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BDS

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

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

Articles for publication should be sent to the Editor. Instructions for authors appear inside the back cover.

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Cover illustration: Newly emerged male *Somatochlora arctica*. Photograph by Pete Vandome.

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

- Word processed manuscripts may be submitted in electronic form either on disk or by e-mail.
- Manuscripts should be one and a half spaced, on one side of the page only and with margins at least 25mm on both sides and top and bottom. Footnotes should be avoided.
- Use of these terms is acceptable: 'exuvia' for cast skin (plural: 'exuviae'); 'larva' (instead of 'naiad' or 'nymph'); 'prolarva' to designate the first larval instar.
- Dates in the text should be expressed in the form: 24 July 2010.
- References cited in the text should be in the form '(Longfield, 1949)' or '...as noted by Longfield (1949)'. All references cited in the text (and only these) should be listed alphabetically at the end of the article in the following forms:
  - Hammond, C.O. 1983. *The Dragonflies of Great Britain and Ireland* 2nd Edition (revised by R. Merritt), Harley Books, Colchester, 116pp.
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- Titles of journals should be written out in full.
- Figures, plates and tables should be presented on separate, unnumbered pages.
- Legends for figures, plates and tables should be presented together in sequence on separated, unnumbered pages.
- The legend for each table and illustration should allow its contents to be understood fully without reference to the text.

Please refer to a recent issue of the journal for further style details.

SCIENTIFIC AND ENGLISH NAMES OF BRITISH ODONATA

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

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

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

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Colonisation of a new pond: new habitat for *Coenagrion hastulatum* (Charpentier) (the Northern Damselfly) and other odonate species at a site in Aberdeenshire.

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Summary

A new pond was constructed in 2011 for the purpose of providing nearby Odonata populations with a new habitat in which to live. This provided the opportunity to begin a long-term colonisation study, part-funded by a British Dragonfly Society Philip Corbet award. The results of the first survey, in summer 2012, indicate quick colonisation by five of the ten known local species, i.e. *Lestes sponsa* (Emerald Damselfly), *Pyrrhosoma nymphula* (Large Red Damselfly), *Ischnura elegans* (Blue-tailed Damselfly), *Sympetrum danae* (Black Darter) and *Sympetrum striolatum* (Common Darter). The reasons for this are discussed.

Introduction

A pond (the flight pond) is present at Castle Fraser, Aberdeenshire (NJ723134) (Fig. 1, Plate 1) which hosts 10 species of Odonata: six species of Zygoptera, i.e. *Pyrrhosoma nymphula* (Large Red Damselfly), *Enallagma cyathigerum* (Common Blue Damselfly), *Lestes sponsa* (Emerald Damselfly), *Ischnura elegans* (Blue-tailed Damselfly), *Coenagrion puella* (Azure Damselfly) *and Coenagrion hastulatum* (Northern Damselfly) and four species of Anisoptera, i.e. *Aeshna juncea* (Common Hawker), *Sympetrum danae* (Black Darter), *Sympetrum striolatum* (Common Darter) and *Libellula quadrimaculata* (Four-spotted Chaser), with all species breeding here. For the endangered *C. hastulatum,* this is currently the most easterly-recorded population in Scotland. Furthermore, the flight pond is one of only two known sites where *C. hastulatum and C. puella* coexist. The flight pond is about 275 m long (west to east) and has a maximum width of about 25 m. The site is about 15 miles (23 km) WNW of Aberdeen.

Concerns had been raised over the potential negative effect on Odonata of the release of goldfish into the flight pond and of planned changes to the surrounding woodland. Due to the importance of the pond for the endangered *C. hastulatum,*

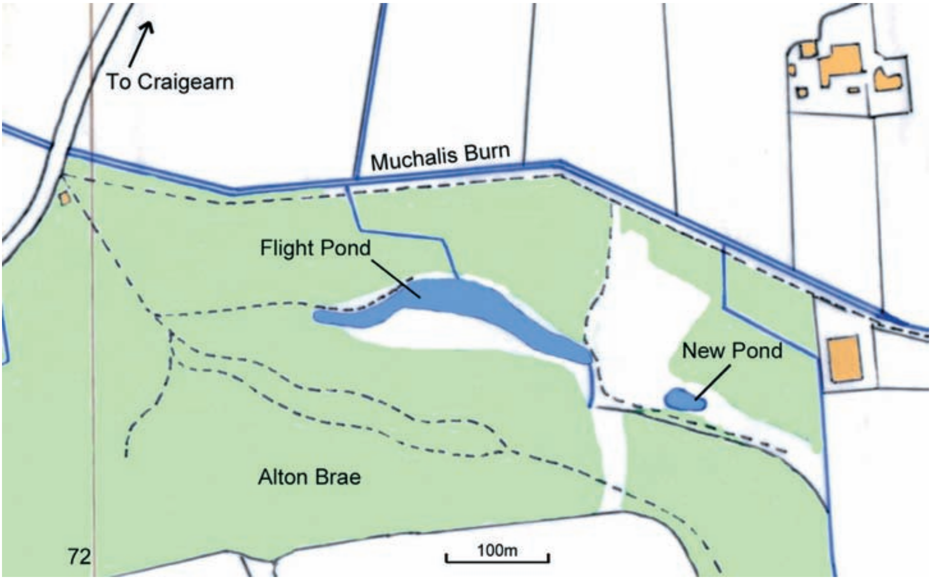

Figure 1. The flight and new ponds at Castle Fraser, Aberdeenshire (British National Grid Reference NJ723134). Based on Ordnance Survey data and Google Maps information.

as well as for the other species present, the National Trust for Scotland created a new pond in 2011, situated about 80 m east of the flight pond (Fig. 1, Plate 2). It was hoped that the odonate species present at the flight pond would quickly and successfully colonise the new pond and that, with two separate populations, they would have a greater chance of surviving any changing environmental pressures. Vegetation would also be left to colonise naturally as a biosecurity measure against the new pond becoming contaminated with goldfish eggs from the flight pond. The Philip Corbet Award granted by the British Dragonfly Society was used to buy equipment to set up a long-term, standardised survey.

Methods

The new pond (15 m x 30 m) was constructed on the 12th March 2011. During the summer of 2012, a survey of the new pond began in order to assess initial colonisation. This consisted of weekly counts of larvae present in the new pond and adults present around it.

Between 21st June and 5th September 2012, 10 larval surveys were carried out (Figs 2, 3). For these, six survey points were established and the survey always began at the same point. In accordance with the National Pond Survey Method Guidelines (Biggs *et al*., 1998), a standard pond net was used: 250mm wide,

Plate 1. Castle Fraser Flight Pond. Photograph by Toni Watt.

Plate 2. Castle Fraser New Pond. Photograph by Toni Watt.

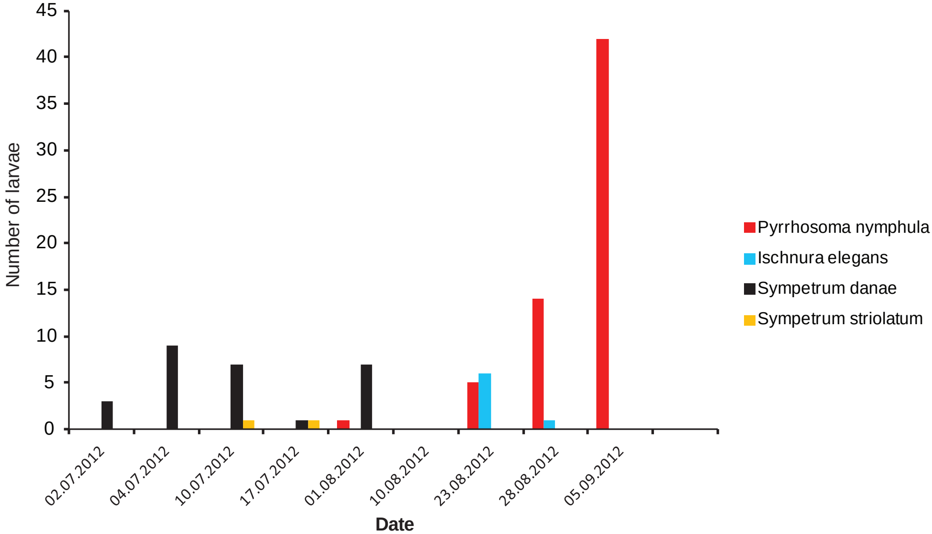

Figure 2. Larval counts on each sample date. The counts for *Lestes sponsa* are shown in a separate graph (Fig. 3) due to the high numbers.

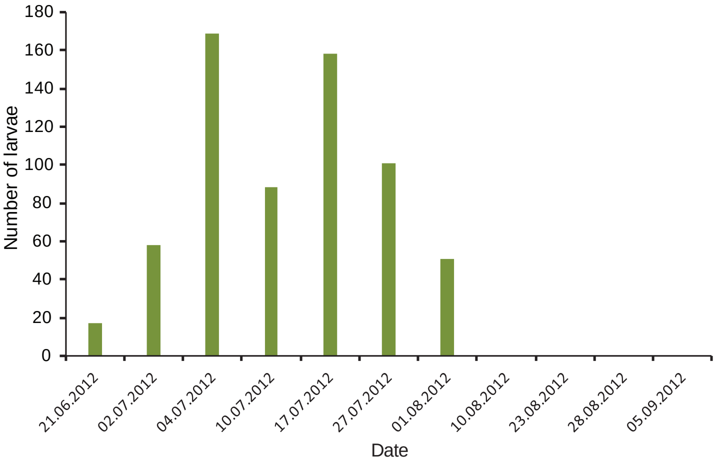

Figure 3. *Lestes sponsa* larval counts on each sample date.

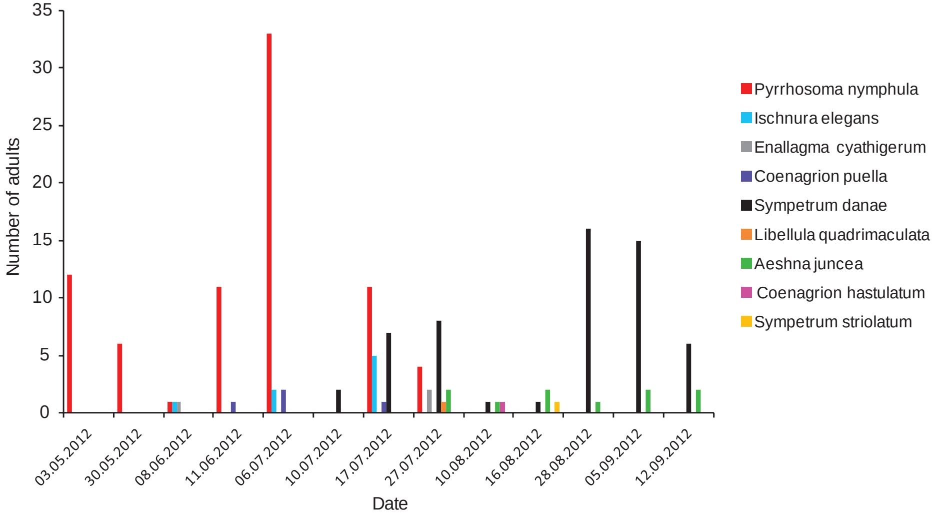

Figure 4. Adult counts on each sample date. The counts for *Lestes sponsa* are shown in a separate graph (Fig. 5) due to the high numbers.

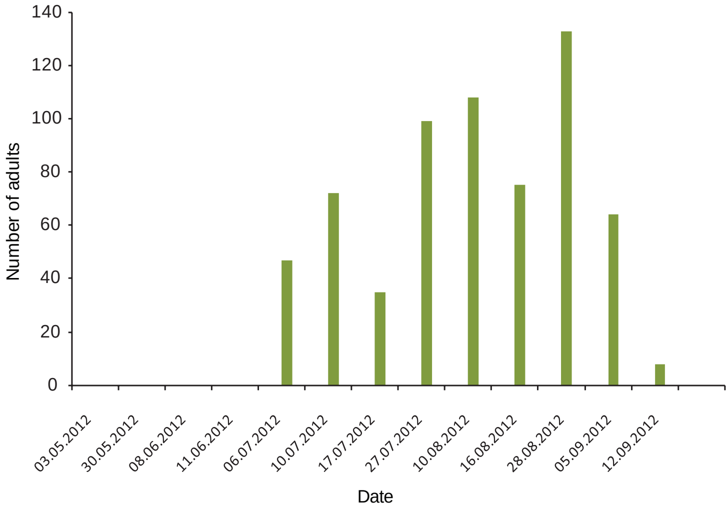

Figure 5. *Lestes sponsa* adult counts on each sample date.

30mm deep and with a 1mm mesh. At each survey point, the dip was carried out for thirty seconds by moving the net in a figure-of-eight motion through the water; this gave a total survey time of three minutes. The net was then emptied into a large, white pond tray and the odonate larvae found were identified to species and counted.

Between 3rd May and 12th September 2012, 10 adult surveys were carried out (Figs 4, 5). A transect around the edge of the pond was established and, using Pentax Papilio binoculars, the surveyor (Toni Watt) spent 45 minutes on each visit carefully following the transect and recording all species observed.

Results

Larval survey

Larvae of five of the ten odonate species were recorded: Three zygopterans (*Lestes sponsa*, *Pyrrhosoma nymphula* and *Ischnura elegans*) and two anisopterans (*Sympetrum danae* and *Sympetrum striolatum*) (Figs. 2, 3). Of these, *L. sponsa* was by far the most abundant species, with well over a hundred larvae obtained on two of the sampling dates, the last ones being recorded on 10 August (Fig. 3). Sightings of them emerging from the new pond were also recorded. *S. danae* was the next most abundant in samples but there were also reasonable numbers of *P. nymphula* and *I. elegans* on the last sampling occasion, towards the end of August (Fig. 2). During the survey, only two larvae of *S. striolatum* were found, as well as a single, separate recording on 15th July 2012 by a different recorder (Juliette Dinning, pers. comm.).

Adult survey

Despite relatively low temperatures during the survey period, each of the species previously recorded at the flight pond was recorded present in adult form at the new pond (Figs 4, 5). *L. sponsa* was the most abundant adult, being present at the new pond for about two months from early July, and over 100 individuals were observed during August (Fig. 5). *P. nymphula* was recorded from the beginning of May, when the first survey was carried out, until the end of August. It was the second most abundant species, with over 30 individuals being recorded on one occasion. The other zygopterans (*I. elegans*, *Coenagrion puella* and *Coenagrion hastulatum*) were only recorded in small numbers; indeed only one individual of *C. hastulatum* was seen (Fig. 4). Separately recorded by Juliette Dinning (pers. comm.) were mating pairs of *P. nymphula, Enallagma cyathigerum* and *L. sponsa* on 24 July 2012, as well as a mating pair of *C. hastulatum* on 27 May 2012

The most abundant anisopteran was *S. danae,* with the highest number recorded on a single day being 16. The species was present from mid-July through to the end of the survey period in early September. *A. juncea* was seen in only small numbers, although there was a separate observation by Juliette Dinning (pers. comm.) of a female *A. juncea* ovipositing on 28th August 2012. Single individuals of both *Libellula quadrimaculata* and *S. striolatum* were observed on two separate occasions (Fig. 4).

Discussion

Corbet (1983) noted that dispersal is one of the limiting factors for odonate colonisation. The close proximity of the new pond to the flight pond allowed odonate species in the flight pond to find the new habitat easily. It also allowed plants and other species to quickly colonise the pond, naturally providing the necessary habitat and resources for odonate larvae. Allowing natural colonisation, rather than planting the new pond with specimens from the flight pond, also decreased the risk of contaminating the new pond with goldfish eggs.

Enallagma cyathigerum, Ischnura elegans and *Pyrrhosoma nymphula* are known early colonisers and were expected to be the first Odonata to breed in the new pond (Merritt, 1994; Dorsetdragonflies, 2013). In the new pond, *Lestes sponsa* was actually found to be the most successful coloniser initially. The early colonisers *I. elegans* and *P. nymphula* were also recorded in the survey but *E. cyathigerum* was not. To begin with, *L. sponsa* larvae were the far more numerous of these species but notable numbers of *P. nymphula* larvae were observed towards the end of the survey.

As the new pond was little over a year old when the surveys began, along with the fact that most of the species are semivoltine, it was likely that the majority of the adults recorded were the result of migration from the flight pond. However, *L. sponsa, Sympetrum danae* and *Sympetrum striolatum* have univoltine life cycles and hence some of the adults observed may well have emerged from the new pond. What is more, it is highly likely that a proportion of *L. sponsa* adults present at the new pond had emerged from the new pond itself and this is supported by the *L. sponsa* larval counts. The number of *L. sponsa* larvae found showed a steady decrease, indicating possible emergence. Emergence is further suggested by an increase in the adult counts of *L. sponsa* at the same time as the larval counts declined.

As of September 2012 no larvae of *Coenagrion puella*, *Coenagrion hastulatum, E. cyathigerum, Aeshna juncea or Libellula quadrimaculata* had yet been observed. Nevertheless, adults of these species were sighted at the edges of the new pond, suggesting that these species had perhaps started to breed in the new pond. A new habitat takes time to develop and stabilise and early

colonisers may experience population surges. However, as later colonisers begin to establish themselves and compete successfully with the existing inhabitants, a more balanced and stable community is likely to emerge (Cleland, 2012).
For future studies, the undertaking of a thorough botanical survey of the pond edges should be considered. This could provide information as to the possible impact of vegetation on odonate populations at the different survey points. Furthermore, factors such as depth, pH and sediment should also be studied to consider their impact on odonate colonisation.

Despite the early stage of the study, the benefits of providing additional suitable habitats within the range of established odonate populations are already evident. Five species rapidly colonised the new pond, suggesting that this course of action may have provided some degree of security for odonate species against ever-changing environmental challenges.

Acknowledgements

Thanks to the British Dragonfly Society for a Philip Corbet award, Juliette Dinning for her expert advice and data, Toni Watt for her guidance, photographs and contribution of adult Odonata data and to the National Trust for Scotland for the research opportunity and support.

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Dorsetdragonflies.org.uk. 2014. http://www.dorsetdragonflies.org.uk/blue-tailed.php

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Possible range expansion of *Coenagrion puella* (Azure Damselfly) in North-East Scotland

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Summary

The clear fell of a coniferous plantation near the Ley Pond at Crathes Castle, Aberdeenshire, in the winter of 2011/12 was followed by a survey of the Odonata populations at the pond, with the purpose of understanding the progress of these populations after a significant change to an adjacent habitat. In the second year of the survey, individuals of *Coenagrion puella* (Azure Damselfly) were found for the first time and this is discussed in terms of range expansion of this species.

Introduction

The presence of trees and bushes in the proximity of a water body can have both positive and negative effects on odonate populations. Such vegetation provides cover for overnight roosting, shelter and food prey but if the vegetation is too close to the water it can lead to shading which, if excessive, is detrimental for most odonate species. The current study aimed to determine the effect on the odonate fauna of a pond where a nearby coniferous plantation was felled in the winter of 2011/2012. Sporadic records had been taken before the clear fell, which provided a reference for the species living in the pond previously.

Coenagrion puella (Azure Damselfly) is a very common and widely distributed species in Britain, mostly south of the Central Belt of Scotland (Hammond, 1983). According to the NBN Gateway (2014), Castle Fraser, which is about 12 miles (19km) north of Crathes, is the most northerly record in North-East Scotland (formerly Grampian). In addition, there are four records in Angus just north of Forfar: at Memus (an introduction in the 1970's (Prendergast, 1986)), at Mile Hill plantation and Loch of Kinnordy (both west of Memus) and at Powsoddie, north of Montreathmont Forest. These last three are all recent (2007) records. There is an old historical record at Scotstown Moor, north of Aberdeen, but the site no longer appears to support this species. There are also records north of the central belt, from near Dundee and to the north-west of Aberdeenshire in Speyside and

Inverness-shire. In addition, there is a record from Shetland but it is thought that this was brought in with pondweed (Pat Batty, pers. comm.). Additionally, in 2013 another two sites close to Castle Fraser have been found and a new pond nearby has also been colonised (unpub obs.). It is not unreasonable to assume that the species may have been previously under-recorded in Aberdeenshire.

Site

The Ley Pond is a small pond on Crathes Estate, Aberdeenshire (British National Grid Reference NO72479683). It has a surface area of approximately 600 m^2 (15x40 m) (Fig. 1). The nearest watercourse is the Coy Burn, which rises in the hills north of Banchory and discharges into the River Dee about 1km from the Ley Pond. The pond is in a sheltered location and is surrounded by a road leading to Banchory on the west and a spruce plantation on the south. It is surrounded by a ring of willow and birch and has a small island in the middle, which also supports these two species of tree. Rushes, sedges and sphagnum mosses make up the surrounding emergent pond vegetation. In summer, pondweed covers much of the pond surface (Plate 1). There was a plantation of conifers on the north and east flanks but this was felled in the winter of 2011/12 (Plate 2).

Methods

Due to the significant change in the habitat near the Ley pond, the National Trust for Scotland started to monitor the populations of dragonflies in the summer of 2012, with the aim of discovering if the clear fell has caused a significant impact on these invertebrates. Both larval and adult surveys were carried out in 2012 and 2013.

Larval Survey

The larval survey was carried out following the National Pond Survey Method Guidelines (Biggs *et al*., 1998). This involved sampling in the different habitats in the pond, with the maximum time of three minutes split between these habitats. Seven sampling points were chosen. The net used had a 1 mm mesh which ensured that even small larvae were caught. After dipping, the net was turned upside down into a tray of water and shaken gently to empty the contents for identification. The larval surveys were carried out on the 30th April and 1st May in 2012 and on the 15th April in 2013.

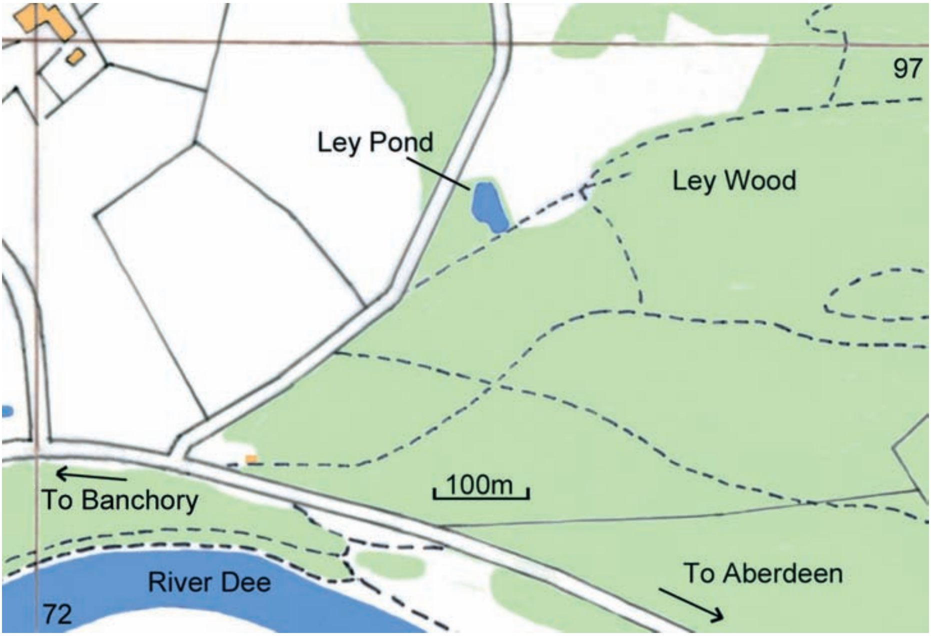

Figure 1. The location of the study site on Crathes Estate, Aberdeenshire. British National Grid Reference NO72479683. Based on Ordnance Survey data and Google Maps Information.

Adult Survey

A series of summer adult surveys were carried out. These surveys used an adapted method based on the Pollard Walk and closely followed the procedure of the British Dragonfly Society Dragonfly Monitoring Scheme (British Dragonfly Society, 2009.) It consisted of walking around the pond, close to the water's edge, identifying and counting every adult dragonfly seen. Pentax Papilio close-focus binoculars were used, as well as a digital camera, when issues of species identification arose. To standardise the surveys, they were carried out over the course of one hour, walking slowly and covering all the edges, once a week when possible. The transect length was approximately 130 metres. Due to the weather and temperature requirements of dragonflies, the surveys were done when the weather was sunny and not too windy. In 2012, 23 surveys were carried out between 16th May and 12th September and 14 were carried out between 20th May and 27th August in 2013.

Following the discovery of adults of *Coenagrion puella* (Azure Damselfly) at the Ley Pond in 2013 (see Results), a search was started to look for larval and exuvial evidence at the pond and also to look for adults in places nearby which

Plate 1. The Ley Pond in summer.

Plate 2. The Ley Pond in winter, showing the effect of the clear felling of conifers to the north of the pond in the winter of 2011/12.

could be the source.

Results

In 2012, the adults of six species of odonates were recorded at the pond, three damselflies and three dragonflies. These were *Pyrrhosoma nymphula* (Large Red Damselfly), *Enallagma cyathigerum* (Common Blue Damselfly), *Lestes sponsa* (Emerald Damselfly), *Aeshna juncea* (Common Hawker), *Sympetrum danae* (Black Darter) and *Sympetrum striolatum* (Common Darter). However, the only larvae found in the samples were those of *Pyrrhosoma nymphula* and *Aeshna juncea* (Table 1).

In 2013, adults of all six species that had been recorded in the previous year were recorded again. In addition, the adults of three further species were recorded, two damselflies and one dragonfly. These were *Ischnura elegans* (Blue-tailed Damselfly), *Coenagrion puella* (Azure Damselfly) and *Libellula quadrimaculata* (Four-spotted Chaser). Of these, *L. quadrimaculata* was recorded in 2011 and also prior to then. *I. elegans* had not previously been recorded at the Ley Pond but did occur in other parts of Crathes Estate in previous years. *C. puella*, however, is a significant discovery as, although it is one of the most common species in the UK, it is uncommon at such a northerly latitude, not usually being found in North-East Scotland. Hence its occurrence was unexpected. Only larvae of *P. nymphula* were found in the samples. However, exuviae of *P. nymphula*, *E. cyathigerum*, *L. sponsa*, *I. elegans*, *A. juncea* and *S. danae* were found (Table 1). Hence these six species can all be considered to definitely breed at this site.

In both 2012 and 2013, *P. nymphula* was by far the most abundant odonate at the site, although it was closely followed in number in 2013 by *L. sponsa*. The exuviae and larvae of three of the species recorded as adults in 2013 (*C. puella*, *L. quadrimaculata* and *S. striolatum*) have not yet been found and hence these may not breed at the Ley pond.

Following a search of the surrounding area, a single adult male of *C. puella* was found at the ornamental pond at Mains of Drum Garden Centre, around six miles from Crathes. No other individuals were found in the vicinity.

Discussion

With only two years of data since the clear felling of the conifer plantation and rather few records prior to that, it is not possible to provide definitive conclusions

Table 1. The total number of larvae, exuviae and adults counted over all surveys in 2012 and 2013.

	2012			2013		
Species	Larvae	Exuviae	Adults	Larvae	Exuviae	Adults
Zygoptera						
Pyrrhosoma nymphula	140	-	437	69	79	177
Lestes sponsa	-	-	17	-	2	121
Enallagma cyathigerum	-	-	52	-	1	28
Coenagrion puella	-	-	-	-	-	6
Ischnura elegans	-	-	-	-	1	1
Anisoptera						
Aeshna juncea	3	-	22	-	1	33
Sympetrum danae	-	-	16	-	21	19
Libellula quadrimaculata	-	-	-	-	-	5
Sympetrum striolatum	-	-	4	-	-	1

about the changes to the dragonfly populations at the Ley Pond. It is of interest that most of the species found in the adult stage were not found in the larval stage. This may indicate that they had not previously bred in this pond or that they had but that, either they were in such small numbers that the sampling was not sufficiently intensive, or that they were present in areas not covered by the sampling. However, on the basis of the exuviae it is clear that larvae of at least six of the nine species were present in 2013.

It is possible that the recording of adult *Coenagrion puella* at the Ley Pond represents a natural range expansion of the species into areas in North-East Scotland. Indeed, there is evidence of more species of animals and plants appearing in regions north of traditionally recorded sites, most likely as a result of climate change. It is also possible that eggs or small pieces of matter containing eggs, could be moved from one pond to another by animals, especially waterfowl, which are highly mobile.

However, there is also the possibility that the species has appeared at the Ley Pond due to an introduction of the species in the vicinity. Thus the record of a single adult male *C. puella* at Mains of Drum Garden Centre could well have been another introduction like that recorded by Prendergast (1986). A member of the staff there confirmed that aquatic plants had been sold from the centre until 2011. These plants had been sourced from the South of England. The garden centre itself is relatively new and the ornamental pond was constructed less than five years ago, having been planted out rather than left for natural colonisation. C. puella has a two year development time and hence larvae transferred as eggs in aquatic plants in 2011 would be seen as emerged adults in 2013. It is also possible that aquatic plants were sold to, or imported by, a nearby owner, from this or another garden centre, with the damselflies having become established at a private pond and then having colonised through the area. With so much commercial transportation today between countries, regions and sites, there is always the potential for unintended introductions of non-native and non-local species. This will continue unless changes in legislation are made.

One aspect of unintentional, direct human introduction involves enthusiastic members of the public who, unaware of the issues involved, may play a part in transferring species between sites. Many people enjoy pond dipping and collecting animals, such as tadpoles, to release into their own garden ponds and, in so doing, transfer other aquatic invertebrates. This may not be a problem if ponds are close and likely to colonise naturally in time. However, if collectors release the captured specimens into a natural pond, native habitats may be potentially threatened.

This brings up an important question about biosecurity and steps in the environmental education process. Making the public aware of wildlife is important and their right to access and enjoy our natural communities is to be encouraged but this should not be the only aim. Biosecurity is an important issue for conservation organisations and successful outcomes on biosecurity strategies will only be effective if the public are involved and made aware. A greater effort should be made with education in this specific area, guiding the public on how best to enjoy wildlife and nature without potentially causing the problems that introductions may precipitate.

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Surveying Odonata: are current monitoring methods up to the task?

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Summary

Surveying odonates has focused historically on adult populations which are visible and amenable to standard types of surveying but recent work has suggested this may be giving a biased result, with consequent impact on conservation decision making and management. This study attempts to investigate whether there is a difference in results of larval and adult surveys and whether any difference found is specific to type of habitat or particular species.

Locations were chosen at Wigan Flashes LNR, Lancashire, utilising a variety of types of water body. Each water body was surveyed using two methods; a standard visual survey for adult species, according to the methods advised by the British Dragonfly Society, and a larval survey involving pond netting. Comparisons between larval and adult survey results were made and the relationships existing between larvae and adults found at the different types of water body were tested. The study found that the different surveys produced different results. Adult Odonata were always found where larvae were present (but not always of the same species) but larvae were not always found where adults were present. This extended over all water body types tested. Results differed when individual species were considered; some species were found to be present at many locations but larvae were absent from a large number of them, some species occurred in larger numbers as larvae than as adults and one species had few larvae found compared to the numbers of adults found. The data were analysed using Fisher's Exact Test. No significant relationship was found between the species richness of adults and larvae found at ponds, lakes or channels using Margalef's Index of Species Richness.

It is concluded that effective surveying requires a combination of surveying for adults, larvae and exuviae to provide unbiased information for use in conservation decision-making.

Introduction

Surveying populations of invertebrates has been the subject of much discussion (New, 1998), with consequences for understanding basic information about population abundances, decline, movement and the general concept of risk of extinction. Counts or surveys which are adequate for plant and vertebrate species have considerable limitations when applied to invertebrates and New (2009) suggested that “often ‘what we see’ in insect surveys at any time or within any single season of sampling is not a valid representation of ‘what is there’”. For many invertebrates, the longest period is spent as larvae, the adult stage being brief. This is true for the Odonata where, for species in Britain, one or two years is typical for the larval stage, followed by a few weeks as an adult (e.g. Smallshire & Swash, 2010). For a mobile species, the presence of adults may not equate to successful breeding (e.g. Hanski, 1999). The standard survey recommended by the British Dragonfly Society is based on counts of adults (Dragonfly Monitoring Scheme, 2010 (see also Moore & Corbet, 1990)); this follows the principles of surveys of butterflies and moths (United Kingdom Butterfly Monitoring Scheme, 2012). The British Dragonfly Society only accepts proof of successful breeding when exuviae are found at a site (Key Sites Criteria, 2004). Observations of ovipositing or the presence of larvae indicate that successful breeding is probable, while the presence of a copulating pair is only an indication of possible breeding. Raebel *et al*. (2010) investigated the relationship between the presence of adults, larvae and exuviae of Odonata and demonstrated a significant difference in results when surveys of adults were compared with surveys of exuviae and surveys of larvae. They suggested that adult surveys on their own could produce biased results with regard to suitable breeding sites. They further suggested that surveying exuviae or larvae provide data of better use for achieving conservation objectives. Their survey was restricted to farmland ponds, which are discrete and specific habitats; the conclusions drawn may not equate to other habitats.

This study investigates whether there is a significant difference between surveys of larval and adult populations. Furthermore, the study attempts to determine how results are influenced by different types of habitat or different species of odonate. Surveys were undertaken over a range of habitats, including ponds in non-agricultural settings, lakes, streams and channels, to widen the habitat range investigated and the species of Odonata present. A survey of exuviae was not carried out. However, Raebel *et al*., (2010) found that surveys of exuviae and surveys of larvae produced similar results.

Site

The location chosen for this survey was Wigan Flashes LNR, south of Wigan, Lancashire (Plate 1). It covers 240ha and lies on either side of the Leeds - Liverpool canal (British National Grid References SD5803-SD5903-SD6002). It contains approximately 15 habitats, many of them wetland habitats of interest and rarity. The southern area includes the Bryn Marsh and Ince Moss SSSI; the northern area, Westwood, was designated an SBI in 2001 (Champion & Rimmer, unpub.). The LNR contains seven lakes (known locally as flashes), numerous ponds and interconnecting streams and channels of varying ages.

Methods

Fifty-seven sampling sites were chosen in January 2012 (so any potential bias caused by visible adult activity was avoided); they were based on accessibility, variability of habitat and if potentially suitable for Odonata. Of these, only 48 were used for analysis due to the remainder becoming inaccessible to survey or showing no evidence of odonate activity.

Plate 1. Pearson’s Flash, one of seven lakes making up the Wigan Flash Nature Reserve, showing typical reedbed habitat at the lake margin.

Adults

The adult survey was carried out between April and September 2012 at monthly intervals. The method followed British Dragonfly Society guidelines (British Dragonfly Society, 2012). The transect was a 100m length along the waters edge or the circumference of smaller water bodies. In most cases, the full transect was walked but, in certain cases where access was restricted, a series of fixed points along its length were used. Each transect was walked between 10.00am and 4.00pm, with wind below force 4 (Beaufort scale), temperature 15 ^{o}C or higher and cloud cover less than 60% (or more at higher temperatures). All species were identified and counted using close focusing binoculars. Any observed feeding, territoriality, mating and oviposition behaviours were recorded.

Larvae

The larval survey was carried out three times, in March, April and July 2012. A location was identified along each transect for sampling the larvae or, where habitat varied along the transect, a series of sampling points were identified. The larvae were sampled by sweeping with a 1mm mesh pond net for three minutes. The collected material was transferred to a white tray partially filled with water and larvae were identified to species and counted. Larvae incapable of accurate identification to species, typically with wing buds not covering the fourth abdominal segment, were excluded (Cham, 2012). Where multiple sampling points were used, the three minutes were divided equally between them.

Statistical Analysis

Fisher's Exact Test (2-tailed) was used to test associations between the presence or absence of adults and larvae found (McDonald, 2009). In this study, a value of P=1 indicates that the presence of the two life stages (larval and adult) are completely dependent on each other; more specifically that sites containing larvae will also have adults present, which is what would be expected if the two survey methods are of equal validity. Conversely, a value of P=0 indicates that the presence of one life stage is completely unrelated to the presence of the other. The test was used to analyse presence and absence of adults and larvae irrespective of species, both at all types of water body together and at each of the three types (lake, pond and channel (natural or man-made) separately. Analyses were also carried out for individual species, with presence/absence restricted to that particular species.

Margalef's Index of Species Richness was calculated for each type of water body (lake, pond and channel) and tested using 2 way ANOVA.

Results

Odonata were present at 48 transects, 36 of these having adults and larvae present and 12 having only adults present only. At no transect were larvae found but no adults. Fisher's Exact Test gave P=1, indicating a certainty of adults being present where larvae were present but no certainty of larvae being present where adults were present (Table 1). This is irrespective of species (i.e. when the species data were combined).

The same result (P=1) was obtained between adult and larval surveys for each of the three types of water body, again irrespective of species. Both lakes and ponds had adults present in 19 transects, four of which had no larvae. In channels, adults were present in 10 transects, in four of which larvae were absent (Table 2).

When the data for individual species were analysed, the results were more variable. In the case of *Lestes sponsa* (Emerald Damselfly), *Aeshna grandis* (Brown Hawker) and *Aeshna mixta* (Migrant Hawker) P=1, confirming that adults were always present when larvae were present but larvae were not always

Table 1. The relationship between the presence and absence of adults versus larvae for all species of Odonata, irrespective of species. The values of P are derived from Fisher's Exact Test (2-tailed).

Group	Adults + larvae	Adults only	Larvae only	Total	P
Odonata	36	12	0	48	1.000

Table 2. The relationship between the presence and absence of adults versus larvae for all species of Odonata by water body (lakes, ponds and channels/ streams), irrespective of species. The values of P are derived from Fisher's Exact Test (2-tailed).

Group	Adults + larvae	Adults only	Larvae only	Total	P
Lakes	15	4	0	19	1.000
Ponds	15	4	0	19	1.000
Channels	6	4	0	10	1.000

Table 3. The relationship between the presence and absence of adults versus larvae for individual species of Odonata. The values of P are derived from Fisher's Exact Test (2-tailed).

Species	Adults + larvae	Adults only	Larvae only	Total	P
Zygoptera					
Lestes sponsa	2	2	0	4	1.000
Ischnura elegans	25	8	5	38	0.563
Enallagma cyathigerum	7	27	1	35	0.229
Coenagrion puella	10	12	4	26	0.100
Pyrrhosoma nymphula	2	9	5	16	0.005
Anisoptera					
Aeshna grandis	10	23	0	33	1.000
Aeshna mixta	3	14	0	17	1.000
Sympetrum striolatum	4	18	1	23	0.217
Orthetrum cancellatum	0	4	1	5	0.200
Libellula quadrimaculata	1	4	2	7	0.143
Libellula depressa	1	2	6	9	0.083
Aeshna cyanea	0	6	2	8	0.036

present where adults had been observed (Table 3). However, *L. sponsa* was only recorded from four transects in total. This positive relationship was also the case for seven other species, although the relationship was less marked, P values ranging from 0.563 for *Ischnura elegans* (Blue-tailed Damselfly) down to 0.083 for *Libellula depressa* (Broad-bodied Chaser).

I. elegans (P=0.563) had a minority of sites where only one stage or the other existed but a much larger number where both existed. *Enallagma cyathigerum* (Common Blue Damselfly) (P=0.229) and *Sympetrum striolatum* (Common Darter) (P=0.217) showed a high number of transects where only adults were found but, for both of these species, there was only one transect in which larvae alone were recorded. For *Coenagrion puella* (Azure Damselfly) (P=0.100), 38.5% of the transects from which it was recorded had both larvae and adults but four of the 26 transects had only larvae present. For *Orthetrum cancellatum* (Black-tailed Skimmer) (P=0.200), *Libellula quadrimaculata* (Four-spotted Chaser) (P=0.143) and *L. depressa* (P=0.083) the total number of transects from which they were recorded was low. For *L. cancellatum* there was no transect where both larvae and adults were present; for the two libellulids, only one transect in each case had both larvae and adults (Table 3).

For two species there was a significant P value, 0.036 in the case of *Aeshna cyanea* (Southern Hawker) and 0.005 in the case of *Pyrrhosoma nymphula* (Large Red Damselfly), which indicate that, for these species the probability is that there is no interdependence of the two life stages, a surprising result. In the case of *A. cyanea*, no transect had both adults and larvae present but the total number of transects from which this species was recorded was low. In the case of *P. nymphula*, only two transects had both larvae and adults, nine having adults present but no larvae and five having larvae but no adults; the total number of transects from which it was recorded was not particularly low (Table 3).

Frequency and Abundance

No species was present at all transects (Tables 3, 4). *E. cyathigerum* was the most frequently found species as an adult and was seen at 34 transects but was only found as larvae at eight transects. *I. elegans* and *A. grandis* were also very frequently found but only with *I. elegans* did the frequency of larvae found approach the frequency of adults found (Fig. 1).

I. elegans were present across the range of water body types and, although mating and territoriality were observed throughout, oviposition was observed only once. *A. grandis* was similarly ubiquitous across the range of water body types and was also observed ovipositing across this range. Although *E. cyathigerum* was present at all types of water body, territoriality, mating and oviposition were only observed at lake transects, with the exception of one mating occurrence at a pond in the near proximity to a lake, which was also the only occurrence of a female found away from lake transects. *L. depressa* was the only species found in a higher number of transects as larvae than as an adult.

E. cyathigerum was the most abundant adult species, with 474 individuals counted (Fig. 2), although only 25 larvae were found. Amongst the other zygopterans, *C. puella* and *I. elegans* were abundant in both adult and larval forms; in the case of *I. elegans* more larvae were found than adults. Of the anisopterans, *S. striolatum* and *A. grandis* were most abundant as adults, although considerably fewer were found as larvae. Twenty-three *L. depressa* were found as larvae but only three adults of this species were seen.

There was a disparity between numbers of Odonata adults seen (1153) and the number of larvae caught (413). This was also the case for all individual species,

Table 4. The total number of transects in which odonates were found, those in which oviposition was observed and those in which both oviposition was observed and larvae were recorded.

Group	Total transects	Transects with Oviposition	Transects with Oviposition and Larvae
All Odonata	48	20	18
Ponds	19	7	7
Lakes	19	11	9
Channels	10	2	2
Ischnura elegans	*38*	1	1
Enallagma cyathigerum	*35*	6	2
Aeshna grandis	*33*	9	4
Coenagrion puella	*26*	7	3
Sympetrum striolatum	*23*	6	0
Aeshna mixta	*17*	1	0
Pyrrhosoma nymphula	*16*	1	0
Libellula depressa	*9*	0	0
Aeshna cyanea	*8*	0	0
Libellula quadrimaculata	*7*	1	1
Orthetrum cancellatum	*5*	0	0
Lestes sponsa	*4*	0	0

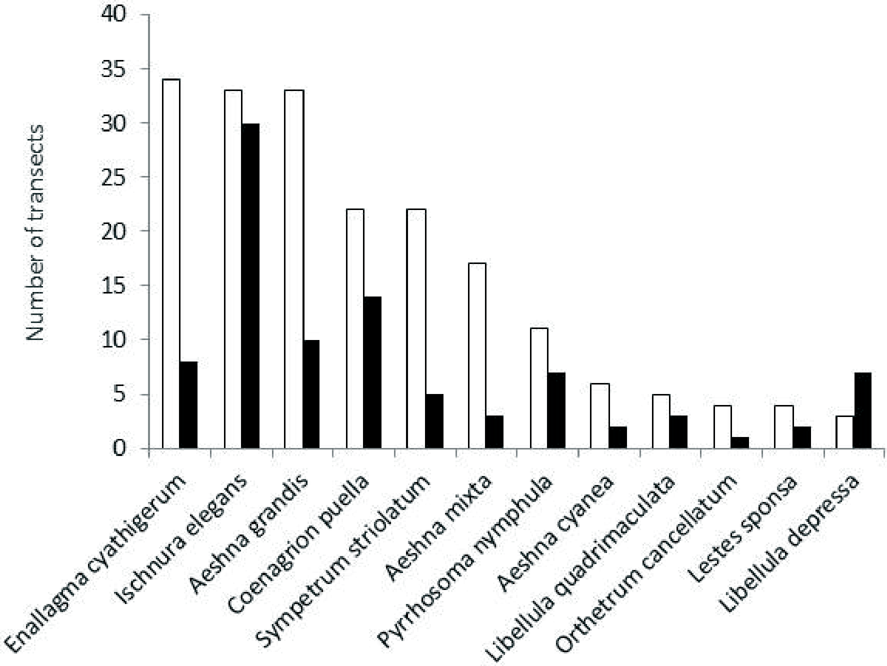

Figure 1. The number of transects at which each species was found. □, adult(s), ■ larva(e). The total number of transects was 48.

except *Ischnura elegans* and *Libellula depressa*, for which species more larvae than adults were found. It was also the case between habitat types, although the difference in abundance of adults and larvae was much less marked for ponds.

Species richness

Margalef's Index of Species Richness, calculated separately for both water body type and for adults and larvae, showed some variations (Table 5). Species richness for adults varied little and was not significantly different across the water body types, being highest at ponds and lowest at lakes. Larval species richness was also highest for ponds, noticeably so compared to lakes and channels. There was no significant difference between species richness of adults and larvae (2 way ANOVA, $F_{2, 3}$ =0.98, P=0.46). The most species-rich transect had 10 species associated with it, eight of which were found as both larvae and adults, one as larvae only and one species as adults only; this was a relatively new and not heavily vegetated pond.

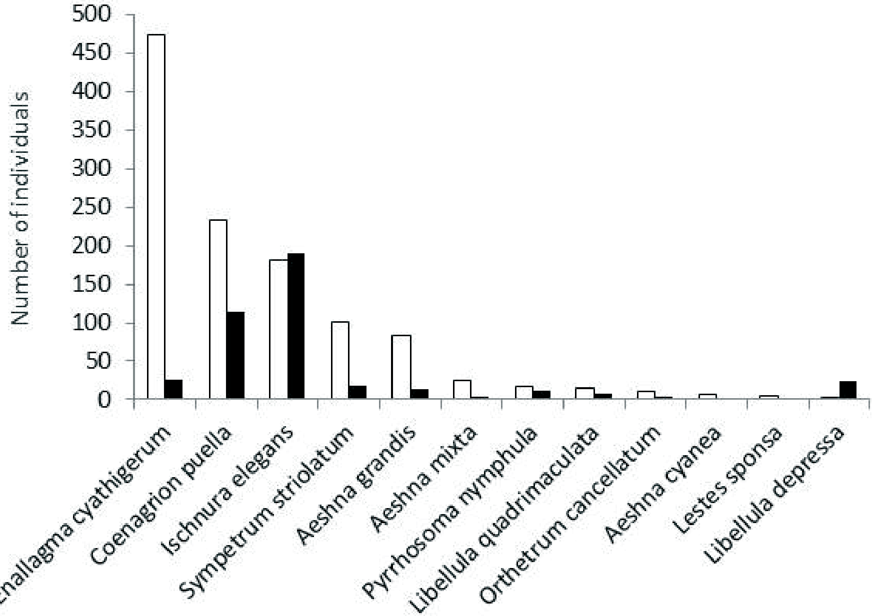

Figure 2. The number of individuals of each species found in total for all 48 transects. □, adult(s), ■ larva(e).

Table 5. The values of Margalef's Index of Species Richness for larvae and adults, according to habitat.

		Channel	Pond	Lake
Adult	Number of Individuals	143	343	667
	Number of Species	9	11	11
	Margalef's Value	1.6120	1.7130	1.5378
Larvae	Number of Individuals	35	251	127
	Number of Species	5	10	6
	Margalef's Value	1.1251	1.6288	1.0322

Oviposition

Oviposition was seen at 20 of the 48 transects which had Odonata present (Table 4). Two transects in which oviposition was observed did not produce any evidence of larvae. *A. grandis* were observed ovipositing at the largest number of transects (9) but larvae of this species were only found at four of those transects. Of the Zygoptera, *C. puella* were observed ovipositing at the highest number of transects (7) but larvae of this species were only found at three of those. Eight of the 12 species encountered in this study were observed ovipositing.

Discussion

There is clear evidence that surveys of adults do not necessarily equate to presence of larvae and therefore to suitable habitats for successful breeding. However, it does show that, where odonate larvae are found, there will also be adult odonates. This confirms the conclusions of Raebel *et al*. (2010), at least with regard to larval and adult surveys. Since both they and Foster & Soluk (2004) found that survey results of populations based on larvae and exuviae are largely interchangeable, it can be supposed that, if a survey of exuviae had been done during this study, the results would have been the same, although abundance and numbers of species may be expected to be higher, particularly in habitats which are more difficult to sample for larvae. This analysis further demonstrates that the difference is not restricted to ponds in agricultural settings but also extends to ponds in other settings, lakes and channels, which suggests it is a general issue with all bodies of water. Locations in which adults are seen do not necessarily demonstrate good habitat for larvae; a number of sites where oviposition was seen to take place in this survey had no larval records, suggesting little larval development would ensue or surviving larvae would be too scarce to appear readily in sampling. It is of course possible that larvae were present but not at the locations where sampling took place.

Sampling Considerations

The adult survey highlighted several problems likely to be encountered frequently. 2012 was the wettest summer since 1912 and the dullest since records began; this was particularly acute in the north-west of England (Met. Office, 2012). In practice, this severely restricted the potential surveying time available and meant that less than ideal conditions often had to be used or frustrating hours wasted when conditions clouded over mid-survey. It is also likely to have had a major effect on abundance, emergence times, survival rates and general activity. Poor weather may explain the small numbers of adults of some of the species seen, although in many cases larger numbers of those species were seen away from the transects. Even with the poor weather, the number of adults seen generally far exceeded the number of larvae caught.

An unexpected consequence of the wet weather was that transects initially deemed accessible became inaccessible owing to heavy growth of vegetation. This was contributed to by reduced maintenance of the reserve, combined with reduced visitor numbers, so paths became overgrown. As well as the direct effects on access, this lush growth also increased shading and encroachment of open water. Furthermore, increased water levels flooded areas of fen and turned ponds which had been discrete bodies into floodplain, allowing movement of species between lakes and ponds across the flooded areas, as noted by Bayley & Li (1996). It also effectively hid the ponds both for purposes of survey and for odonates to locate suitable habitat. However, the impact on surveying was minor, as the larval survey was already completed and the adult survey had repetitions either side of the flood event.

More general problems encountered during the survey for larvae impacted on the time taken to complete it. Sediment was found to be a significant issue in places; large parts of the reserve are on pulverised fuel ash and this has created a very black sediment. Other parts of the reserve had a very peaty, dark sediment that stayed suspended for a long time, which made seeing through the water in the sample tray difficult and required long waits between sampling for it to clear sufficiently. This did not affect larval sample results in this case but would have if sample sorting had been time-limited, as in some environmental surveys.

Difference in abundance of Adults and Larvae

The difference in numbers between adults and larvae is likely to be the result of the very different sampling methods for each type of survey. The adults are generally easy to see and a transect walk has a good chance of accounting for the majority of active Odonata, especially as the area covered in each transect is large. Larvae, particularly those which hide in sediment, are much more difficult to find. For a small pond, a sampling time of three minutes is more likely to provide a good representation of the larvae present than for a lake, where a much smaller proportion of the habitat can be sampled within the time limit. There is always likely to be this disparity in numbers, which will make the estimation of population numbers difficult, becoming more difficult with increase in size of the water body.

Effects of Voltinism

The aim of a survey is to discover what is present and what is breeding and, by inference, make judgements on habitat, ecology, etc. This raises issues pertaining to what life stage to survey and to the habitat and ecological position that this life stage occupies. As New (2009) suggested, “for each insect species, or life stage of that insect, the habitat may be viewed as two interacting and complimentary suites of resources”. Most of the species found during this survey are semivoltine (or longer) (Corbet & Brooks, 2008) and so, for these species, the habitat when oviposition took place may be different to the habitat when emergence occured, generally some two or even three years later. For instance, in the current study, *L. depressa* was found in seven transects as larvae but in only three as an adult; only once were adults and larvae found in the same transect. Corbet & Brooks (2008) suggested that this species prefers early successional habitat with little vegetative cover; the transect in which both forms were found was such a habitat but much of the rest, which may have been open habitat two years previously, is now highly vegetated. Similarly, *Orthetrum cancellatum* larvae were found in highly vegetated areas which were no longer frequented by adults. These are extreme examples but important to consider in habitat management.

Differences Between Species

Whilst it can be argued that surveying for larvae or exuviae gives a better indication of breeding success for the majority of odonate species, this is not the case for all species. In particular, a survey of *E. cyathigerum* based solely on larvae would have produced a very different picture, with only 25 larvae caught and in only 8 transects. This compares to 474 adults observed over 34 transects. *E. cyathigerum* is primarily a lake species and larvae of overwintering species are suggested to move into deeper water to escape freezing during winter (Cham, 2012). Personal observation would suggest that this desire for some depth is not restricted to winter, as the transects where these were found tended to be the precipitous edges of the lakes with a depth of approximately 0.4m or more; most of the lakes in Wigan Flashes LNR slope shallowly, so suitable depth is more distant from the lake edge. This would mean that to survey them adequately would require moving to deeper water and, because many of the lake bottoms are deeply silted, this would require a boat, which would be prohibitive in most surveys. To get a satisfactory number of samples proportionate to the volume of a lake would also be prohibitive for most surveys. Also, as noted earlier, this may mean that, although reasonable numbers of larvae may be present in the lake, they may not have been present where sampling was carried out.

Conclusion

Cham (2012) reported that only 1.2% of records on the Dragonfly Reporting Network relate to larvae, 2.7% to exuviae and 1.3% to emergents. This study, therefore, suggests that 94.8% of the records, while useful for showing adult behaviours and locality, cannot be assumed to show successful breeding sites and good habitat for odonate species.

Surveying larvae will provide a specific record of locations in which species successfully reach late stadia. Locating sites of successful oviposition, larval development and cross-referencing the areas used by adults for meeting, mating and feeding will give an indication of habitat requirements for each of these activities and how they interrelate spatially. This will be of use to reserve managers for managing habitat for the benefit of Odonata and ensuring the importance of existing habitat is understood. Whilst surveying for exuviae would provide proof of successful emergence, the additional time required for this would add costs for limited gains over late stadia larval surveys. Surveys of larvae have the advantage over surveys of exuviae as they do not require synchronisation with times of emergence and are relatively less resource intensive, as they do not require exhaustive searches of vegetation. However, it is clear that some species, particularly lake dwellers, are significantly under-represented in larval surveys, unless highly intensive sampling is undertaken. Ideally, surveys of larvae, exuviae and adults would all be undertaken but financial and time restrictions will usually prohibit this. A survey of exuviae remains the only way of proving the breeding success of odonate species but a combination of larval and adult surveying would seem to offer the best compromise for most purposes to provide the unbiased data necessary to make sound conservation decisions.

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Species Review 8:

Somatochlora arctica (Zetterstedt, 1840) (The Northern Emerald)

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Summary

Somatochlora arctica (The Northern Emerald) is one of seven *Somatochlora* species found in Europe. In the British Isles it is only found in Scotland, where it is widely distributed in the west, and in a very small number of localities in the south of Ireland. The species and its life cycle are described and its conservation is discussed in the light of potential threats and the possible effects of climate change.

Introduction

The genus *Somatochlora* or 'striped emeralds' (Corduliidae) is a large genus, especially in North America. In Britain there are two species, *S arctica* (Northern Emerald) and *S. metallica* (Brilliant Emerald). In addition to these, a further five species are found in continental Europe, i.e. *S. alpestris* (Alpine Emerald), *S. meridionalis* (Balkan Emerald), *S. flavomaculata* (Yellow-spotted Emerald), *S. sahlbergi* (Treeline Emerald) and *S. borisi* (Bulgarian Emerald) (Dijkstra & Lewington, 2006)

Description of *Somatochlora arctica*

Egg

The eggs are ellipsoid to sub-spherical in shape and develop an outer gelatinous layer when in contact with water. They are laid in clusters (Corbet & Brooks, 2008).

Larvae

The larvae have a hairy appearance, unlike any other British species of dragonfly. They are medium-sized, the final instar being 17-20 mm long (Hammond, 1985). The abdomen is short and blunt with a rounded base. It has no dorsal or lateral spines. The legs are long and the hind pair extend to well beyond the abdomen when stretched out. (Cham, 2007) (Plate 1). The labial mask has 8 to11 crenulations, each with three to five setae (Gardner, 1954; Hammond, 1983).

Plate 1. Larva of *Somatochlora arctica* with well-developed wing buds. Note the long legs and rounded abdomen.

Adults

The adults are dark, medium-sized dragonflies. The overall length is 45-51mm, with an abdomen length of 30-36mm and a wingspan of 68mm. In flight, the overall appearance is of a glossy, black body with green eyes. On closer inspection, the wings of the male have a yellow suffusion. The wings of the female are almost clear but tinged with saffron near the base. The pterostigma is reddish brown (Hammond, 1983; McGeeney, 1986).

Plate 2. A newly emerged male *Somatochlora arctica*. Note the waisted abdomen and the calliper-shaped anal appendages. The buff eyes will become brilliant green as it matures. Photograph by Peter Vandome.

Plate 3. A newly emerged female *Somatochlora arctica*. Note the pair of yellow spots on the abdomen. Photograph by Tim Caroen.

The head is bronze-green with yellow mouthparts and two yellow spots on either side of the frons. The eyes are brilliant green, typical of the emeralds, but brown when immature. The thorax is bright metallic green with fine yellow hairs (McGeeney, 1986; Brooks & Lewington, 1997). The dark abdomen reflects metallic green in certain lights.

The male has a relatively narrow, waisted abdomen between segments 3-5. The first two segments and the base of segment 3 are swollen and appear to merge with the thorax (Brooks & Lewington, 1997). These first two segments are marked along the sides with yellow. The male has distinctive calliper-shaped upper anal appendages, ‘earwig’ like with inwardly pointed hooks. No teeth are visible from above but they are irregularly toothed below. The shorter, lower appendages are upwardly curving and tongue-shaped. (McGeeney, 1986; Brooks & Lewington, 1997) (Plate 2).

The female has a distinctive pair of yellow lateral spots on the third segment of the abdomen, with light rings around the first two joints. The abdomen is less slender than that of the male, with a blunt vulvar scale below the eighth segment, which hardly protrudes, unlike that of *Somatochlora metallica* (Brilliant Emerald). The female appendages are cylindrical and almost straight (Hammond, 1983; McGeeney, 1986; Brooks & Lewington, 1997; Nelson & Thompson, 2004; Smallshire & Swash, 2004; Dijkstra & Lewington, 2006) (Plate 3).

Habitat

Somatochlora arctica is a species of peat bogs and runnels and is not usually found over open lochs like the other emeralds. In Scotland, it is usually associated with boggy clearings in native pine woodlands. It can also be found in wet birch and oak woodlands. However, a small number of breeding sites are in open moorland some 2 - 3 km from the nearest woodland.

The breeding habitat includes shallow bog pools, runnels, seepages, old peat cuttings and ditches. Many sites have some water flow. *Sphagnum* is nearly always present, often forming dense mats (Brooks & Lewington, 1997) (Plates 4-7).

Typical sites consist of:

- Moorland slopes with scattered pine, birch or oak, dissected by runnels or seepages, where it is flat or gently sloping and there are boggy hollows.
- Peat bogs with small pools and extensive *Sphagnum.* These can be mires

Plate 4. Sphagnum filled pool-complex in a large boggy area with surrounding woodland and scattered pines at Abernethy, Strathspey (Morayshire).

Plate 5. An extensive area of Sphagnum-filled forestry ditches in a large bog of more than four hectares, surrounded by a mature plantation. Young conifers were cleared 20 years previously. There is water to a depth of 30cm amongst the Sphagnum. Sunart (Inverness-shire).

Plate 6. A runnel in Doire Darach Pinewood (Argyll), which is a productive site for larvae.

Plate 7. A pool in Sunart (Inverness-shire), where 11 exuvia and three larvae were found. The pool is approximately 8 m by 5m and has water flow.

near lochans, in woodland clearings or on open moorland, often near woodland.

- Old peat cuttings or disused forestry ditches which are infilling with *Sphagnum*, in boggy clearings in forestry plantations or along forest tracks or rides.

Surrounding and emergent vegetation at breeding sites includes *Eriophorum angustifolium* (Cotton Grass), *Carex nigra* (Black Sedge), *Narthecium osifragum* (Bog Asphodel), *Drosera sp.* (Sundew) and, occasionally, *Rhyncospora alba* (White Beak Sedge) (Butler, 1983). The water ranges from acidic to neutral (Corbet, 1999).

In Ireland, *S. arctica* is also associated with wet heaths and shallow *Sphagnum* pools (Nelson & Thompson, 2004). In southern and central Sweden, the preferred habitat includes forest lakes, peat bogs and waters with low nutrients (De Knijf *et al*., 2011). It may be that the species has a wider range of habitat preferences in Scandinavia than in those parts of Europe where it is at the edge of its breeding range (De Knijf *et al*., 2011).

In the rest of Europe, the habitat is similar, i.e. floating *Sphagnum* bogs, puddles overlying *Sphagnum sp.* and with *Scheuzeria palustris* (Rannoch Rush) present. It also occurs in transition bogs with *Menyanthes trifoliata* (Bog-bean) and sedges (Corbet, 1999) and in raised mires dominated by *Sphagnum* mosses, where it breeds in the smallest, shallowest pools, seepages and tiny rivulets (De Knijf *et al*., 2011). In The Netherlands, it is associated with peat areas on moorlands or in peat areas surrounded by forest, old peat cuttings and small peat-filled pits (Groenindijk & Bouwman, 2010).

Wildermuth & Spinner (1991), in experiments, showed that sparkling reflections on their own are not attractive to *S. arctica.* Peat bogs have floating vegetation which breaks up reflected light and adults are drawn to this habitat rather than to large areas of open water.

Altitude

Somatochlora arctica can be found on lowland mires and in mountain areas. In Scotland, breeding sites generally have been found from just above sea level to 350 m above sea level (a.s.l.) in Argyll. However, an unusually high breeding site was recorded in 1989 at 510 m a.s.l. on Meall nan Samhna, in Perthshire, but it has not been seen there recently. In Ireland, the only two known sites are both low lying, below 85 m a.s.l., and are close to broad-leaved woodland in Killarney (Nelson & Thompson, 2004).

In the French Alps, it reaches an altitude of over 2000 m a.s.l. (Grand & Boudot, 2006) while, in the Swiss Alps, 90% of sites are at an altitude of 800-1900m a.s.l. In the southern part of its range, it is limited to mountain areas, possibly due to the absence of peat outside the mountain ranges (De Knijf *et al*., 2011). In Romania, it is found at 1360-1380 m a.s.l., where it coexists with *Somatochlora alpestris.* The latter species has an altitudinal range up to 2500 m a.s.l. (De Knijf *et al*., 2011).

Life Cycle

Eggs

Eggs are laid in tiny areas of open water overlying bog moss (Smith, 1984; Smallshaw & Swash, 2004) or occasionally into wet peat. They are sometimes laid on the surface of moss close to the water and hatching is then delayed until water levels rise (Corbet & Brooks 2008). A jelly-like layer develops after 30-60 minutes, which is strongly adhesive, sticking the eggs to vegetation. The eggs are laid in clusters and those in the middle of the clump may die from oxygen deficiency (Sternberg, 1995).

Somatochlora arctica lays diapause and non-diapause eggs, the proportion of the former increasing later in the season. Diapause is a state of suspended development which can occur as a response to unfavourable conditions. This stops eggs hatching late in the season when it is too cold for larvae to feed (Corbet & Brooks, 2008). Thus, eggs laid late in the season can overwinter in this stage, developing slowly and hatching in the spring, when water temperatures are more favourable (Sternberg, 1995).

Larvae

One to two days after hatching, the larvae sink to the *Sphagnum* at the bottom of the pool (Corbet, 1999). In Scotland, larvae live amongst *Sphagnum* in a semi liquid '*Sphagnum* soup' (Butler, 1983) or in shallow water just above the *Sphagnum*. They have been found in pools as small as 25 by 15cm with a water depth of 10-30cm. However, the water level can vary according to weather conditions. They can be found in long narrow ditches or depressions. Pools often have some water flow and many are associated with runnels; they have at least 50% *Sphagnum* cover. Larvae may also be found in shallow water (10cm deep) flowing over *Sphagnum.*

Larvae are able to survive dry periods by retreating deep into the *Sphagnum* and they have been reported surviving some 30cm below the surface (Brooks & Lewington, 1997). The hairy body reduces water loss. Larvae of *Somatochlora spp.* have the capacity to rehydrate and behave normally after nine months in dry moss without free water (Corbet, 1999). At high latitudes *Somatochlora spp.* larvae are able to suspend development for several months and can overwinter at any stage of development (Corbet, 1999).

Shallow bog pools and runnels often dry out during periods of spring and summer drought. During these times it is very difficult to search for larvae without damaging the sites. On several occasions, exuviae and emerging adults have been found at sites with no visible water. It is not known whether larvae are able to feed in this situation or suspend development until wetter conditions return. The density of many populations appears to be low, as few larvae are ever found in any one site. In runnels, in particular, they can be the only dragonfly species present. However, where *Libellula quadrimaculata* (Four-spotted Chaser) and *Pyrrhosoma nymphula* (Large Red Damselfly) larvae are present, these latter species are usually found in larger numbers (Butler, 1983; Brooks & Lewington, 1997). Other species found with *Somatochlora arctica* include *Leucorrhinia* *dubia* (White-faced Darter), *Sympetrum danae* (Common Darter) and *Aeshna caerulea* (Azure Hawker). In cases of co-existence, *S. arctica* larvae are found in the shallowest parts of the water body with the greatest *Sphagnum* cover (Brooks & Lewington, 1997).

Tansley Bog in the Loch Maree area of Wester Ross was sampled for larvae between 1998 and 2000. A small area with extensive *Sphagnum* cover had dozens of *S arctica* larvae and few *L. quadrimaculata* larvae in 1998. The reverse was true in 2000, when several small holes had been created in the *Sphagnum*. This suggests that opening up even small areas of *Sphagnum* favours *L. quadrimaculata* at the expense of *S. arctica* (Smith & Fairweather, pers. com).

From personal experience, larvae are elusive and many hours can be spent searching suitable habitat to find one larva, even at known sites. For example, at Meall na Samhna in Perthshire, three days were spent in 2010 and 2011 looking for larvae but only one emerging adult was found. At Crannach Pinewoods (Argyll), eight days were spent in total during 1998, 2002 and 2007 trying to locate the breeding site. Two larvae were eventually found in 2007 in one small pool. When the site was revisited in 2013, larvae were not present in this pool but two larvae were found in another boggy runnel some distance away after half a day searching. At Uath lochs in Strathspey, Betty and Bob Smith spent two hours intensive searching to produce two larvae and five exuviae during two visits in July (Brooks & Lewington, 1997).

The same breeding pools are not regularly used, particularly at the edge of the breeding range. At Carsaig mires in Argyll, three larvae were found in 1998 and 11 exuviae in 2000. Despite searching annually since then, larvae have not been found. However, in 2013 two larvae and an adult were found at a new site in the area several miles away. Some sites are more consistant and hold a good population. Thus larvae have been found in the same area of Doire Darach Pine woods (Argyll) in 1998, 2002, 2004, 2007 and at sites nearby in 2009 and 2010. A maximum number of 44 larvae were recorded here on 12 May 2002, scattered along a number of runnels in the wood and a roadside ditch.

The sizes of larvae from three sites in the west of Scotland (Doire Darach, Sunart and Crannach Wood) have been measured (Fig. 1). They ranged in size from 5 mm to 19 mm, the largest having well-developed wing buds and being close to emergence. The larvae were caught in May, June and August. Those obtained in May were from early in the month, before any emergence had occurred, and all size classes were represented without obvious cohorts of a particular size; the majority were between 8 mm and 16 mm (Fig. 1). Records for June and August were from smaller samples and the larvae were, as expected, larger as

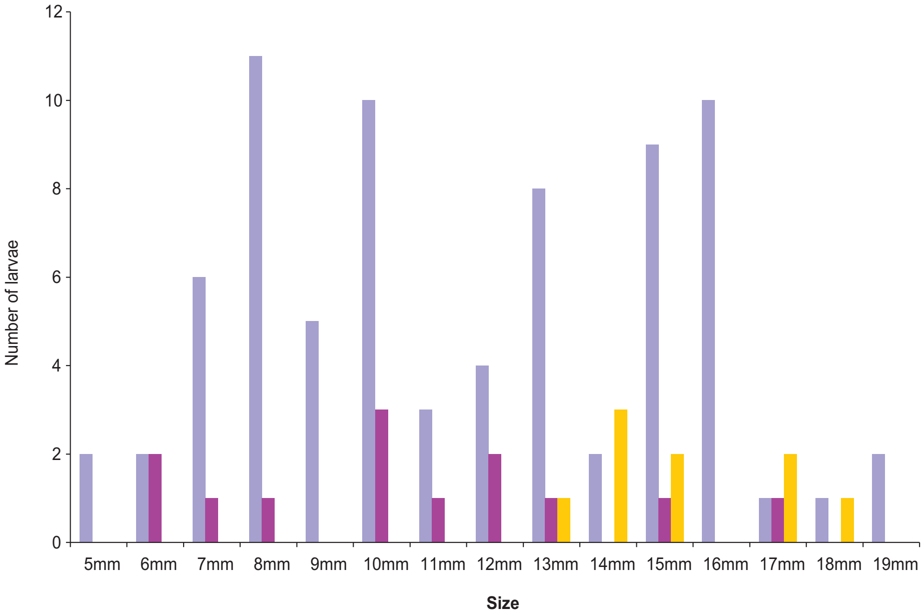

Figure 1. Sizes of larvae of *Somatochlora arctica* found at three sites in the west of Scotland from 1998 to 2013. The records are from 10 May 1998, 12 May 2002 and 6 June 2004 at Doire Darach (Argyll), 8 August 2007 at Crannach Wood (Argyll) and 24 June 2013 and 6 August 2013 at Sunart (Inverness-shire). May June August.

the season developed. The distribution of sizes (Fig. 1) indicates at least a two-year period of development, as noted by Corbet & Brooks (2008).

Two *S. arctica* larvae were captive-reared and survived to maturity before being released. They were seen feeding as soon as food was given (Smith & Fairweather, pers. com.). This contrasts with *Somatochlora metallica* larvae, which fed secretly (Batty, 2013; Fairweather, pers. com.). The sizes were recorded from when they were collected in May 2000 to when they emerged in May 2001, noting their size at each moult (Figs 2, 3). One larva (A) was 8 mm long at capture and took 100 days to reach 15 mm. During this time it had three moults, taking 16 days for the first, 45 days for the second and 35 days for the third, growing 2-3 mm between moults. Larva B started at 11 mm long and had two moults, growing 4 mm in 40 days to reach 15 mm. The first moult occurred after 11 days, the second after a further 30 days. Both over-wintered as larvae: A at 15.5 mm and B at 17.5 mm (Fig. 3).

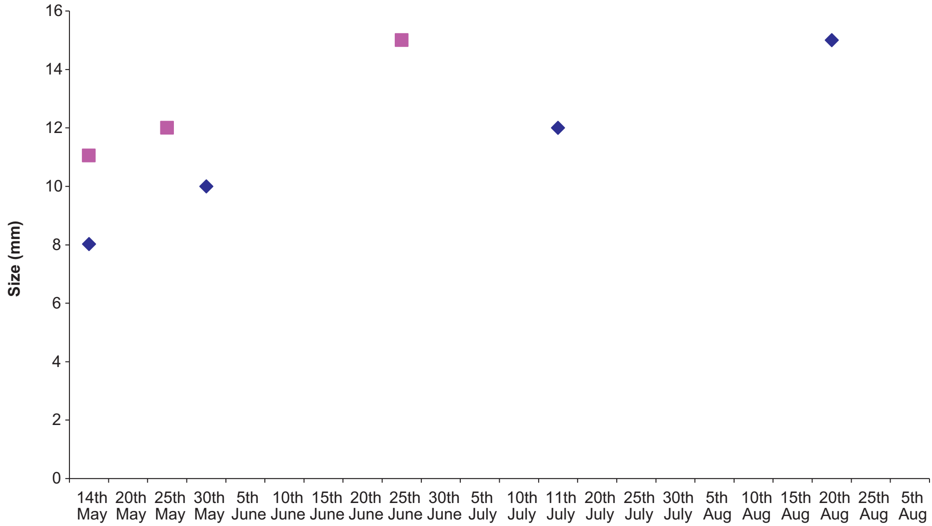

Figure 2. The size and date of moulting in 2000 of two captive reared *Somatochlora arctica* larvae. ◆ A ■ B. Information from Betty Smith and Lesley Fairweather.

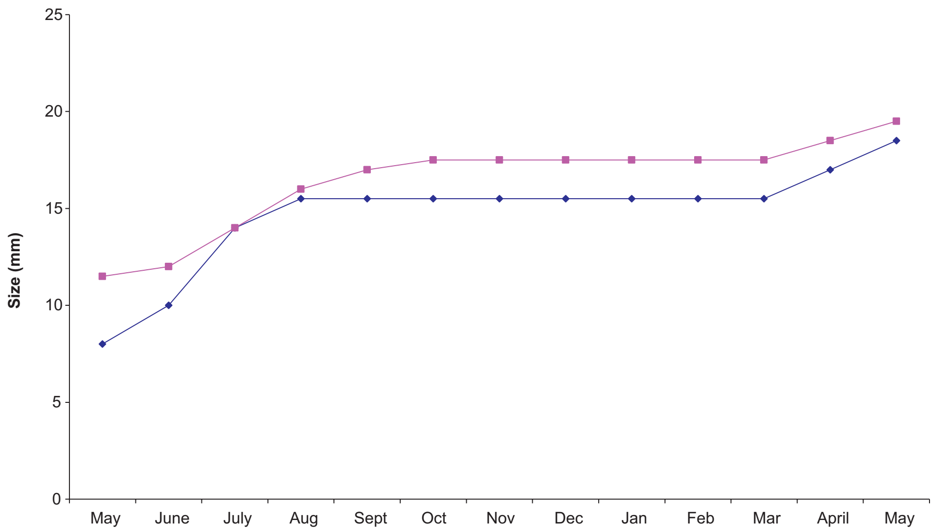

Figure 3. The size of two captive reared larvae of *Somatochlora arctica*, from their capture in May 2000 to their release in May 2001. ◆ A ■ B. Information from Betty Smith and Lesley Fairweather.

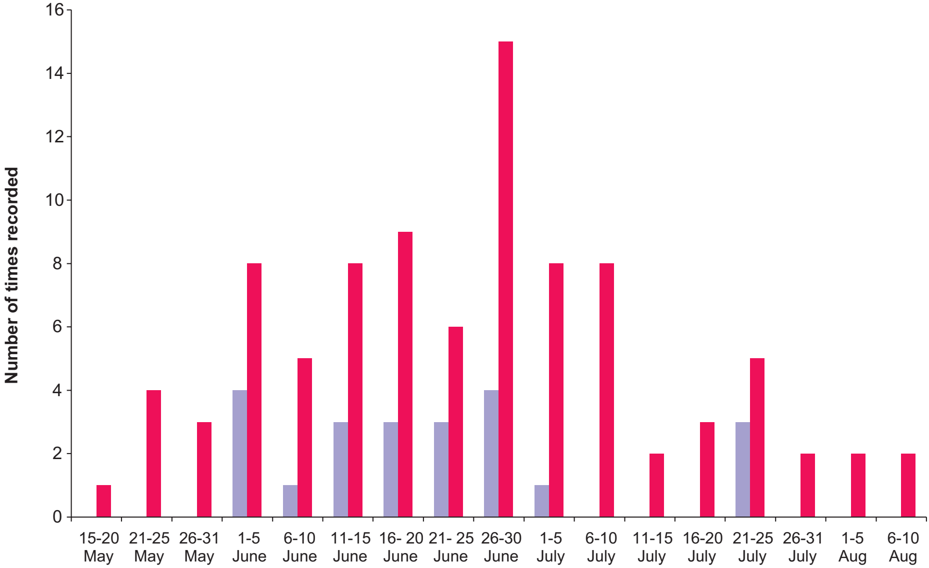

Figure 4. The dates when exuviae and emerging adults of *Somatochlora arctica* were recorded, based on the British Dragonfly Society records from 1900 to 2013. The data are from over twenty-five sites from throughout Scotland. Exuviae Emerging.

Emergence

In Scotland, the main emergence period of Somatochlora arctica extends throughout June into July, although exuviae have been recorded from 17 May to 9 August (Fig. 4), based on records from a range of sites throughout Scotland from 1990 to 2013. In Scottish weather conditions, exuviae rarely remain long at a site after emergence; thus their presence gives some indication of emergence dates. Emerging adults have been recorded from 2 June to 25 July (Fig. 4).

In Corbet & Brooks (2008), *S. arctica* is classed as a Type 1 or 'spring' species. Such species exhibit a synchronised emergence in the spring or early summer, with 50% of emergence occurring over a short period of time. Also, the larvae of spring species that are going to emerge the following spring usually overwinter in the final stage of development. However, from Scottish data, the extended emergence period (Fig. 4) and range in larval sizes (Fig.1), indicate that *S. arctica* does not have the characteristics of a 'spring' species. This is further supported by an emergence study at Tansley Bog in 2000 (Smith & Fairweather, pers. com.). Here, 58 out of 65 (89%) of *L. quadrimaculata* exuviae, which is a 'spring' species, were collected from emergence posts between 12 and 19 May,

Plate 8. Exuvia of *Somatochlora arctica* in a typical emergence site, 5cm up on rush.

whereas, in comparison, *S. arctica* exuvia were found on two occasions 38 days apart (six on 11 June and five on 19 July) (Smith & Fairweather, pers com.). Exuviae have been found clinging to emergent vegetation, including grasses, sedges, rushes and *Myrica gale* (Bog Myrtle). They were generally found at a height of approximately 5 to 10 cm, occasionally 25 cm (Brooks & Lewington, 1997; Vandome, pers. com. 2011) (Plate 8). The largest number of exuviae found at a site was 20; these were at Ardnamurchan (West Inverness-shire) on a large area of *Sphagnum* mire, approximately 300 m by 300 m, where six people searched for over an hour.

Emergence usually occurs early in the morning in calm, moist conditions. Midttun (1977) found that peak emergence was observed between 8:30 and 10:00 a.m. In poor weather conditions, emerging adults have been seen in late afternoon. An extended emergence of over five hours has been recorded and photographed by Vandome (pers. com.), with the first flight not taking place until a day and a half later. Thus, on 14 June 2011, he located a larva searching for a suitable support and observed it over a period of 30 minutes in and out of the

A

B

C

D

Plate 9. An emergence sequence for *Somatochlora arctica*. (A) larva seeking emergence site, in its final position at 10:18, (B) start of emergence at 11:20, (C) adult exiting the exuvia at 11:28, (D) wings expanded and starting to colour at 13:14. Photographs by Peter Vandome on 14 June 2011.

water, until it finally found a stem that was strong enough. The larva was in its final position by 10:40. Emergence started at 11:16 and the emerging adult was clasping the exuvia by 12:15 and the wings were fully expanded by 12:45. The final colouration took over 90 minutes (until 15:30), by which time the wings had opened. On 15 June, after overnight rain, the male pre-flight teneral was still in the same place when visited twice that day. It had disappeared by 12:25 on 16 June when weather conditions improved and presumably it had flown (Plate 9).

Adult

In Scotland, the flight season of *Somatochlora arctica* is from mid-May to mid-September, the latest adults being recorded on 21 September (Brooks & Lewington, 1997). However, in the far north of Scandinavia the season can be more restricted, i.e. from mid-July to mid-August (Dijksta & Lewington, 2006).

The species is elusive. Adults forage along woodland rides and high among tree tops. They have been seen feeding amongst trees and scrub, using a slow leisurely flight, occasionally perching on branches. When disturbed, they will ascend rapidly and disappear over the tree tops. If the sun goes in or the temperature drops they will quickly perch on heather or amongst foliage in the trees. (Brooks & Lewington, 1997; Dijkstra & Lewington, 2006).

Males also fly fast with a zigzag flight, dashing to and fro or pausing to hover at waist height. When guarding a territory, they patrol low over bog pools no more than a metre above ground, frequently hovering in one place before resuming a steady flight. They will suddenly disappear from a territory to resume feeding. The main period of territorial behaviour is in the morning or early afternoon (Nelson & Thompson, 2004; Smallshire & Swash, 2004; Dijkstra & Lewington, 2006). Aggressive interactions with other male *S. arctica* are common. Clashes occur between rivals, when they can fly up high and then drop downwards, intertwining in a spiralling flight. Afterwards they will fly off in different directions (Brooks & Lewington, 1997). Clashes have also been recorded with *Aeshna juncea* (Common Hawker) and this can curtail the time a male *S. arctica* spends at a site. Breeding sites are widely scattered, so adults do not remain long at a site.

Females are inconspicuous, flying very low over the bog. If detected by a male, they will fly into the woods pursued by the male. If a male comes too close, the female will plunge into the sedges and feign death. The pursuing male will stop and hover trying to locate her (Corbet & Brooks, 2008). When a male finds a female, the pair fly off in tandem into trees or scrub to mate. Copulation takes over an hour (Brooks & Lewington, 1997).

The female lays eggs alone in flight, with the tip of her abdomen held up, dipping it into small areas of open water overlying bog moss or wet peat (Smith, 1984; Smallshaw & Swash, 2004). Although males are sometimes hovering close by, the female is often alone. She regularly moves to different oviposition sites and dips at intervals of 0.5 to 1.5 seconds (Brooks & Lewington, 1997).

Distribution

Somatochlora arctica is a boreo-alpine species. It is widely distributed in the Baltic Countries, Scandinavia and north-east Europe (Askew, 1988; Dijkstra & Lewington, 2006). Its range extends across Siberia east to Kamchatka and Japan. It is also found in the mountains of central Europe (Switzerland, Austria, North Italy, Poland, Czechoslovakia, Hungary and the eastern Pyrennes) (Merritt *et al*., 1996; De Knijf *et al*., 2011) and in heaths and fenlands in the north European lowlands of Belgium, The Netherlands, Germany and Poland. Towards the southern edge of its range its distribution is scattered (Dijkstra & Lewington, 2006). In large parts of Europe, knowledge of its distribution is limited; it is rarest and least known in the north-western part of its range (Groenendijk & Bouwman, 2010). It has been found recently in Bulgaria and at two sites in Romania (De Knijf, 2011). In the British Isles it is only found in Scotland and in Co. Killarney in Ireland.

Scottish Distribution

In the UK, *Somatochlora arctica* is only recorded from Scotland (Fig. 5). It was first recorded from the Blackwood of Rannoch in1844 by Richard Weaver (Merritt *et al*., 1996) and is still present there.

Through increased field work for the first atlas of Dragonflies of Britain and Ireland (Merritt *et al*., 1996), the number of recorded hectads doubled between 1982 and 1990 (Brooks & Lewington, 1997). Since then, the increase in recorded distribution has continued and the number of recorded hectads nearly doubled again by 2012. Thus, *S. arctica* has been recorded in 71 hectads since 2000, with a further 12 hectads recorded between 1990 and 2000, giving a total 83 hectads, compared with 45 by 1990. Since 2000, there have been records from 34 new hectads (Fig. 5). However, some hectads have not been revisited. Also there are still many areas to be visited and old records, prior to 1990, to be investigated (Fig. 5). Thus it is likely that the number of known sites will continue to increase.

Many sites are isolated bog pools and runnels in upland areas which are difficult

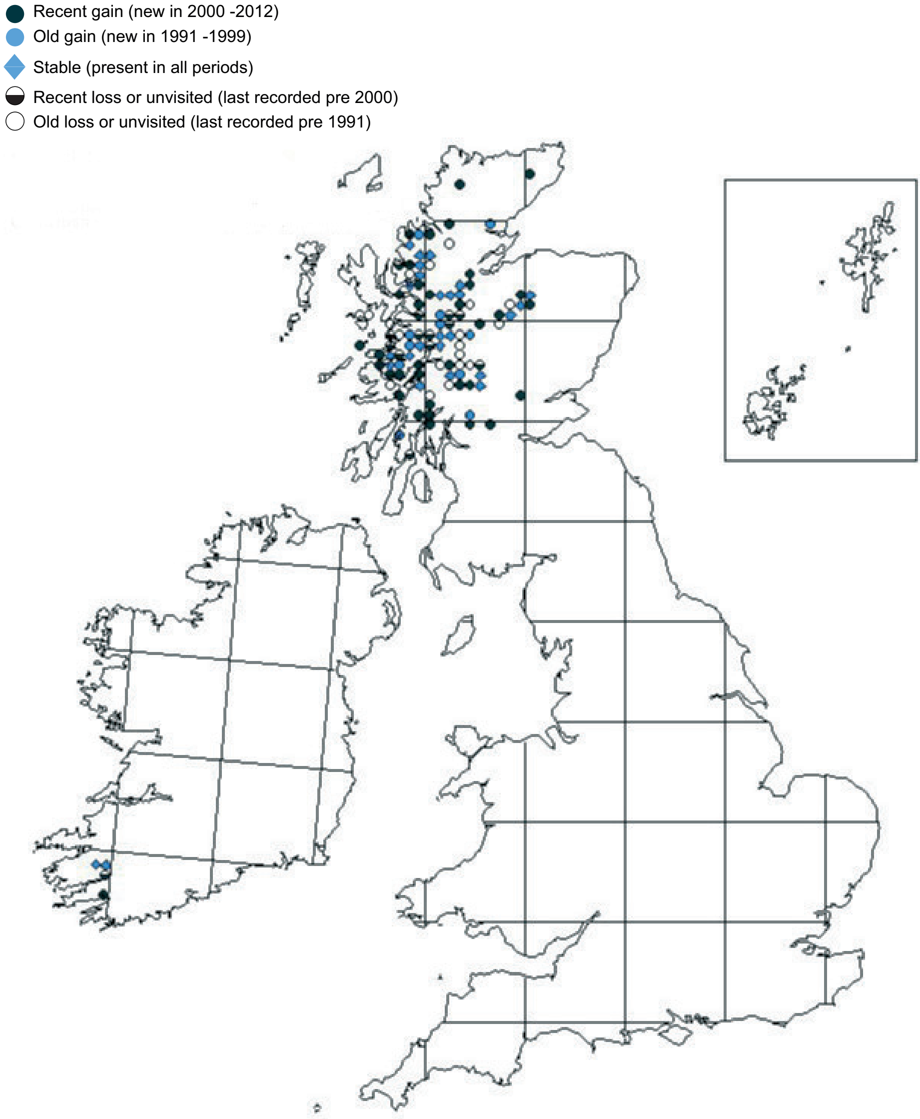

Figure 5 Distribution of *Somatochlora arctica* in Great Britain and Ireland.

to access. These have been less attractive to odonatists in the past. However, there has been increased recording in these areas. In particular, the habitat requirements of larvae are now better understood. Recording of larvae and exuviae is not as weather dependent as recording adults and this has helped increase the number of sites found. New sites are being discovered each year.

S. arctica has strongholds in the pinewoods of Strathspey, Glen Affric and in areas along the west coast. These include Mull, Loch Arkaig, Ardmamurchan and Sunart, then north to Torridon and the Loch Maree area. The known range has recently been extended considerably north into Caithness and Sutherland and south into Argyll. However, its distribution is scattered. The most northerly breeding record is from Spinningdale bog in Sutherland and the most southerly sites are Flanders Moss in Stirlingshire in the south-east and near Lochgilphead in the south-west. A single adult was seen on the island of Muck. The recent discovery of *S.arctica* in Sutherland in 2011 and in Caithness in 2012 could lead to further records, as both these counties have large areas of potential habitat.

Conservation

In Europe, the species is declining, particularly on lowland heaths. In The Netherlands, where it has declined in the twentieth century down to a handful of sites, it is now endangered and subject to a species protection plan. In France, outside the mountains, it is hardly found. In Germany, though it is common in mountain areas, it is only known from a few isolated localities in lowland areas. However, recent work in Lower Saxony (Niedersachen) has shown that it is present at more sites than previously assumed (Bouwman & Groenendijk, 2007). It is Ireland's rarest dragonfly and, under the IUCN Red List criteria, it is classified as vulnerable due to its restricted range (Nelson & Thompson, 2004). *S. arctica* is a nationally scarce species in Britain and is regarded as near threatened (Daguet *et al*., 2008). However, after recent field work, the species appears to be more widespread than was originally thought (see above).

Conservation is difficult. For instance, sites are widely scattered, often isolated, areas of peat bog. The viability of many sites is not known; some have been visited for several years in succession before the species was recorded again. The southern sites in particular have intermittent sightings. Thus it can be difficult to be definitive about the current status of a site. Only a small number of known sites produce records on a regular basis but this most probably reflects the accessibility and popularity of sites for recorders. At some sites, only a single individual has been seen. Thus, Flanders Moss has records for one exuvia in 2007, a larva in the same area in 2010 and an adult in 2013. Indeed, at only a few sites have more than five individuals been recorded. The sites with larger populations generally are in its stronghold areas. On a rare occasion, 50 individuals were seen along several kilometres of forest road in woodland near Claish Moss (Sunart, Inverness-shire).

Threats

Across its European range, habitat decline is a serious threat to the species. In The Netherlands, habitat has been lost through agricultural expansion and peat cutting. The remaining peat lands are of poor quality and suffering from desiccation or eutrophication. Other threats include the spread of scrub, birch and willow (Groenendijk & Bouwman, 2010); also drainage of sites and afforestation.

In Scotland, there have been significant changes in the upland habitat over the last sixty years, with the expansion of commercial forestry and changes in grazing patterns. Some historical sites from the early 1900s are now covered with extensive forestry plantations. On resurveying some of these sites (e.g., at Tulloch and Glen Spean (near Fort William)), *Somatochlora arctica* was not found and suitable breeding habitat had become limited.

Continuing afforestation and drainage of sites is the main threat to the species. Small bog pools and runnels with little water, often scattered in remote upland areas or woodlands, are difficult to locate and protect. The pressure for planting areas will continue with the Scottish Government's forestry strategy to offset climate change. However, the expansion of conifers into formerly open areas does provide shelter and feeding areas for adults but some bog habitat needs to be left unplanted. The species has also colonised some forestry ditches.

Other threats include cessation of grazing and fencing for conservation management in native woodlands. This can lead to the increase of scrub and to extensive growth of *Molinia caerulea* (Purple Moor Grass) and of *Sphagnum,* making sites less favourable. Sites also become infilled through natural vegetational succession. If possible, the best wetland areas should remain unfenced, as at Doire Darach in Glen Orchy, Argyll.

Climate Change

Somatochlora arctica has specialist habitat requirements. In Europe, one of the main problems of climate change is the increased occurrence of extreme events, particularly extended periods of summer droughts (Groenendijk & Bouwman, 2010; De Knijf *et al*., 2011). This leads to drying out of the small breeding pools and the desiccation of peatlands. This has caused some local populations to become extinct in Switzerland. These events are more likely to be critical in determining the survival of local populations than long-term, continuous climate change (De Knijf *et al*., 2011). However, they might become more frequent as climate change continues. Conversely, increased precipitation can lead to the fall out of nutrients and increased acidification of pools (De Knijf *et al*., 2011) and possibly promote *Sphagnum* growth. New sites with peaty vegetation are unlikely to develop in the next few decades at those higher altitudes where *S. artica* occurs in southern Europe (De Knijf *et al*., 2011).

In Scotland, *S. arctica* is on the edge of its climatic range. In upland areas, peat bogs are a dominant habitat. Sites do become dry during periods of drought. However, they are replenished later as a result of our wet climate and larvae can survive drought by retreating into the *Sphagnum.*

Management

In The Netherlands, sites are being actively managed through:

- Coppicing encroaching trees and bushes,
- Creating new pools and peat pits in bogs where *Sphagnum* grows
- Blocking drains to stop local run off

In Scotland, some sites have become dry in periods of drought. Some sites have also become completely infilled through natural vegetational succession. Other sites have been afforested. *Somatochlora arctica* has benefited from the removal of conifers for broad-leaved regeneration and deer management. It has the ability to colonise old peat cuttings and forestry ditches as *Sphagnum* growth increases. It may be possible to carry out specific management similar to that in The Netherlands in the future, if necessary, to safeguard this species. This may involve creating new pools. However, getting the right balance of *Sphagnum* and open water, with some water flow, may be difficult as we are still learning about the ecology of this species.

Conclusion

Further recording and study of the species is needed to determine the extent of its distribution and to increase our ecological knowledge of the species. In Scotland, *Somatochlora arctica* is now known from more sites and is more widespread than was previously thought. Recording work for the atlas suggests that, with increased field work, it is likely to be found at more sites in the future.

However, knowledge of this species is patchy, with little published work. More research and observations are needed on the habitat requirements and the phenology of *S. arctica* to enable full understanding of the species.

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