum danae* phenomenon.

Alternatively, decline could be the result of management practice. For example, reviewing the *Sympetrum danae* records in Oxfordshire, Burch (2022) cast doubt on historical reports of it "being a common breeding species at Cothill NNR" considering "currently this species appears to be absent from Oxfordshire, although there is always the remote possibility that wandering individuals may be encountered." Indeed, loss of a breeding site and records from dispersing adults would fit the wider picture. However, when looking at the wider picture, all these sites have their patterns of ecological success and management but the same picture of decline is seen.

Finally, it is unlikely to be the result of the effects of poor weather on an individual season alone, since this analysis reflects a decline over 20 years.

Habitat requirements and causes of decline in *Sympetrum danae*:

Waterside vegetation. While the adults are often seen on *Sphagnum* mats round heathland ponds, *Sphagnum* does not seem to be essential for the species. For example, it has colonised the new ponds at Bush Fields, Swinley Forest, where large amounts of *Sphagnum* are not evident and there are historical examples locally of it on gravel pits and modern records at Pamber Heath, Tadley. Smith (1998) recorded it trying to establish on several sand and marl pits in Lancashire. *Sympetrum danae* readily colonises new ponds with bankside vegetation, such as at Bush Fields (SU891648) at Swinley Forest before those where vegetation has not yet grown (for example Cobblers Hole Bog SU894644). At the Buttersteep Brickpits, *Hypericum elodes* (Marsh St John's Wort) appears to substitute for *Sphagnum*. The actual species of *Sphagnum* is considered important for *Somatochlora artica,* (Northern Emerald) but seems unimportant for *S. danae* (Table 1).

Table 1. *Sphagnum* species providing potential egg laying sites for Sympetrum danae at various heathland sites in Berkshire and North Hampshire, together with the Sympetrum species present; also records of other mosses and liverwort. Sphagnum identification by Sue White. Nomenclature according to Blockeel et al. (2021).

Site	*Sphagnum* species	Liverworts & mosses	*Sympetrum* species
Swinley Forest, Cobblers Hole bog pool SU894644	*S. auriculatum* *S. rubellum*		*S. striolatum,* *S. danae* (occasional records- vagrant?)
Swinley Forest, Bush Fields SU891648	*S. palustre,* *S. rubellum,*	*Calypogeia fissa* (liverwort)	*S. striolatum,* *S. danae*
Crowthorne Woods, SU853650	*S. inundatum / denticulatum*		*S. striolatum,* *S. danae*
Warren Heath, Top pool SU78335887	*S. auriculatum,* *S. inundatum / denticulatum*		*S. striolatum,* *S. sanguineum,* *S. danae*
Simon's Wood, SU811640	*S. denticulatum (typical) ,* *S. palustre,*	*Polytrichum commune* (moss)	*S. striolatum*
50 Acre Piece, SU631649	*S. denticulatum (typical) ,*	*Polytrichum commune* (moss)	*S. striolatum,* *S. sanguineum,* *S. danae*

Acidity. *Sympetrum danae* is often described as preferring acid conditions. However, there are many unpopulated ponds that are below a pH of 6.0 and Brooks (1994) described how liming of ponds, increasing them from pH 4.0 to 8.0, did not affect *S. danae* populations (Foster 1994). Brooks (1994) considered *S. danae* to be capable of tolerating acid conditions rather than being acidophilic. Foster (1994) suggested dependency on a peat substrate or tolerance of cool or nutrient-poor conditions, although in Germany and through personal observation they are found in ponds with silt.

Nitrogen deposition. Nitrogen deposition in combination with climate change is making habitats become less nutrient-poor and so is opening up habitats to new predators of *S. danae* (Billqvist M. *et al*, 2024)

Low pH as protection against larval predation. Low pH could potentially benefit *S. danae* by preventing the presence of some, but not all, aquatic

predators such as fish. Foster's study (Foster, 1994) involved increasing pH so that trout could be reintroduced, as has also been proposed for *Salvelinus alpinus* (Arctic Charr) (Hesthagen *et al.,* 1995*).* Crayfish, whose calcium skeletons are considered sensitive to pH, are typically absent from low pH waterbodies. Šigutová *et al.* (2018) considered the long spines of *Sympetrum* to be a response to fish predation, so the relatively short spined *S. danae* might be relatively vulnerable. Šigutová *et. al.* (2021) demonstrated that *S. sanguineum,* which they considered able to coexist with fish, was more likely than *S. danae* to oviposit in a pond with fish. Michiels *et. al*. (1990) considered frogs a major threat to *S. danae* ovipositing on *Sphagnum* in Belgium.

The potential effects of fish predation on *S. danae* are seen at Buttersteep Brickpits, where there are two deep lakes, one with fish probably released to serve an illicit fishing interest (SU905670) and one apparently without fish (SU907670). *Sympetrum danae* occurs only at the second lake. At Warren Heath, *S. danae* is restricted to the top pool (SU783589) and not seen at the two lower pools (SU778587 and SU777587). The top pool (pH 5.2-6.7) is probably the only pool without fish but is populated with *Lissotriton helveticus* (Palmate Newt), which is known to be acid tolerant. This newt is found at high densities when netting in many low pH water bodies in Southern England and may well be a significant overlooked predator, possibly more relevant than even fish. The other ponds have *Pacifastacus leniusculus* (Signal Crayfish) not (yet) found at the top pool, and also saucer bugs (Naucoridae).

The effects of the presence of less studied predators such as diving beetles, which are active nocturnal predators, in these water bodies must also be considered. Water bodies without outlets minimising colonisation by fish have been considered favourable to *Dytiscus lapponicus* (Highland Diving Beetle) (Sutton 2008) and this might be applicable as to whether a location is favoured by *S. danae*. However, the colonisation by *S. danae* of new ponds at Bush Fields, Swinley Forest, which do have fish, speaks against a too simple explanation.

Turbidity. Ponds made cloudy with trampled bankside vegetation as a result of heavy dog use are not favoured by *S. danae* and the more successful ponds in Swinley Forest are either fenced off or not obvious to the public.

Water depth. Foster (1994) found that *S. danae*, and other odonate species, favoured steep-sided rather than shallow ponds (although *O. coerulescens*, which likes shallow seeps, was not present at a Galloway peat bog study area). If this is a general requirement, it implies a preference for the thermal stability of deep pools for larvae, giving them stable conditions to complete their relatively long larval cycle. Preference studies on captive larvae in a tank with different conditions might illuminate this.

In practise, the actual water depth in the middle of these water bodies is difficult to measure. However, the shallowest water body where the author has found the species is in the Top Pool at Warren Heath which has a depth of about 600 mm, which agrees with experience in the Netherlands. (Naturalis Biodiversity Center, 2024)

Drought. 'The State of Dragonflies' (Taylor, *et al*., 2021) mentions "the desiccation of blanket bog due to climate change is a further potential threat" and it is likely that drying out, either through sediment infill or due to dry seasons, has been responsible for the loss on some sites, especially if the species is sensitive to high temperatures in shallow water. However, Valtonen (1986) reported that the eggs and/or larvae of *S. danae* can survive a season of drought. However, Jödicke & Pix (2021) described how there was a widespread loss of the species, in the moors of the Lower Saxony/Bremen area of Germany in the drought summer of 2018 with adults only emerged in small numbers. They considered the high summer temperatures may have been fatal for the larvae. *Sympetrum danae* had a mixed but very low level of recovery in the 2019 and 2020 flight seasons. Winter rain had allowed larval development even in those moors that were particularly affected by the drought but, in many areas, there was no emergence, presumably because hardly any eggs had been laid. They expressed concern as to how or whether the population would recover.

Although there are many anecdotal reports of loss of *S. danae* at sites dying out in Southern England, it has proved impossible to correlate poor *S. danae* seasons with drought, either in that season or with the year before.

Fluctuating water levels. Ward-Smith & Sussex (2006) noted that varying water levels left *C. tenellum* without "shallow margins with low-growing vegetation suitable for oviposition". Parr & Parr (1979) also noted a colony of *C. tenellum* dying out temporally when a water body dried out. Fluctuating water levels may also be a significant issue for *S. danae*. In 2023, during a long flooding event, no *S. danae* were found at the Swinley Brick Pits despite thorough searching. The Environment Agency 2023 Water Situation Reports showed the drought of 2022. But perhaps as important is the sequence of the drought of early summer 2023, followed by the flooding of later summer, again depriving *S. danae* of access to marginal vegetation, which can only be detrimental, and such fluctuations may explain the sharp decline of the species.

Additionally, drying and wetting of peatlands can result in a short-term release of nutrients, encouraging the growth of invasive vegetation and further tipping the balance against its preferred *Sphagnum* habitat and species like *S. danae* dependant on it. This can be mitigated by planned damming of mires (Tenning, 2016; Pönisch *et al*., 2023; Billqvist *et. al*., 2024).

Threats to heathland. Some of the first losses in populations of *S. danae* were on small sites, as would be expected from chance, stochastic events. Fragmentation of heathland is a well-known problem (Rose *et al*., 2000). Heathlands are subject to scrub invasion, *Rhododendron* encroachment and fire. This affects all heathland species, but the marked decline in *S. danae*, supposedly one of the most dispersive of moorland odonate species, shows that other factors are involved. Nonetheless, threats to heathland are clearly very significant.

Dispersion. *Sympetrum danae* was not originally considered highly dispersive. However, Benstead (1994) recorded them dispersing 40 km to Holt Lowes, Norfolk and Smith (1998) recorded them dispersing 30-40 km in Lancashire and into non-heathland habitat. Additionally, there are records of vagrants at Moor Green Lakes Nature Reserve, Berkshire on 8 Aug 2006 and 12 Jun 2010, (Crick, 2006, 2010). But these records on a former sandpit system along the River Blackwater, with reports of presence from the 1990s, no longer occur. The species is now considered "capable of dispersive/ migratory movements in both the immature and fully mature state" Parr (2023).

Dispersion due to territorial competition among males, especially early in the season, as reported for *C. tenellum* by Parr & Parr (1979), might also be true for *S. danae*. For example, at the Millpond, Swinley Forest, the population has been so high that displaying males were forced into non-preferred shaded habitat under trees. Dispersion due to high numbers emerging has been suspected at Bramshill as well. (K. Crick *pers. comm.)*

Lack of a tendency to disperse is clearly not a cause of decline of *S. danae* in Southern England. At Simons Wood/The Ridges, both *C. tenellum* and *O. coerulescens* have recolonised sites lost, but *S. danae* has not. To disperse effectively, a population needs to have a certain size of source population, as Moore (1986) found with isolated colonies in East Anglia.

Larval temperature tolerance. It was noted earlier that *S. danae* had been particularly associated with *Sphagnum* mats. Suhling *et al*. (2015) noted that the upper layers of *Sphagnum* in bog pools can be surprisingly warm even at high altitude in the summer months and this is noticeable even on dull spring days in southern England. However, this warm layer is on a colder body of water and the larvae can easily migrate to the optimal water temperature.

Bowler *et al*. (2022) considered *S. danae* as cold-adapted based on a correlation between temperature and distribution data. Waringer (1983) raised larvae at a mean temperature of 18.7°C in Austria, where the eggs in diapause "survived 9 weeks in a block of ice". He commented that, in *S. striolatum*, eggs develop

directly and the winter is spent in the larval stage, whereas *S. danae* has a delayed egg development and the winter is spent in the egg stage. He also noted that, in *S. sanguineum*, both types of development may occur. Bilkova *et al*. (2022) found that the optimal temperature for larval development of *S. striolatum* was 24 °C, but sustained temperatures of even 2°C higher were lethal. Repeating this work directly on *S. danae* larvae would be helpful.

Franz-Josef Schiel (pers. com.) confirmed the difference in diapause strategy between *S. danae* and *S. striolatum* and showed that the former grew the faster, in his opinion forcing it into a more active hunting strategy, and so it was more vulnerable to predation. Hogreve & Suhling (2022) confirmed the lack of obligate winter diapause in *S. striolatum.* Billqvist *et al*. (2024) reported that "higher water temperatures lead to a lower oxygen availability for the larvae which leads to higher mortality and changes in larval development and flight period" and hence an active hunting strategy would make *S. danae* especially vulnerable.

Adult Temperature tolerance. Jödicke & Pix (2021) stated that *S. danae* retreats to shade in trees at a surprisingly high air temperature of 33 °C. However, Holmes (2024) found little difference in the mean temperature at which flight was recorded in *S. danae* compared with the other species when he compared the records in Southern England with the temperature data from the centrally located Reading University. The mean July temperature in Southern England at which *S. danae* was recorded was 18.7°C; for *S. striolatum* 18.4°C and for *S. sanguineum* 18.8°C. So adult insensitivity to high temperatures seems unlikely. *Sympetrum danae* showed no particular avoidance of hot, sunny basking positions (pers. obs.)

A test of the sensitivity of *S. danae* to high temperatures was found on the Devon and Cornwall moors, where both it and *A. juncea* still have strongholds. While normally thought of as warmer than the rest of the country, there are cold spots where cold adapted species could survive. In contrast, the stronghold of both species in the New Forest shows no such cold spot.

Phenology. Changes in life cycle timing of Odonata have been seen in response to climate change (Doi, 2008). In the two southern areas of Southern England and in Wales and the English Midlands, where the data is the most complete, the timings of observations of exuviae and emergence of *S. danae*, which logically should be the same or at least parallel in these locations, are not, although presumably the data may be distorted by the low numbers of emergent records.

The first adult record of *Sympetrum striolatum* for the year has become earlier by about 28 days in the period 1990 to 2023 and the latest adult record later by

Table 2. Comparison between various records for *Sympetrum danae*, *S. striolatum* and *S. sanguineum* in 1990 and 2023. Note that dates are not dates from that year but taken from an averaging trendline from a plot covering this period.

	Sympetrum danae			*Sympetrum striolatum*			*Sympetrum sanguineum*		
	1990	2023	**Var**	1990	2023	**Var**	1990	2023	**Var**
Earliest adult record	28-May	24-May	**-4**	19-Apr	22-Mar	**-28**	29-May	14-May	**-15**
Earliest oviposition record	07-Jul	28-Jun	**-9**	05-Jun	11-Jun	**6**	28-Jun	18-Jun	**-10**
Average adult record	20-Aug	20-Aug	**0**	18-Aug	27-Aug	**9**	11-Aug	07-Aug	**-4**
Latest oviposition record	09-Oct	18-Oct	**9**	08-Nov	25-Nov	**17**	06-Oct	06-Oct	**0**
Latest adult record	28-Oct	15-Nov	**18**	25-Nov	08-Dec	**13**	20-Oct	15-Nov	**26**
Length of recorded flight season (days)	153	175	**22**	220	261	**41**	144	185	**41**
Length of oviposition period (days)	94	112	**18**	156	167	**11**	100	110	**10**
Gap between latest oviposition record to latest adult record (days)	19	28	**9**	17	13	**-4**	14	40	**26**

13 days, though unusually among British dragonflies, the average record is also slightly later. The gap between earliest and last record has extended to 41 days but the period of reported oviposition only 11 days, partly due to the earliest oviposition being recorded six days later (Table 2, Fig. 7).

Sympetrum danae and *S. sanguineum* have significantly fewer records than *S. striolatum* and so the results must be treated with caution, but *S. danae's* reported flight season has extended by 22 days and the oviposition period by 18 days. The extended oviposition season has been achieved by the earliest record being reported 9 days earlier, in contrast to *S. striolatum.* The reported flight season of S*. sanguineum* has also extended by 41 days but the oviposition period by only 10 days (Table 2, Fig. 7). On this basis, *S. danae* seems to be at no competitive disadvantage to the other two species. In all three species it

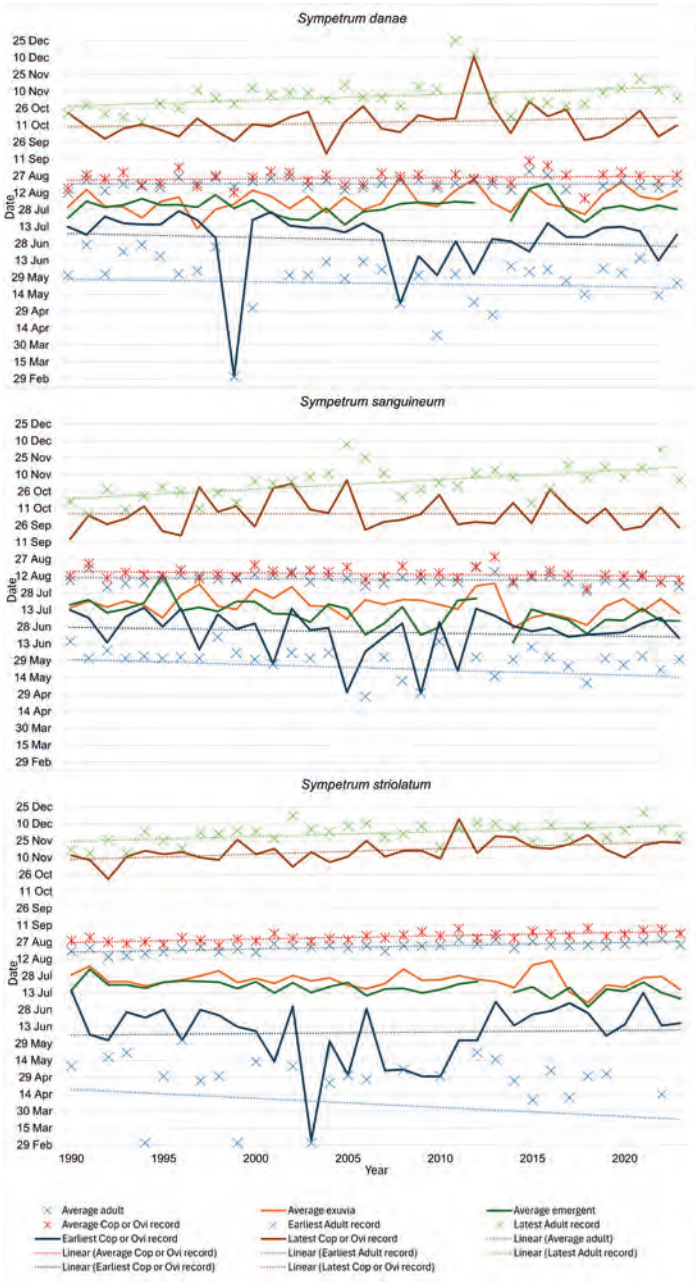

Figure 7. Average and first and last dates for adults and for copulating pairs/oviposition based on records for the whole country (A) *Sympetrum danae*; (B) S*. sanguineum*; (C) *S. striolatum*. Records with vague or improbably early or late dates have been removed. NBN download 13 April 2024.

seems that there is a period when the over-mature adults that survive the first frosts are either past breeding or the density of potential mates is too low to enable fertilization.

Conclusions

Despite the general decline in abundance and occupancy, *Sympetrum danae* is clearly still surviving at optimal sites, including at some which have been recently created. Hence conservation efforts can help this species.

The ideal habitat for *Sympetrum danae* seems to be relatively deep water bodies to provide thermal stability, as it is unable to cope with the thermal instability of shallower water bodies. This is in contrast to the more tolerant *Orthetrum coerulescens*, *Lestes sponsa* and *Ceriagrion tenellum*, all of which have a more southerly distribution than *S. danae*. Stable water levels permit reliable ovipositing. Low pH is usual but not necessary. The absence of fish in ponds inhabited by *S. danae* is beneficial to its survival. A broad waterside vegetation of *Sphagnum* is preferred but other vegetation is acceptable on some sites. The ponds should not be overshadowed by scrub, which should either be removed by management or grazing; alternatively, by siting the pond in waterlogged soil to prevent tree growth. Excessive dog activity needs to be discouraged either by fencing or keeping ponds out of sight of dog walkers.

Sympetrum striolatum, having no diapause at the egg stage is at a competitive advantage over *S. danae* when the winters are warm enough for *S. striolatum* larvae to survive. Both *S. striolatum* and *S. sanguineum* have extended their flight seasons more than *S. danae*. However, *S. danae* has extended its oviposition period by more than the other two species.

All heathland specialist Odonata species are in decline in southern England in comparison with generalist species. *Sympetrum danae* is an indicator species of healthy, waterlogged peatlands with their biodiversity and carbon-storing services. But the situation is not without hope as we have examples of well-maintained sites where the species is holding on, although it seems to be losing out to the effects of both habitat degradation and loss alongside climate change.

Acknowledgements

This work would not have been possible without the observations and reporting of thousands of observers over 43 years. When one thinks of the hours of work, one can only be in awe. In particular, I am indebted to the late Chris Hall and his detailed long term data set for Eelmoor and to Marwell Wildlife for access to it.

I am grateful to the Crown Estate and the National Trust for access to their land; also to the helpful comments of members of the BDS Statistics Group, Steve Cham, Adrian Parr, Ken Forbes, Matt Geary, David Smallshire, David Hepper, Ellie Colver, Michael Jeffries and Mike Averill, to Sue White for identifying the *Sphagnum* samples, to field discussions with Steve Cham, for access to Steve Hewitt's maps, for discussions with Franz-Josef Schiel and Roy van Grunsven, David Hepper, to Wendy Appleby for reading the manuscript and to the referee.

Data Sources

Data were provided from the British Dragonfly Society Recording Scheme and occurrence data from the NBN Atlas. Data from other organisations are included with permission and remain the copyright of the provider.

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Received 14 July 2024, revised and accepted 6 November 2024