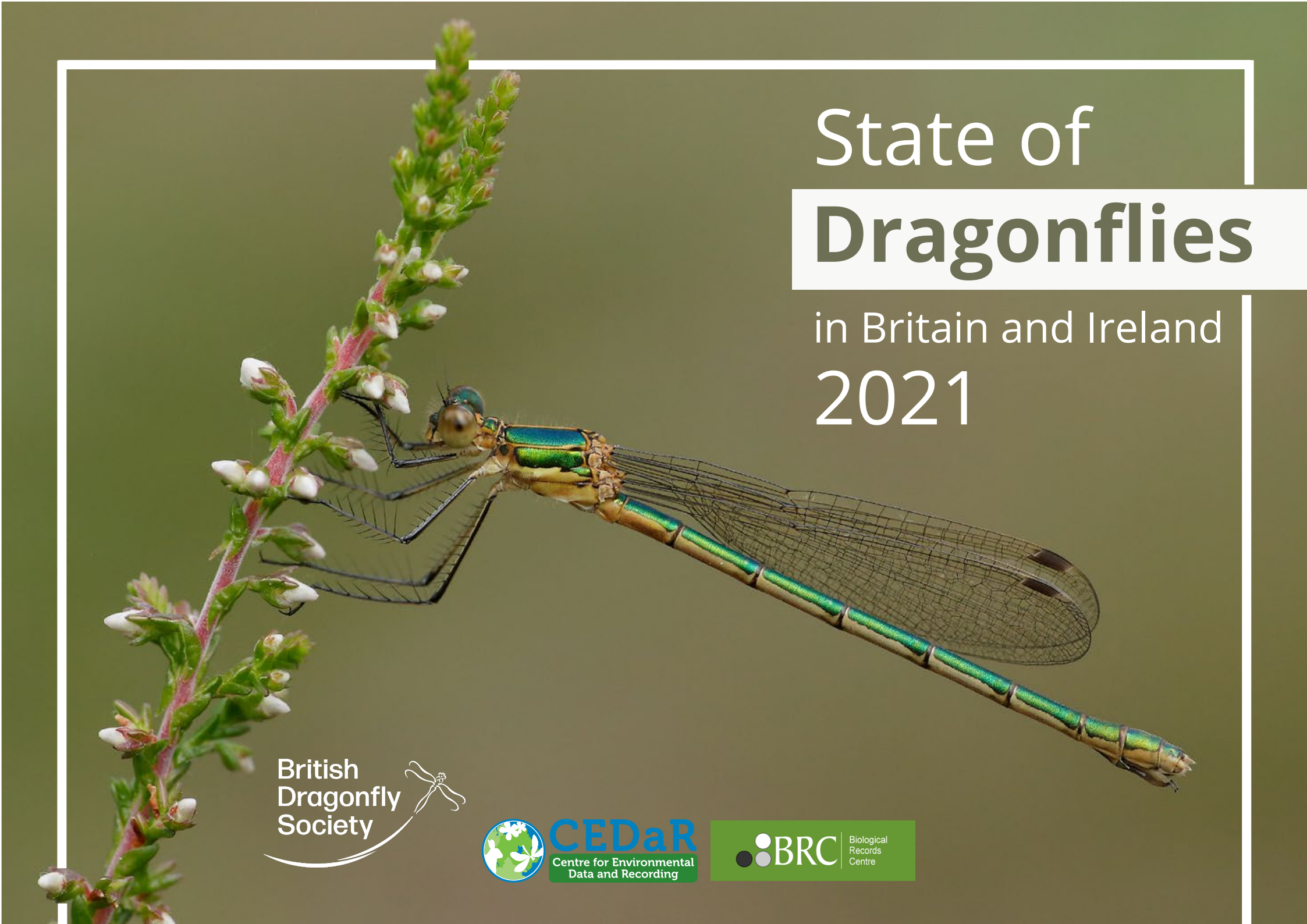


State of Dragonflies in Britain and Ireland 2021

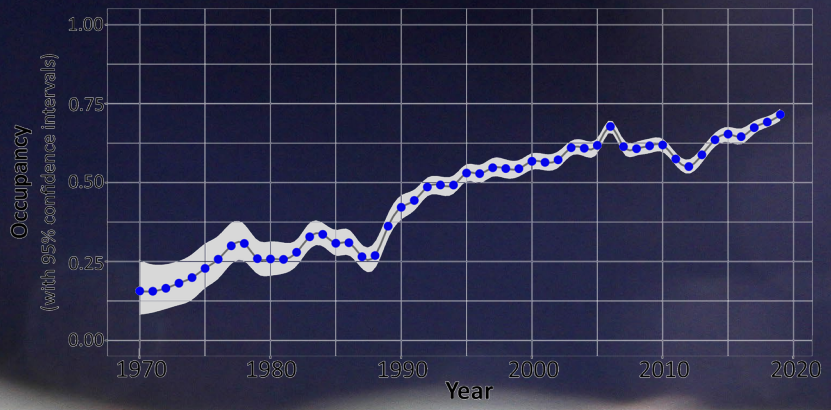
British Dragonfly Society

CEDaR Centre for Environmental Data and Recording

BRC Biological Records Centre

State of Dragonflies 2021

Presenting the trends of dragonflies and damselflies in Britain and Ireland over fifty years.



Editors and main authors
Pam Taylor
Dave Smallshire
Adrian Parr

Other authors: Steve Brooks, Steve Cham, Ellie Colver, Martin Harvey, David Hepper, Nick Isaac, Mark Logie, Damian McFerran, Fiona McKenna, Brian Nelson and David Roy

Female Emperor Dragonfly © Gordon Gray Cover image: Female Emerald Damselfly © Iain Leach

Headlines and Summary

- The current British and Irish list of damselflies and dragonflies (Odonata) comprises 56 species, of which 46 are residents or regular migrants since 2000; a further ten species have occurred as rare vagrants.
- Trend analyses carried out by the UK Centre for Ecology & Hydrology for this BDS report show that 19 of our resident and/or regular migrant species (41%) have significantly increased in occupancy since 1970. These included both common and/or widespread species and scarce and/or localised species, as well as five new colonists.
- Just five (11%) of our resident and regular migrant species have shown significant declines overall. One of these is a widespread damselfly, two are predominantly upland and/or northern species, and two are specialists of seepages, pools and small streams. In addition, one scarcer migrant has shown some signs of a decline, though appearances have always been somewhat erratic.

Female Four-spotted Chaser © Mark Waldron

Male Small Red Damselfly © David Kitching

- The production of species trends does not reveal the underlying causes. There has been little scientific study to determine the precise causes and their relative impacts on dragonfly populations, although climate change and habitat quantity and quality are clearly important. Our assessment of the driving forces behind the observed trends in this report is therefore based principally on expert opinion using what is known of dragonfly biology and ecology.
- Dragonfly species new to Britain and Ireland are arriving and colonising at a greater rate than ever before. No less than six species have colonised Britain since 1996, while a seventh has recolonised after an absence of almost 60 years. The new colonists are Lesser Emperor (first record 1996), Red-veined Darter (breeding from 1996), Small Red-eyed Damselfly (first record 1999), Southern Emerald Damselfly (first record 2002), Willow Emerald Damselfly (colonisation from 2007) and Southern Migrant Hawker (colonisation from 2010). Dainty Damselfly became extinct in Britain during the coastal floods of early 1953, but successfully recolonised around 2010.

Headlines and Summary continued

- Species richness has increased over time, especially in the northern half of Britain, but also in the south as new species arrive and colonise; increased recording intensity in recent years may explain some of these increases.
- Trends for individual species in Britain and Ireland are often mirrored by those in Europe. For example Emperor Dragonfly *Anax imperator* is increasing in the Netherlands and Germany, as well as in Britain and Ireland, while Emerald Damselfly *Lestes sponsa* has declined in all these areas.
- Trends and responses to climate or habitat changes in dragonflies are often matched by other taxa. For example, there is evidence of northwards range shifts for several birds and butterflies, and it has recently been found that despite overall insect declines, more of our larger moth species are increasing in occupancy, than decreasing. Additionally, populations of freshwater invertebrates such as caddisflies and mayflies have recovered in recent decades, a result in line with that seen overall for dragonflies.
- Climate change in the form of increased temperatures is behind many of the positive dragonfly species trends and new colonisations, but it should be remembered that climate change does not act in isolation. Increases in the availability of suitable habitats through restoration and creation projects have also played a significant role. Climate change may also have negative impacts for some species, especially in the future. It is important that we continue to record and assess all species, but especially those in northern, upland and specialised habitats, although much still needs to be discovered about the individual needs of dragonfly species, especially during the larval stage.
- Species declines are harder to record and explain, but habitat losses and degradation through land drainage, afforestation, acidification and lack of appropriate management are strongly indicated as major factors. Changes in weather patterns, causing both flood and drought conditions, are also implicated, as are pesticides, fertilisers and other pollutants of a similar nature. It is also the case that increases in distribution may mask underlying declines in species abundance.
- The 50-year occupancy trends in this report are based on 1.4 million records, collected by some 17,000 individual recorders during 1970-2019. Dragonfly recording simply could not function without the continuing dedication of numerous volunteers and supporters. We thank them all sincerely.

Minsmere © Gideon Chilton

Messages

George Hassall, BDS Youth Ambassador.

Dragonflies are mind-blowingly fascinating to me. With their jewel-like wings, they are like a living piece of art. There have been many changes in dragonfly populations, which raise lots of questions about their future. I feel there's a great need for young people like me to take an interest in dragonflies and their life cycles, particularly during the aquatic phases of their lives. That's why the 'State of Dragonflies 2021' report is so important.

Mike Dilger, BDS President.

I would like to give a huge thanks to the 17,000 dragonfly enthusiasts who, over the last 50 years, have contributed 1.4 million records, which have provided the backbone of this report. Without the dedication of these volunteers, the British Dragonfly Society simply wouldn't have the tools to continue their vital work of both researching and conserving these enigmatic and mercurial aerial predators. Dragonflies are 'canaries in the coal-mine' for informing us about the state of our wetlands and I urge you to keep enjoying and recording these winged wonders. And to wilfully misquote Lord Kitchener, "your dragonflies and damselflies need you!"

Joel Ashton, BDS Ambassador.

Over the last 16 years I have been professionally designing and installing gardens and larger sites with wildlife at the forefront of these designs. As such, I am aware that a wildlife pond is one of the most important and effective ways to encourage dragonflies and a vast array of wildlife into your own space. Ponds provide vital habitat resources in an ever-increasing urban and agricultural landscape. Even the smallest of ponds can ensure there are stepping-stones between neighbouring gardens and corridors that link urban areas to sites in the wider countryside.

Brian Walker, BDS Chairman.

"This report shows that dragonfly diversity in Britain and Ireland has increased and that many species have spread further north in recent years. One of the main reasons behind these changes is a response to climate change. New species and range expansions sounds like good news for dragonflies, but the speed at which new species are arriving and colonising should actually be taken as further warning about the danger of rapidly changing climate conditions. The evidence suggests that species favouring cooler conditions are contracting their range and certain habitats such as bogs are drying out and this is having an adverse effect on the species which rely on them. Dragonflies are highly mobile and can react to changes more readily than other groups, but as the report shows, even some dragonfly species seem to be adversely affected by the changes."

Contents

Sections are hyperlinked

Data gathering and analysis

Recording and data collection

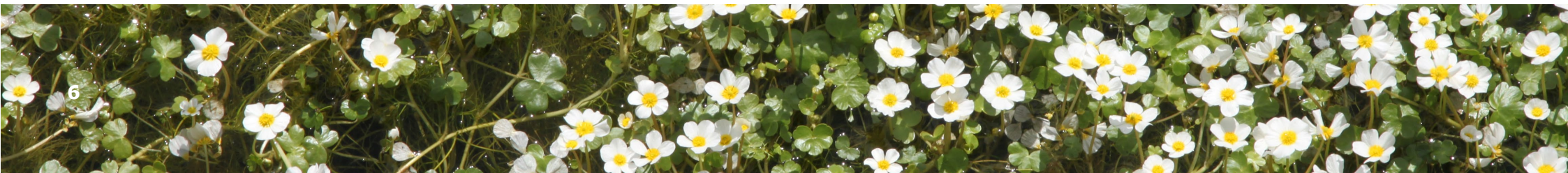
Dragonfly recording in Britain is currently carried out under the auspices of the BDS Recording Scheme, led by the Records Officer. This scheme was initially set up with assistance from the Biological Records Centre (part of UKCEH) and their support has continued to the present day. Records are submitted by a growing network of recorders across the country through a variety of recording systems. A team of over 50 volunteer County Dragonfly Recorders (CDRs), most of whom are members of the BDS, solicit, collect, collate and verify records contributed by recorders in their area. For convenience and long-term comparison, the country is divided for recording and verification purposes into Watsonian vice counties, rather than into the modern counties that change shape as local government is reorganised. At the time of this report, 51 CDRs cover the 71 vice counties of England, Wales and the Isle of Man, while a single coordinator is responsible for all 41 Scottish vice counties, with an assistant CDR in three of them.

Records are also received into the scheme from partners, including the British Trust for Ornithology and the UK Butterfly Monitoring Scheme, both of which have included dragonfly recording within their website recording interfaces. Some CDRs have arrangements with their Local Environmental Records Centre to accept their dragonfly records, but this is a difficult area, with some Local Record Centres declining to share their records.

Dragonfly recording in Ireland since 1990 has taken an independent path: recording is now organised on an all-Ireland basis with a single records coordinator. The records are kept and maintained in Ireland jointly by the two record centres: the Centre for Environmental Data and Recording (CEDaR) in Northern Ireland and the National Biodiversity Data Centre in the Republic of Ireland. The records are displayed on the websites of both data centres. The data from Northern Ireland are also shared through the NBN Atlas (nbnatlas.org). Since the State of Dragonflies analyses are on British and Irish records, special arrangements were made to include Irish records before sending the combined dataset to UK Centre for Ecology & Hydrology for analysis.

Records from the Channel Islands have not been included in the analyses, as biogeographically these islands belong to Continental Europe. At irregular intervals (though we aim for at least annually), the BDS Recording Scheme dataset is updated on the NBN Atlas, ensuring that data on dragonflies are publicly available. The projects in early 2020 to prepare data for the State of Dragonflies analyses and for our NBN Atlas update involved data-cleaning on the combined dataset and were run in parallel. Records can be downloaded from NBN Atlas at full resolution under an open data Creative Commons – By Attribution (CC BY) licence that allows for both research and commercial use. Records from Ireland are available separately on the NBN Atlas at monad (1 km × 1 km grid square) resolution.

Water-crowfoot © Ewan Traveler



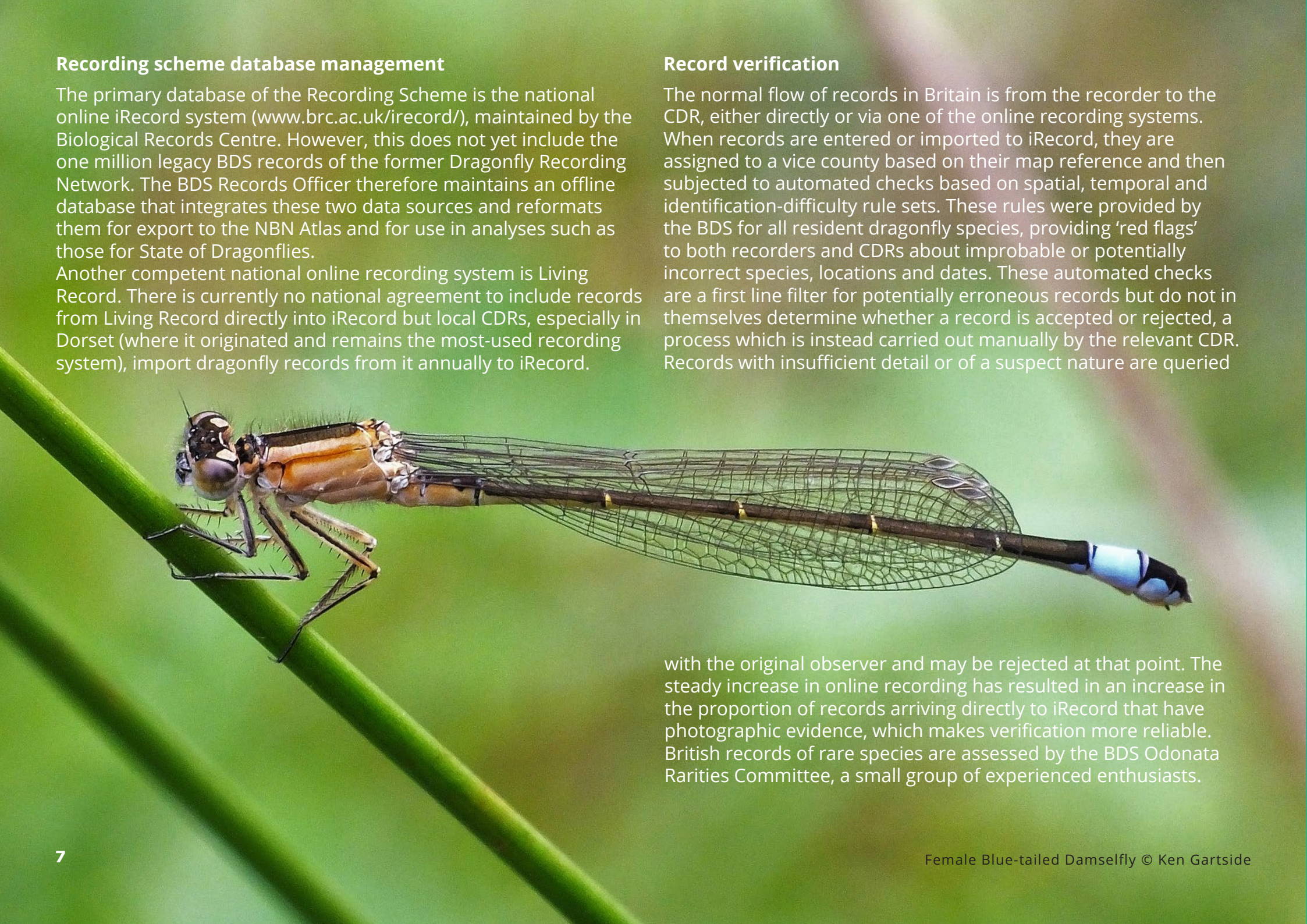
Recording scheme database management

The primary database of the Recording Scheme is the national online iRecord system (www.brc.ac.uk/irecord/), maintained by the Biological Records Centre. However, this does not yet include the one million legacy BDS records of the former Dragonfly Recording Network. The BDS Records Officer therefore maintains an offline database that integrates these two data sources and reformats them for export to the NBN Atlas and for use in analyses such as those for State of Dragonflies.

Another competent national online recording system is Living Record. There is currently no national agreement to include records from Living Record directly into iRecord but local CDRs, especially in Dorset (where it originated and remains the most-used recording system), import dragonfly records from it annually to iRecord.

Record verification

The normal flow of records in Britain is from the recorder to the CDR, either directly or via one of the online recording systems. When records are entered or imported to iRecord, they are assigned to a vice county based on their map reference and then subjected to automated checks based on spatial, temporal and identification-difficulty rule sets. These rules were provided by the BDS for all resident dragonfly species, providing 'red flags' to both recorders and CDRs about improbable or potentially incorrect species, locations and dates. These automated checks are a first line filter for potentially erroneous records but do not in themselves determine whether a record is accepted or rejected, a process which is instead carried out manually by the relevant CDR. Records with insufficient detail or of a suspect nature are queried with the original observer and may be rejected at that point. The steady increase in online recording has resulted in an increase in the proportion of records arriving directly to iRecord that have photographic evidence, which makes verification more reliable. British records of rare species are assessed by the BDS Odonata Rarities Committee, a small group of experienced enthusiasts.



Female Blue-tailed Damselfly © Ken Gartside

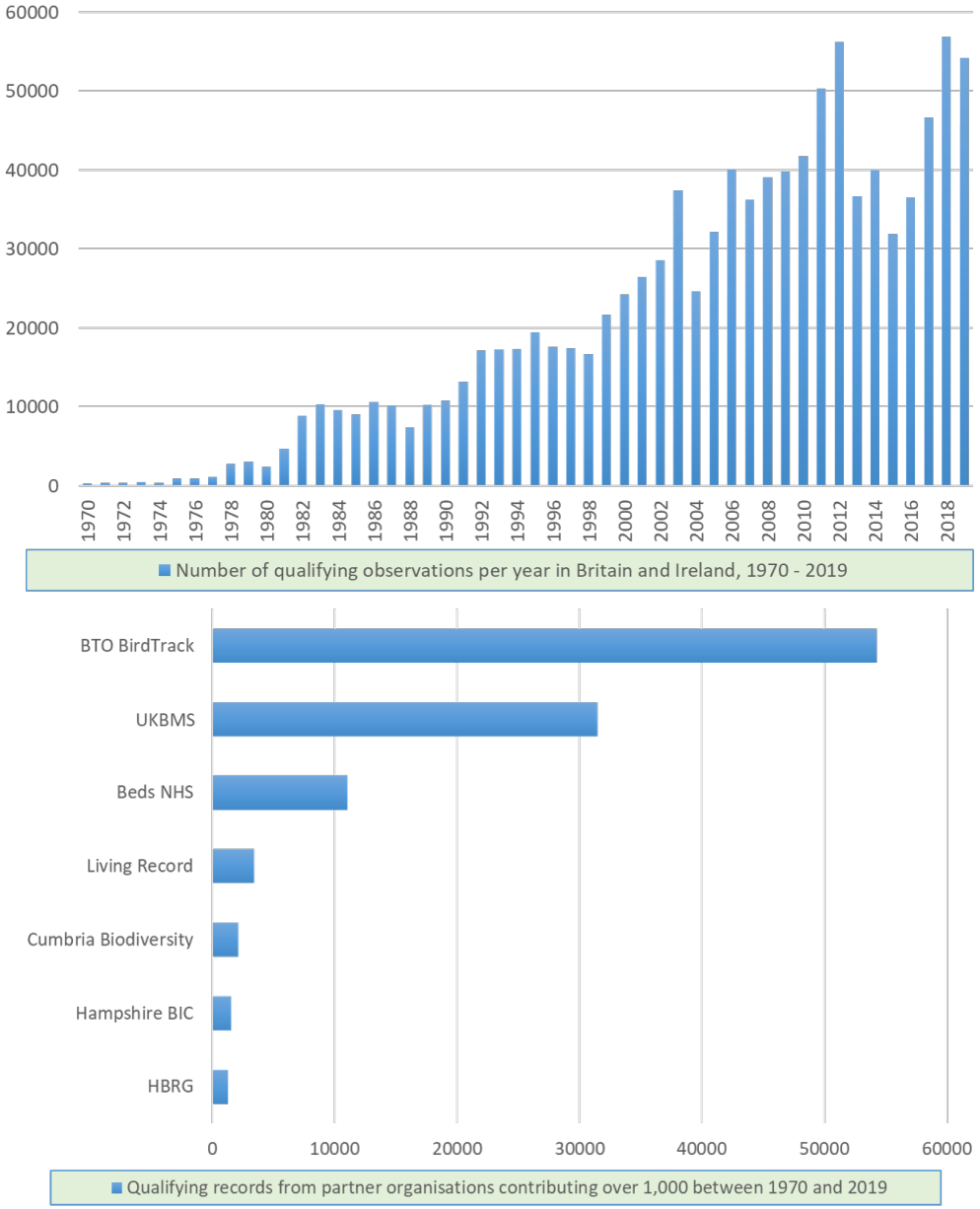
Recording effort

The total number of observations qualifying for inclusion in the analyses has fluctuated annually on an upward trend in recent years, with noticeable highs during years of exceptionally good weather (e.g. 2006). The number of amateur dragonfly recorders has increased dramatically over the last 50 years and the detection of dragonflies by these recorders has improved as a result of improved field skills and better binoculars and cameras. Detection rates have also increased as a result of earlier dragonfly emergences and longer flight periods (through changes in voltinism and/or enhanced adult survival). Pulses of recording activity occurred through concerted effort to achieve good geographical coverage leading up to the two Atlases (Merritt *et al.*, 1996; Cham *et al.*, 2014), while short-term, targeted searches have increased the records of species such as Northern Damselfly, Azure Hawker, Northern Emerald and Keeled Skimmer in Scotland, and to some extent Willow Emerald Damselfly in England. In total, some 17,000 recorders have contributed dragonfly records to the BDS Recording Scheme and its predecessors over the last 50 years.

Contributions from partner organisations

Our partnerships with other organisations have produced significant and increasing numbers of qualifying records. For example, over 50,000 records have derived from BirdTrack and over 30,000 records from the UK Butterfly Monitoring Scheme (UKBMS). Other significant contributors include Bedfordshire Natural History Society, Cumbria Biodiversity, Hampshire Biodiversity Information Centre and the Highlands Biological Recording Group.

Numbers of qualifying records during 1970-2019 for Britain and Ireland (above) and from partner organisations (below).



Selection of records for the State of Dragonflies analyses

Both iRecord and the older BDS Dragonfly Recording Network (DRN) database include many records that, while useful in some contexts, could not be used in the occupancy analyses carried out by UKCEH. The exclusions and the reasons for them are set out in the table below. This helps explain why the number of records considered in the analyses (1.4 million records) is lower than the total number of records in the recording scheme.

Attempts were also made to reduce duplication of individual records between iRecord and DRN, but the presence of these would have no impact on the occupancy analyses.

Record attribute	Inclusion/exclusion criteria	Comments
Observation date	• Of type: single day or day range or single month • Year between: 1970 and 2019	• Excludes vague dates: Month Range, Single Year, and Year Range. • Data for 2019 are likely to be less complete than for earlier years, due to the way records reach iRecord from other schemes.
Survey type	• Include all types other than bioblitz events and NatureSpot	• Excludes surveys where records were not reviewed by a BDS County Dragonfly Recorder.
Taxon	• Identified to species level	• Excludes vague taxa - those only identified to Family, Sub-family or Genus.
Zero-abundance	• Include only where False	• Excludes records of Absence - "I looked for this species but did not find it".
Life stage	• Any stage indicates occupancy	
Abundance count	• Presence is stated or can reliably be inferred	• Excludes records where presence cannot reliably be at least inferred.
Map reference	• Coordinate system is OSGB • Coordinate uncertainty is to monad (1 km × 1 km) or better	• Excludes Channel Isles. • Excludes geographically vague records.
Verifier name	• A current or former County Dragonfly Recorder	• Excludes records verified by an unknown or untrusted verifier (2nd test of this)
Verification status	• Accepted	• Excludes records that are Rejected, Unreviewed (=Pending), Queried or marked Plausible.

Trend analysis and results

Occurrence records as outlined above were used to estimate changes in the distribution of each species. Analysis was carried out at monad (1 km × 1 km grid square) resolution, using records that included the identity of the species recorded, the monad from which the record was made and the precise date. Records with coarser spatial resolution (e.g. tetrad) or where the exact observation date was unknown were not used in the analysis.

A key metric that was calculated was the annual *occupancy*, and plots for each species showing the change in occupancy over time were produced. Occupancy is measured as the proportion of the geographical area in which the species of interest was present in each year. Another equivalent way of considering occupancy is a measure of the probability of a species being present in a randomly selected monad. Thus, occupancy will increase when species become more widespread, and decrease when species become less widespread.

Separate species occupancy plots were produced for each country within Britain and Ireland, as well as for all countries combined. Occupancy is estimated from occurrence records using a modelling technique that accounts for imperfect detection of species, i.e. where species may genuinely be present in a monad but remained undetected or unreported by recorders. This technique is known as occupancy-detection modelling; it is now widely used to analyse trends from occurrence records data. For those interested, further details of the approach used can be found in articles such as those by Outhwaite et al. (2019) and Bowler et al. (2020). Uncertainty that arises from incomplete detection is captured in a statistic known as the Credible Interval (CI) of the occupancy estimate, and these intervals are shown shaded in grey on the occupancy plots given in this report.

Occupancy Change is the change in occupancy from the first to last year for which we have observation data. For example, in Britain and Ireland combined, the occupancy of Migrant Hawker has increased by a best estimate of 0.28 between 1970 and 2019, indicating that 28% of the total monads showed a change from unoccupied to occupied for this species. This is an absolute measure of change, not a relative one (note that the occupancy change number can never be greater than 1 or less than -1). As with the occupancy estimates, the change statistic is subject to uncertainty, so the change statistic is presented as a distribution of estimates. For Migrant Hawker, the 95% credible intervals are 0.19 and 0.36, so we can be 95% confident that the true value of the change metric lies between these values. Because new colonist species do not have data that extends over the full 50 years of our analyses, their calculations cover lesser, but relevant, time periods as indicated in trends tables.

Occupancy trends for Britain and Ireland 1970-2019

(ranked from increasing to decreasing)

Species	Trend
Emperor Dragonfly	0.559
Migrant Hawker	0.282
Ruddy Darter	0.261
Black-tailed Skimmer	0.241
Small Red-eyed Damselfly*	0.232
Broad-bodied Chaser	0.203
Hairy Dragonfly	0.201
Four-spotted Chaser	0.167
Red-eyed Damselfly	0.151
Banded Demoiselle	0.148
Willow Emerald Damselfly***	0.134
Southern Hawker	0.099
Beautiful Demoiselle	0.087
Common Darter	0.085
Azure Damselfly	0.072
Brown Hawker	0.066
Scarce Chaser	0.059
Large Red Damselfly	0.043
Common Blue Damselfly	0.037
Norfolk Hawker	0.032
White-legged Damselfly	0.030
Red-veined Darter	0.029

Species	Trend
Lesser Emperor	0.026
Southern Migrant Hawker**	0.014
Brilliant Emerald	0.008
Northern Emerald	0.008
Downy Emerald	0.007
Keeled Skimmer	0.006
Scarce Emerald Damselfly	0.004
Irish Damselfly	0.001
Southern Damselfly	0.001
Northern Damselfly	0.001
Azure Hawker	0.000
White-faced Darter	-0.005
Common Clubtail	-0.005
Small Red Damselfly	-0.016
Variable Damselfly	-0.018
Blue-tailed Damselfly	-0.018
Scarce Blue-tailed Damselfly	-0.023
Golden-ringed Dragonfly	-0.036
Common Hawker	-0.076
Black Darter	-0.123
Emerald Damselfly	-0.138

KEY

Increase: 95% CI excludes zero

Increase: 90% CI excludes zero

Decrease: 90% CI excludes zero

Decrease: 95% CI excludes zero

cell clear = no significant change

* change over 21 years

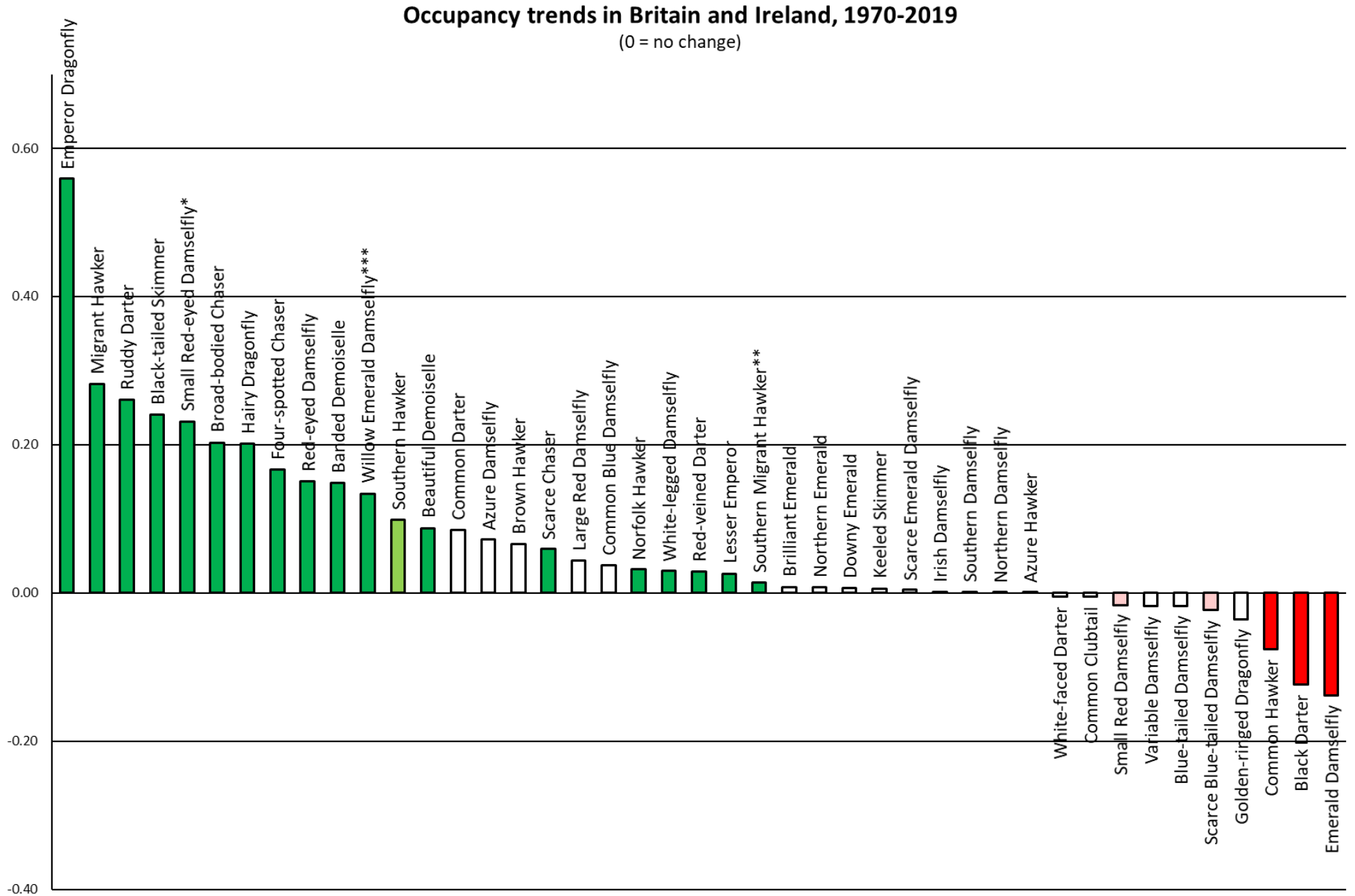
** change over 11 years

*** change over 10 years

n/a = species absent from country

Three resident and regular migrant species, Dainty Damselfly, Southern Emerald Damselfly and Vagrant Emperor, have fewer than 250 records, so are excluded from these tables.

The full data table is available to view on the British Dragonfly Society website.


Occupancy trends in Britain and Ireland, 1970-2019
(0 = no change)
0.60
0.40
0.20
0.00
-0.20
-0.40
Emperor Dragonfly
Migrant Hawker
Ruddy Darter
Black-tailed Skimmer
Small Red-eyed Damselfly*
Broad-bodied Chaser
Hairy Dragonfly
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Scarce Blue-tailed Damselfly
Golden-ringed Dragonfly
Common Hawker
Black Darter
Emerald Damselfly

Trends in occupancy 1970-2019 (ranked by trend in Britain and Ireland)

Species	Brit+Irl	Brit	Eng	Wales	Scot	NI	ROI
Emperor Dragonfly	0.559	0.559	0.637	0.647	0.057	0.080	0.717
Migrant Hawker	0.282	0.288	0.343	0.221	0.023	0.171	0.224
Ruddy Darter	0.261	0.281	0.357	0.084	0.000	0.040	0.048
Black-tailed Skimmer	0.241	0.253	0.294	0.274	0.000	0.000	0.117
Small Red-eyed Damselfly*	0.232	0.249	0.308	0.122	n/a	n/a	n/a
Broad-bodied Chaser	0.203	0.218	0.247	0.308	0.002	n/a	n/a
Hairy Dragonfly	0.201	0.192	0.229	0.113	0.040	0.036	0.484
Four-spotted Chaser	0.167	0.172	0.199	0.127	0.042	0.005	0.061
Red-eyed Damselfly	0.151	0.162	0.218	-0.012	n/a	n/a	n/a
Banded Demoiselle	0.148	0.157	0.194	0.049	0.021	0.043	0.043
Willow Emerald Damselfly**	0.134	0.144	0.188	n/a	n/a	n/a	n/a
Southern Hawker	0.099	0.107	0.082	0.291	0.131	n/a	0.000
Beautiful Demoiselle	0.087	0.091	0.101	0.106	0.027	0.000	0.056
Common Darter	0.085	0.100	0.109	0.053	0.075	-0.212	-0.216
Azure Damselfly	0.072	0.058	0.011	0.247	0.189	0.634	0.135
Brown Hawker	0.066	0.043	0.031	0.183	0.000	0.109	0.491
Scarce Chaser	0.059	0.064	0.084	-0.001	n/a	n/a	n/a
Large Red Damselfly	0.043	0.039	0.069	-0.136	-0.001	-0.032	0.071
Common Blue Damselfly	0.037	0.030	0.034	0.079	-0.052	0.483	0.019
Norfolk Hawker	0.032	0.034	0.044	n/a	n/a	n/a	n/a
White-legged Damselfly	0.030	0.032	0.040	0.015	n/a	n/a	n/a
Red-veined Darter	0.029	0.030	0.039	0.003	0.001	0.004	0.014

KEY

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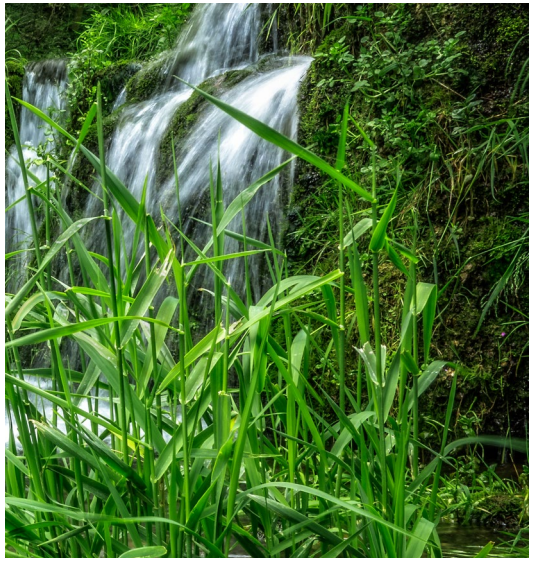

© Nicholas Oakes

Trends in occupancy 1970-2019 continued (ranked by trend in Britain and Ireland)

Species	Brit+Irl	Brit	Eng	Wales	Scot	NI	ROI
Lesser Emperor	0.026	0.028	0.036	0.000	0.004	0.000	0.007
Southern Migrant Hawker***	0.014	0.015	0.019	0.002	n/a	n/a	n/a
Brilliant Emerald	0.008	0.009	0.004	n/a	0.053	n/a	n/a
Northern Emerald	0.008	0.010	n/a	n/a	0.075	n/a	-0.013
Downy Emerald	0.007	0.007	0.007	0.003	0.011	n/a	0.012
Keeled Skimmer	0.006	0.005	0.004	-0.041	0.055	0.007	0.022
Scarce Emerald Damselfly	0.004	0.007	0.009	n/a	n/a	0.002	-0.025
Irish Damselfly	0.001	n/a	n/a	n/a	n/a	0.034	0.020
Southern Damselfly	0.001	0.001	0.002	-0.001	n/a	n/a	n/a
Northern Damselfly	0.001	0.001	n/a	n/a	0.005	n/a	n/a
Azure Hawker	0.000	0.000	n/a	n/a	0.002	n/a	n/a
White-faced Darter	-0.005	-0.005	-0.006	0.001	-0.001	n/a	n/a
Common Clubtail	-0.005	-0.005	-0.010	0.028	n/a	n/a	n/a
Small Red Damselfly	-0.016	-0.017	-0.022	-0.000	n/a	n/a	n/a
Variable Damselfly	-0.018	-0.002	0.001	-0.035	0.004	0.502	-0.471
Blue-tailed Damselfly	-0.018	-0.025	-0.072	0.151	0.112	0.272	-0.013
Scarce Blue-tailed Damselfly	-0.023	-0.023	-0.022	-0.045	n/a	0.018	-0.012
Golden-ringed Dragonfly	-0.036	-0.038	-0.028	-0.131	-0.022	n/a	0.000
Common Hawker	-0.076	-0.087	-0.154	-0.024	0.267	-0.009	0.128
Black Darter	-0.123	-0.123	-0.106	-0.166	-0.186	-0.253	-0.058
Emerald Damselfly	-0.138	-0.122	-0.168	0.088	-0.046	-0.363	-0.391

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* change over 21 years

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n/a = species absent from country

Species richness

Atlases have traditionally used maps as a readily accessible way to illustrate the past and present distribution of British and Irish dragonflies at the hectad (10 km × 10 km grid square) scale (Merritt *et al*., 1996, Cham *et al*., 2014). By comparing the distributions from two or more recording periods, one of the major observations has been the significant northwards spread of species noted in the modern era. This spread is understood to be mainly in response to increasing temperature resulting from climate change.

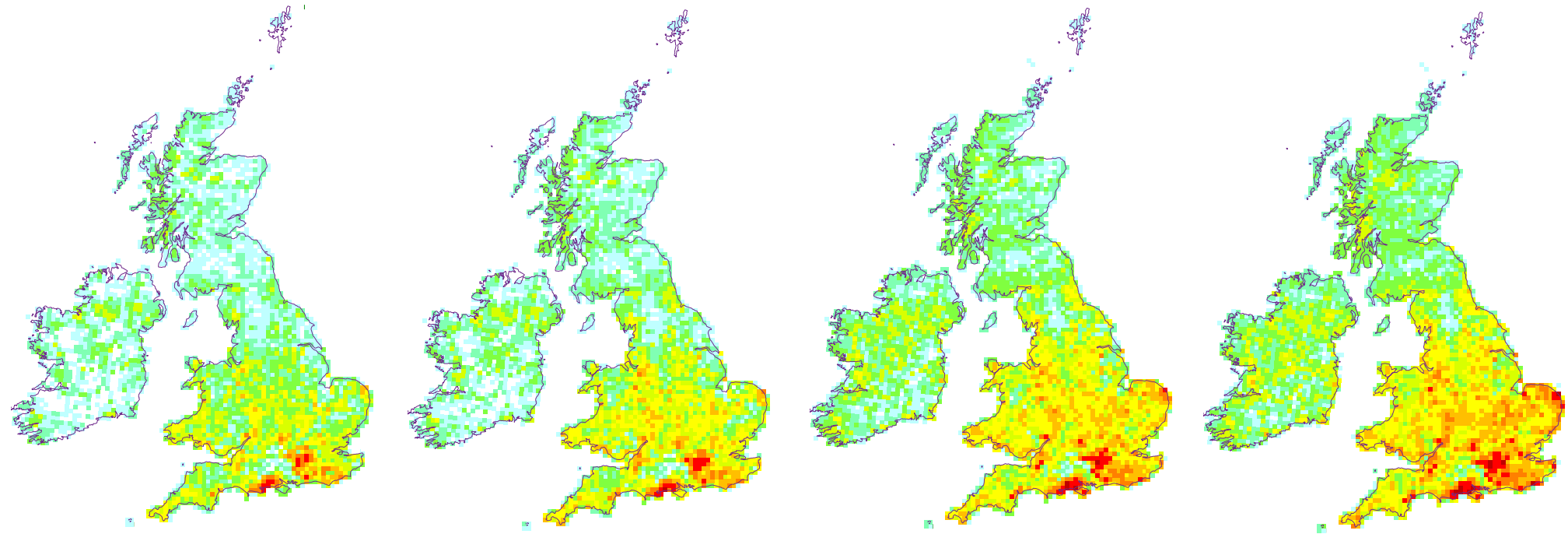
The northwards spread of species over time, resulting in an increase in dragonfly biodiversity at higher latitudes, is very apparent. Changes are clearly continuing, with significant differences being noted in some areas even since 2010. Diversity in more southerly regions has also increased to some extent, due in part to the arrival of new species to Britain over the last 20 years. However, too detailed an interpretation of species richness maps is hampered by the effects of increased recording effort. In recent decades, dragonflies have become a popular group of insects, which has resulted in an increase in recording intensity and observer skills. This needs to be considered when interpreting changes in the maps, particularly where remote or otherwise traditionally under-recorded areas are concerned.

Female Brilliant Emerald © Ryszard, flickr

Hectad maps of dragonfly diversity

(showing the recent increases in species richness)

Golden-ringed Dragonfly larva © Christophe Brochard



Single-colour versions of the maps are available to view on the British Dragonfly Society website.

Species trends

The trend analyses show that 19 out of 46, just over 40%, of our resident and/or regular migrant dragonfly and damselfly species have increased in occupancy across both Britain and Ireland, while just 11%, five species, have shown significant decline. A further five species have increased and three species have decreased significantly in one or more countries, but not changed significantly in occupancy overall in Britain and Ireland. Of the species increasing in occupancy, approximately one-third are damselflies, the rest being dragonflies. On the surface these significant increases are excellent news that counters the decline in insects generally (Sanchez-Bayo & Wyckhuys, 2019), but, as explained elsewhere, these increases could actually be as much of a warning about climate change, as are the declines.

In this section, we highlight some of the key stories behind the individual species' trends and attempt to explain them using scientific studies and expert opinion of dragonfly distribution and behaviour.

Long-term resident species are dealt with before the recent colonists and migrants.

41%

of our resident and/or regular migrant species have increased in occupancy

11%

have shown significant decline

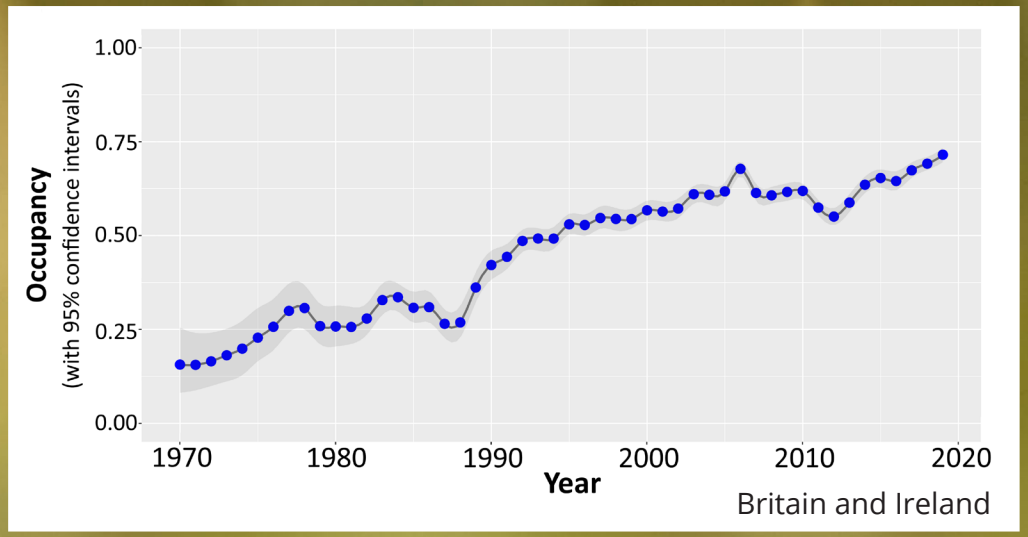
Common Blue Damselflies © Donald Hobern

Species showing increasing trends

Emperor Dragonfly

Anax imperator

Among our resident species, this has the highest increase in occupancy, having spread recently in all countries in Britain and Ireland. Its former distribution until the 1990s was largely confined to the low-lying areas of southern England and south Wales (Cham *et al.*, 2014), since when it has spread both westwards and northwards. It crossed the Irish Sea to reach County Wexford in 2000, before rapidly spreading throughout Ireland. The species has been recorded from parts of Scotland since 2003, but there have been years when it was not recorded. Emperors are regular inhabitants of ponds and lakes, but can also be found in flowing waters such as rivers, canals and ditches. This ability to make use of a wide range of habitats, coupled with the fact that it is a large, strong-flying dragonfly, has contributed to its success and range expansion.

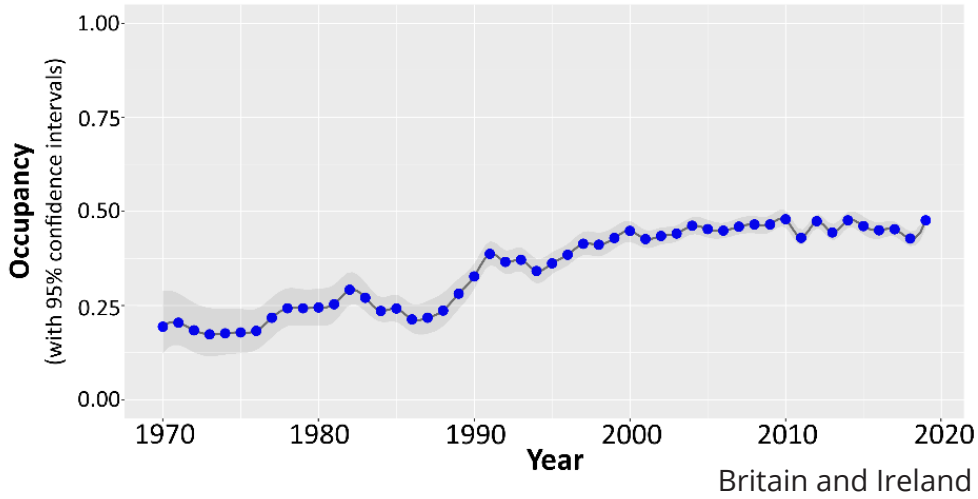


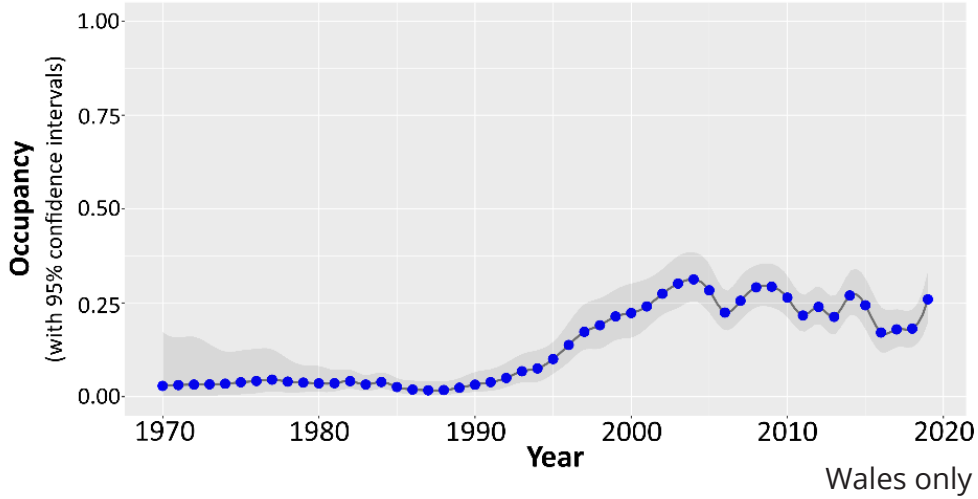
Male Emperor Dragonfly © Hennie Cuper

Migrant Hawker
Aeshna mixta

This is another species that has increased throughout Britain and Ireland. In Ireland, it was first recorded from County Wexford in 1997, a few years ahead of Emperor Dragonfly, and from Scotland in the same year as that species (2003). However, its range expansion overall has moved at a slower pace than that of Emperor. The increase in occupancy is most noticeable between 1986 and 1991, which is mainly attributable to a spread in England during that period. The increase in Wales followed from about 1990 onwards. The species' expansion over recent decades has primarily been driven by climate change (R. Thompson, 2019 pers. comm.). In common with Emperor Dragonfly, it can utilise both still and slow-flowing waters. It has therefore been able to find large areas of suitable habitat as it moves northwards in both Britain and Ireland. Unlike other hawkers, which are usually seen in low numbers, gatherings of hundreds of Migrant Hawkers can be encountered. Although now a resident species, it is also migratory, and therefore capable of moving long distances, especially when aided by weather conditions. Breeding populations in southern Britain are regularly boosted by fresh migrants from the continent.

Male Migrant Hawker © Tony Hisgett

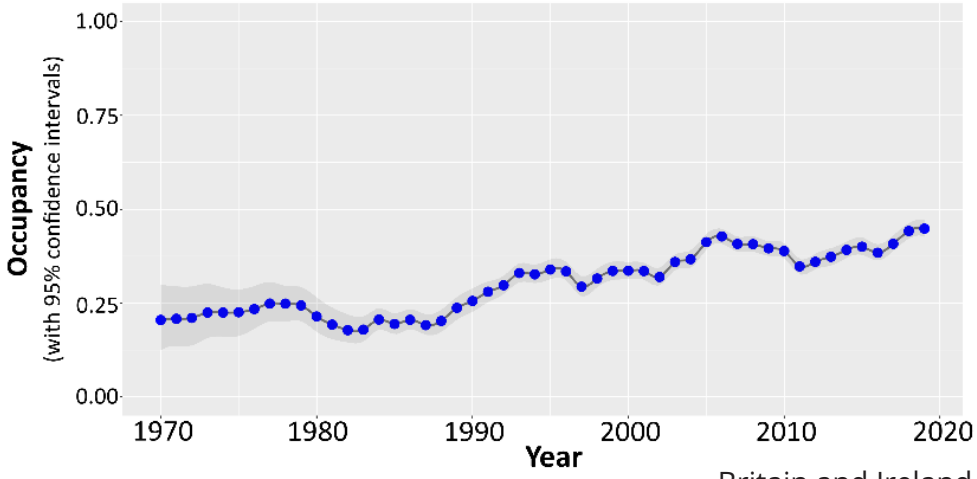




Black-tailed Skimmer
Orthetrum cancellatum

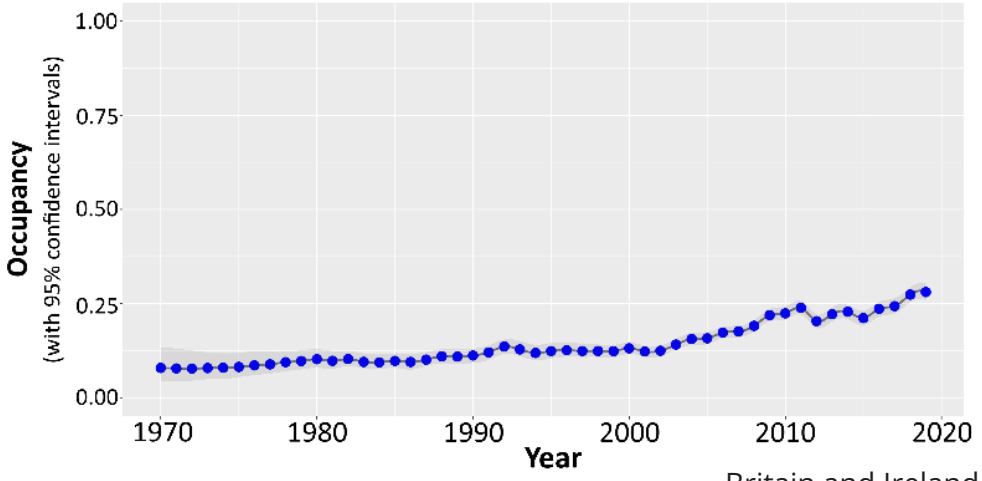
Male Black-tailed Skimmer © Ouwesok, flickr

This species has spread significantly in both England and Wales since the late 1980s, but was only recorded for the first time in Scotland in 2006. There were 11 Scottish records in that year, 10 of which came from Berwickshire and the other from Fife. It was re-found twice in Berwickshire in 2010 and just once in 2015 (NBN Atlas Scotland), with further records again in 2020. Although its increase in England and Wales has been primarily driven by climate, the creation of new wetland areas and more ponds must also have assisted its spread. It appears to have slowed in its current move northwards, hence the erratic Scottish records. In Ireland, there is evidence for recent spread along the south and east coasts and it has also appeared at additional base-rich lakes in the limestone region. The species was recorded for the first time from three sites in the north of Ireland in 2012, although there were just two records from County Antrim in the following year and apparently none since (NBN Atlas NI, CEDaR dataset).

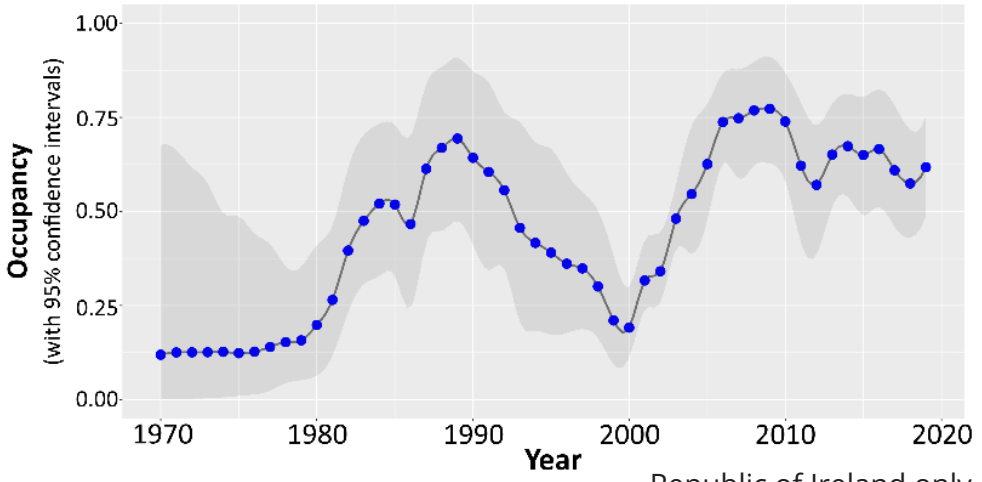


Britain and Ireland

Hairy Dragonfly
Brachytron pratense



Britain and Ireland



Republic of Ireland only

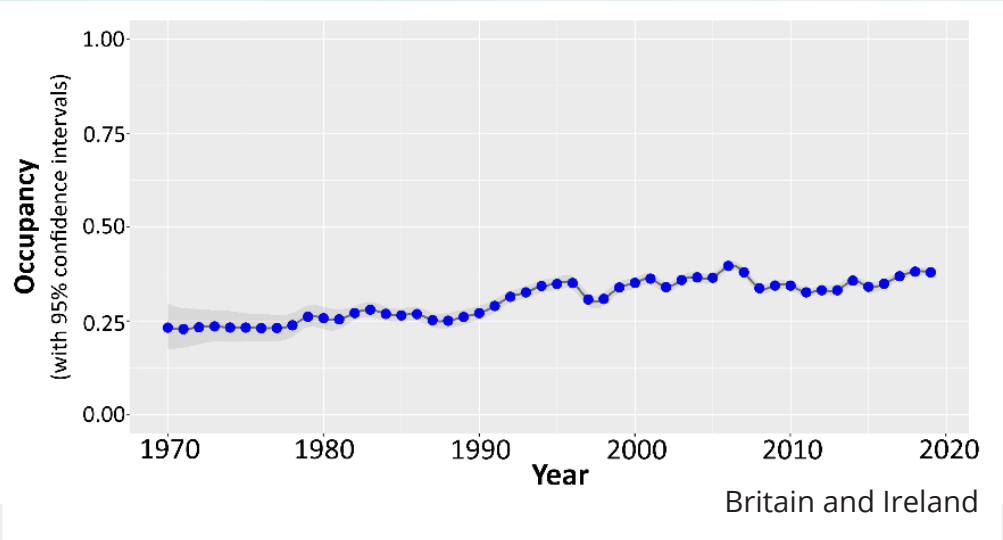
Hairy Dragonfly has increased in occupancy in England and Scotland; in England most significantly since 2000. In Scotland, it was first recorded in 1984, since when it has spread to new sites, although its overall distribution is still limited to relatively small areas of Argyll, and Dumfries and Galloway. Hairy Dragonfly has also increased in occupancy overall in Ireland, although the year-on-year pattern here appears quite variable. It is possible that these fluctuations reflect recorder effort as much as actual changes in occupancy, although the species does seem to have gained new sites, while others have been lost (Cham *et al.*, 2014).

Female Hairy Dragonfly © Jeremy Halls

Banded Demoiselle

Calopteryx splendens

Banded Demoiselle has shown a general increase in occupancy since about 1980, most noticeably in England. Being a species of flowing waters, such as rivers and streams, its success is likely to be linked to both climate change and to initial improvements in water quality. Following range expansion in north-east England, the species was first recorded from Scotland in 2002, since when it has spread northwards along the east coast region to Edinburgh, and westwards in southern Scotland. Banded Demoiselle has been recorded throughout much of Ireland, where recent gains and spread, particularly in the north, have been balanced by a degree of older losses from other areas. Overall, the trend in Ireland is not significant.



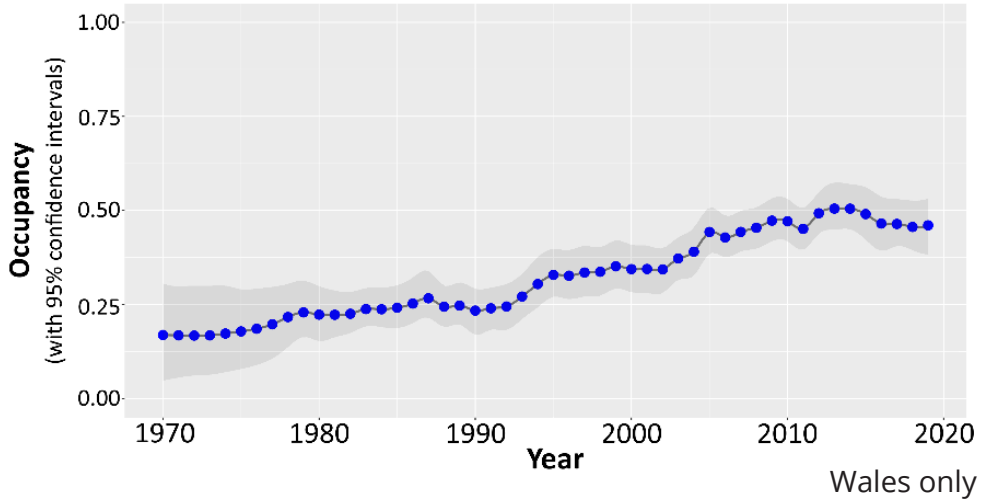
Britain and Ireland

Male Banded Demoiselle © Ivan Radic

Southern Hawker
Aeshna cyanea

Male Southern Hawker © Wildlife Terry, flickr

This species has increased in occupancy in both Wales and Scotland, and hence overall in Britain. The species has been recorded twice in Ireland, from County Cork in 1998, with another record in 2020. In Scotland, the steepest rate of increase can be seen from 1988 onwards, while the increase in Wales has been fairly steady throughout at least the past 50 years. In England, there have also been some range gains in the north, but since the species has always been widespread and common in England, the gains were not significant in the current analysis. This species is another that has benefitted both from climate change and the creation of more habitat, especially the creation of new garden ponds.



Wales only

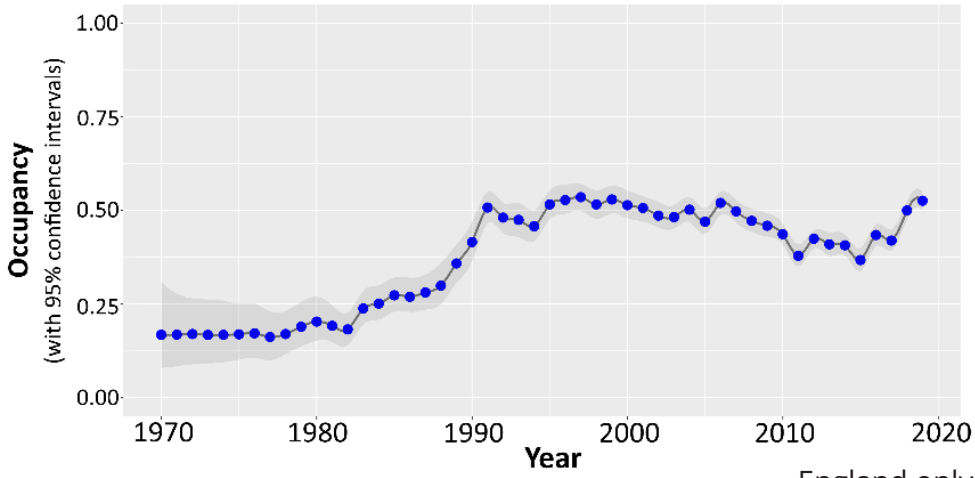
The next eight species have all increased significantly in occupancy in Britain and Ireland, although the only significant individual country increase was in England. In fact, several of these species are actually absent or scarce outside of England.

Mating Ruddy Darters © Mibby23, flickr

Ruddy Darter

Sympetrum sanguineum

Ruddy Darter increased most noticeably in England between 1982 and 1991, after which the pattern stabilised, until fluctuating over the last decade. The occupancy of this species has also apparently varied in both Wales and Ireland over the past 30 years, with gains in some areas being countered by losses in others. Initial range expansions in Wales followed those in England, while most of the Irish gains came after that. The species reached Scotland in 2003, but was not recorded there again until 2016. Expansion of this species is believed to be driven by climate change (Thompson, R., 2019 pers. comm.), but it is thought any further spread beyond its current limit will now be hindered by low water temperatures in the north that affect its larval development (Cham *et al.*, 2014).



England only

Broad-bodied Chaser
Libellula depressa

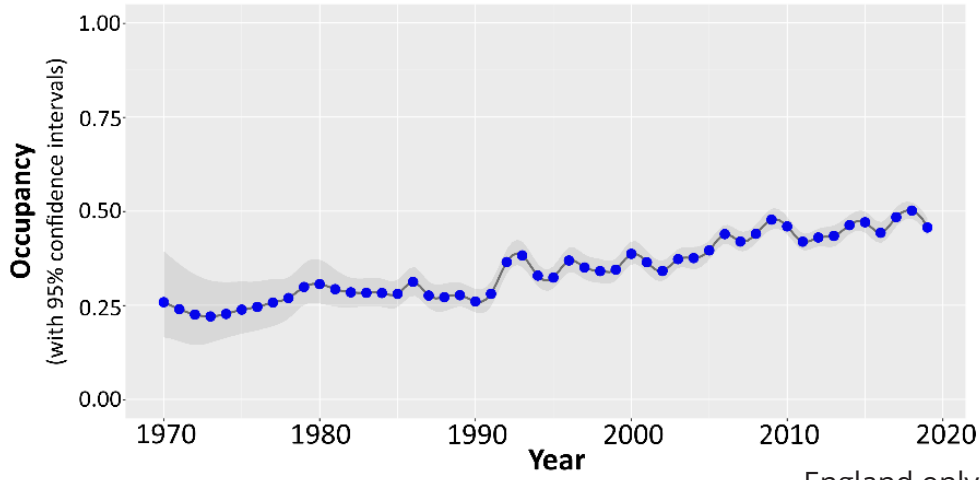
Broad-bodied Chaser has increased in occupancy steadily in England. This is matched by an overall rise in Wales, although the year-to-year pattern there is more variable. Broad-bodied Chaser is mainly a species of ponds, small lakes and ditches. Although both well-vegetated, and open, early successional waters are used, it is particularly noted for being an early coloniser of new or newly-restored ponds (Smallshire & Swash, 2018). Recent projects such as the Million Ponds Project, plus our own BDS initiatives over the last thirty years, will have contributed to the success of this species, while climate change has also assisted its spread into northern England and a few Scottish sites. The species is currently not known from Ireland.

Male Broad-bodied Chaser © Ian Preston

Four-spotted Chaser
Libellula quadrimaculata

This species has increased in occupancy in England most noticeably since 1990. Increases have also been seen in Wales since 1995 and Ireland since around 2000. Four-spotted Chaser can make use of a wide range of still and slow-flowing waters and is widespread throughout Britain and Ireland. It is a species that can rapidly colonise new sites (Smallshire & Swash, 2018), so has probably benefitted from an increase in suitable wetland habitats. Its numbers can also be boosted periodically by immigration events.

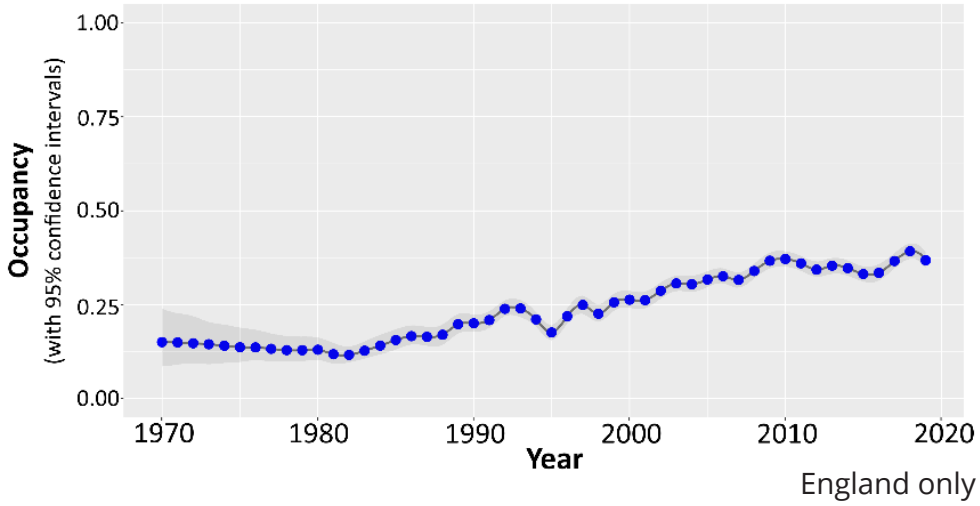
Four-spotted Chaser wings © Iain Leach



England only

Red-eyed Damselfly
Erythromma najas

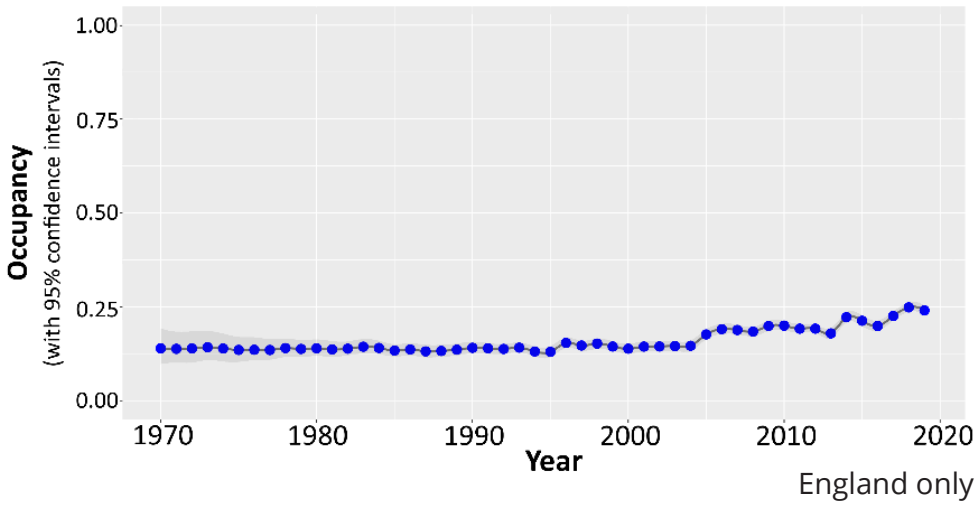
This damselfly has increased in England since 1982 and in Wales from 2006. The first Welsh records came from close to the English border, after which there has been clear colonisation of south Wales. It is a species of larger waterbodies such as large ponds, lakes, canals and slow-flowing rivers, where it can often be found resting on floating vegetation such as waterlilies. In England, it has probably benefitted both from improved water quality within our urban river systems and from the creation or restoration of larger ponds and lakes, all of which will have provided extra habitat. Much of the gain in occupancy over the last 30 years has come from infilling of its previous range, with only a little spread northward (Cham *et al.*, 2014). The species is currently not known from Scotland or Ireland.



England only

Beautiful Demoiselle
Calopteryx virgo

Beautiful Demoiselle is found in both Britain and Ireland, but the bulk of the population is spread across Wales, south-west England and the southern half of Ireland. Elsewhere, there are only a few scattered populations in northern England and western Scotland (Cham *et al.*, 2014). In England, the species has increased most significantly since 2004, with most of the expansion occurring along the eastern edge of its range. In Ireland, it has made a little progress northwards, but most of the site gains have been due to infilling of its existing distribution.



England only

Scarce Chaser
Libellula fulva

Like Beautiful Demoiselle, Scarce Chaser has seen its greatest increase in occupancy since 2004 but, conversely, its main expansion has been on the western edge of its previous distribution. Over the last two decades it has colonised some rivers, drains and canals where it had never been seen before, most notably extending its range into Devon and Somerset. The main populations today are found south of a line from The Wash to the West Midlands. The species is currently not known from Scotland and Ireland, and there are just two (recent) records from Wales. Scarce Chaser is categorised as Near Threatened on the British Red List.

White-legged Damselfly
Platycnemis pennipes

White-legged Damselfly increased in occupancy most noticeably between 1988 and 2005, since when there has been a slight decline in records followed by a more recent recovery. Much of the increase in occupancy can be attributed to infilling within its traditional range in southern England and east Wales, with only marginal spread on the fringes of this. Although its distribution overall has increased, there has been concern for several years that the species is being lost from former strongholds. Such was the concern that the BDS launched its own White-legged Damselfly Investigation with a pilot survey in 2018. Results from the first full survey season in 2019 suggest that, of the 168 monads recorded, the species was seen for the first time in 49 of them, but could not be located in 29 monads where it had previously been recorded (BDS, 2020). Further survey years are needed to clarify the full picture. The species is not currently known from Scotland or Ireland.

Norfolk Hawker
Aeshna isoceles

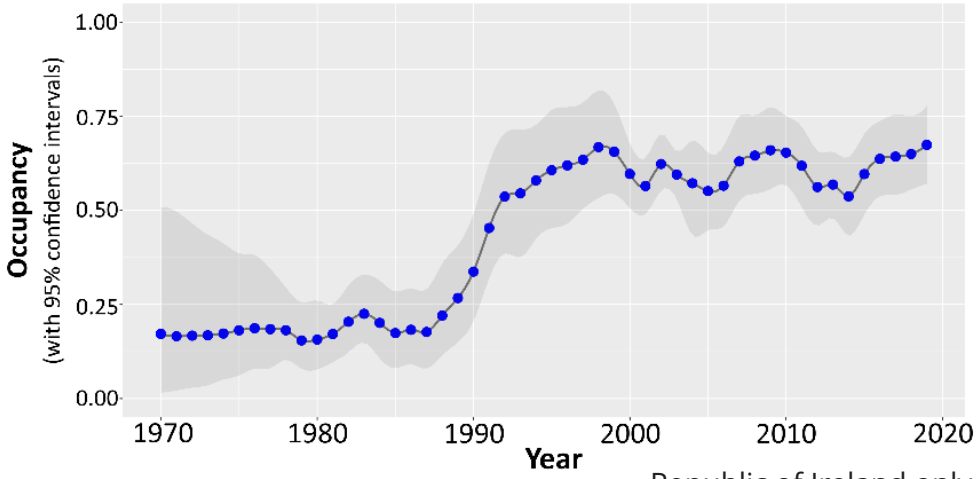
Norfolk Hawker was once confined to the Norfolk Broads and the north-east corner of Suffolk. The species has, however, increased in occupancy in the last two decades, most noticeably since 2012. The initial spread was westwards from the Broads and southwards along the coastal marshes of Suffolk. Westward spread around the southern edge of Norwich was greatly assisted by water quality improvements and habitat creation in areas of former gravel pits. Further spread of this southern species has probably been aided by climate change. Migrants have been found as far west as Devon and as far north as Yorkshire, perhaps originating from Continental populations. The species was recorded from both Cambridgeshire and Kent in 2011, soon establishing thriving colonies, with subsequent expansion leading to colonies now present or presumed in Hertfordshire, Greater London and Dorset. As on the Continent, many of these new sites lack Water Soldier *Stratiotes aloides*, which is closely associated with the species in many of its traditional East Anglian haunts. Norfolk Hawker is currently categorised as Endangered on the British Red List. It is protected in Britain by Schedule 5 of the Wildlife and Countryside Act 1981 (as amended) and is a UK BAP Priority Species.

The next five species have all increased significantly in occupancy in some individual countries within Britain and Ireland, but not all.

Female Brown Hawker © Iain Leach

Brown Hawker
Aeshna grandis

Brown Hawker has increased in occupancy in both Wales and Ireland. In Wales, the increase has been slight and variable, but steadily upwards throughout the last 50 years. Most of the range gain has occurred to the west of central-east Wales. In Ireland, by contrast, there was apparent stability until 1987, after which there was gain for just over a decade until 1998, followed by another period of relative stability. The species now occupies a large area of central Ireland, but is only sparsely scattered in much of the north and the south-west of Ireland. Given the distribution of this species in Wales and Ireland, it is difficult to explain the reasons behind the gains in occupancy. However, the species is known to have spread northwards in England, particularly along the east coast of northern England, so climate change could have played a role. Brown Hawker was initially recorded from Scotland in 2006, but not again until 2020. It is possible that colonisation of Scotland could happen in the future, if the northward movement in England continues.



Republic of Ireland only

Azure Damselfly
Coenagrion puella

Azure Damselfly has increased in both Scotland and Wales according to the trend analyses, but not significantly elsewhere. The increase in Scotland began in 1980 and has continued steadily ever since. It is believed the spread northwards is mainly driven by climate change and increasing average temperatures. The increase in occupancy in Wales has been more variable over time and no discernible pattern can be detected. One possible reason for this is that the species was already widespread in Wales, including many upland areas, and the increase there has mainly derived from increased recording intensity (Cham *et al.*, 2014).

Northern Emerald
Somatochlora arctica

Northern Emerald does not occur in England or Wales, but has increased in Scotland since about 1990. As with Keeled Skimmer, this increase is thought to be mainly due to increased recording effort, although there is some evidence for infilling of its previous range. The greatest gains have happened since 2012, coinciding with a targeted study of potential sites not only to record adults, but to search for larvae and exuviae. The increased use of iRecord for the collection of records and the ability to add photographs to this, has also aided the number of records accepted in recent years. The species is present, but rare, in south-west Ireland, with less than 50 records from Kerry and Cork. The species is categorised as Near Threatened on the British Red List and Endangered on the Irish List.

Keeled Skimmer
Orthetrum coerulescens

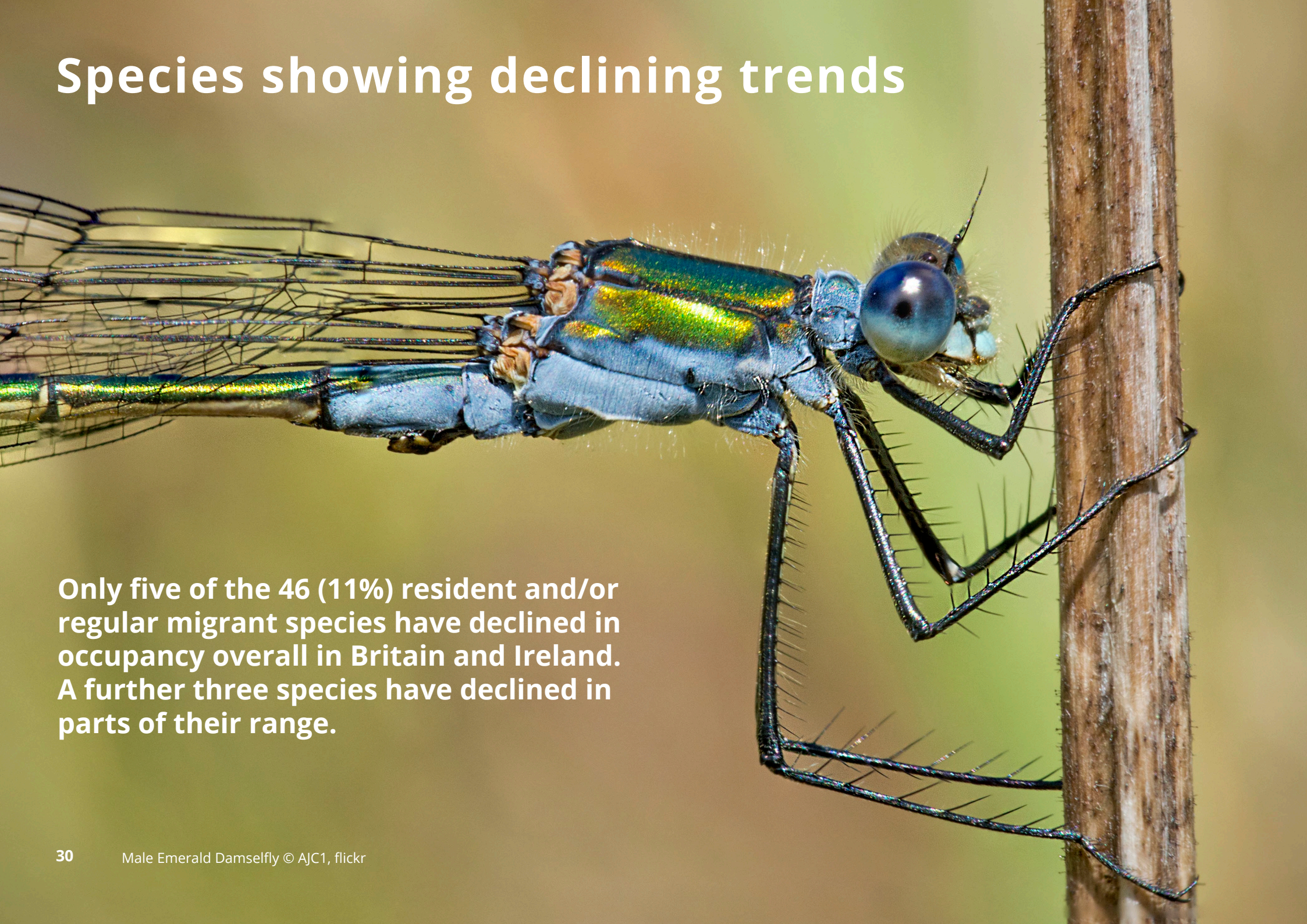
Keeled Skimmer has increased in Scotland since 1990, but not significantly elsewhere. While much of the perceived gain in Scotland is due to increased recording, there is evidence from observers in the area of local expansion into new sites. The species' preferred habitats, mainly slightly flushed burns and runnels, are well scattered, leading to wandering individuals also being recorded as they seek out fresh breeding sites.

Common Blue Damselfly
Enallagma cyathigerum

This damselfly has increased significantly in Northern Ireland, with the most noticeable gains between the mid-1970s and 1990. The species is common and widespread throughout the whole of Britain and Ireland, with much of the apparent gain in Ireland due to infilling within its previous range. There has been similar infilling of records in all other countries, but given the higher level of recording in these, the gains have been less significant as a whole.

© Darren Bradley

Species showing declining trends



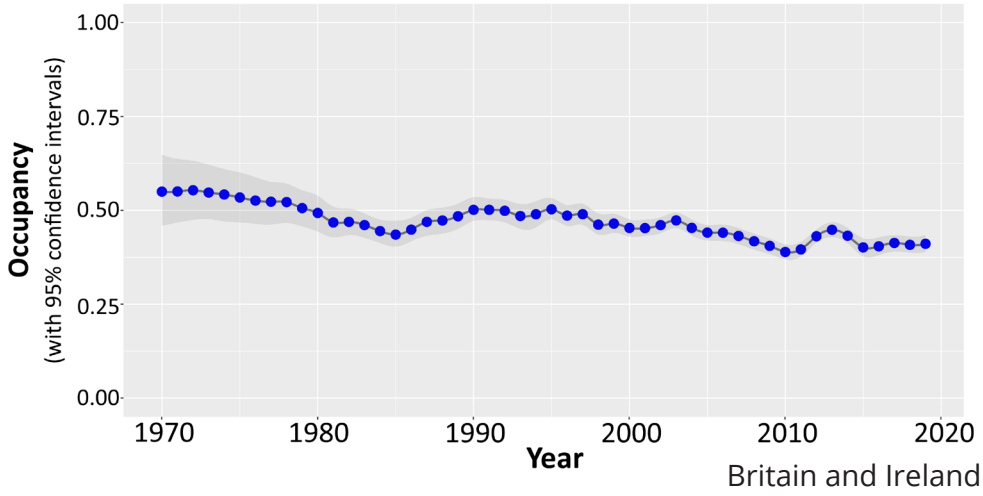
Only five of the 46 (11%) resident and/or regular migrant species have declined in occupancy overall in Britain and Ireland. A further three species have declined in parts of their range.

Male Emerald Damselfly © AJC1, flickr

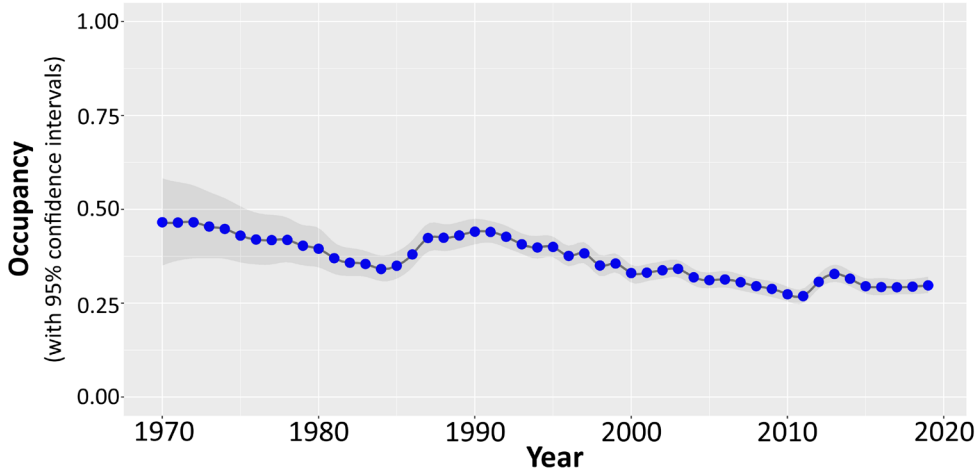
Emerald Damselfly

Lestes sponsa

Emerald Damselfly has shown the greatest decline in occupancy across Britain and Ireland, with much of that decline happening in England since 1990. However, the overall range of this species remains relatively unchanged. While this species is widespread across the whole of Britain and Ireland, there are places within that range where it is sparsely scattered or absent due to a lack of habitat. While the BDS Atlas (Cham *et al.*, 2014) showed both areas of gain and places where the species had been lost, the losses in England in particular have outweighed the gains. There has been a less significant decline in Northern Ireland since the mid-1980s. The species is one that mainly inhabits ponds and bogs, favouring small, shallow waterbodies, some of which are temporary and subject to drying out in late summer. The species is adapted to this, having a late emergence and over-wintering as eggs inserted within plant material. However, it is possible that climate change may be causing some of these temporary waters to dry out earlier each year than the species can tolerate. Additionally, in areas of farmland, increased drainage as a result of changes in land management, could be reducing the amount of suitable waters. It is also likely that pond restorations, which often favour other species of damselfly, could be detrimental to this species. This is particularly so if water depth increases, dense vegetation is removed and competition from other species, absent from temporary waters, also increases. Interestingly, this species has also declined in Continental Europe.



Britain and Ireland



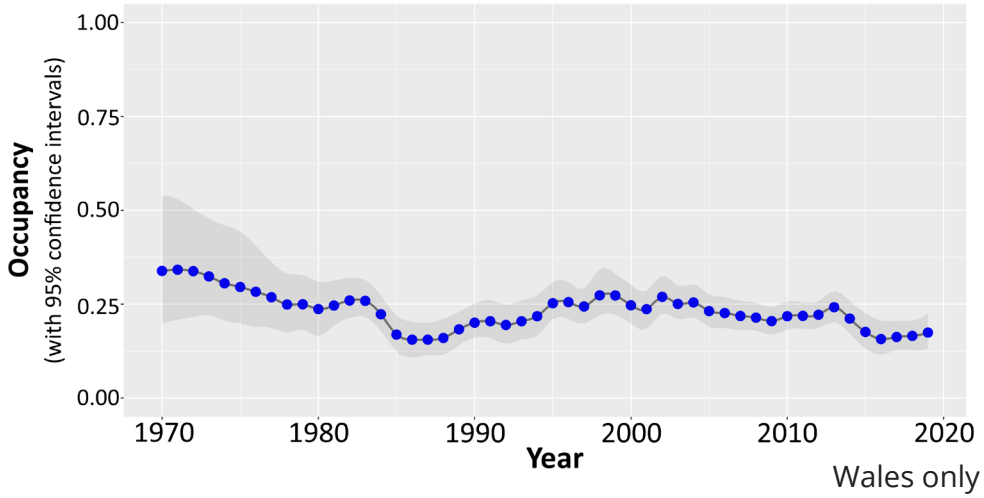
England only

Black Darter
Sympetrum danae

Black Darter is a species typical of acidic bogs, pools and lakes in moorland or heathland. It is capable of thriving in upland areas and is most commonly found in northern and western parts of Britain and Ireland. It has seen a general and significant decline over the past 50 years, particularly in England and Northern Ireland. Interestingly an initial decline in Wales seems to have been followed by a slight increase, but then with an overall decline setting in once again from about 2002. The main areas of loss in Wales appear to be on the eastern side of the country around the English borders. Although not significant in these analyses, this pattern of decline from the early 2000s in Wales is matched in both Scotland and Republic of Ireland (ROI).

Climate change is one possible reason for the decline, particularly in south-east England. Larval competition from Common Darter has also been suggested by some observers, although this is perhaps most likely in the lower parts of the uplands. Habitat changes, through succession and the fragmentation of heathland sites in the lowlands (Rose *et al.*, 2000) has also probably contributed to the decline of this species in England, with the main threat today being a lack of heathland management leading to scrub encroachment. In more upland areas, catchment-scale artificial drainage, afforestation and increased acidification as a result of moorland management for game birds, have all led to lower species diversity (D. Glaves, 2020 pers. comm.). The desiccation of blanket bog due to climate change is a further potential threat both now and for the future.

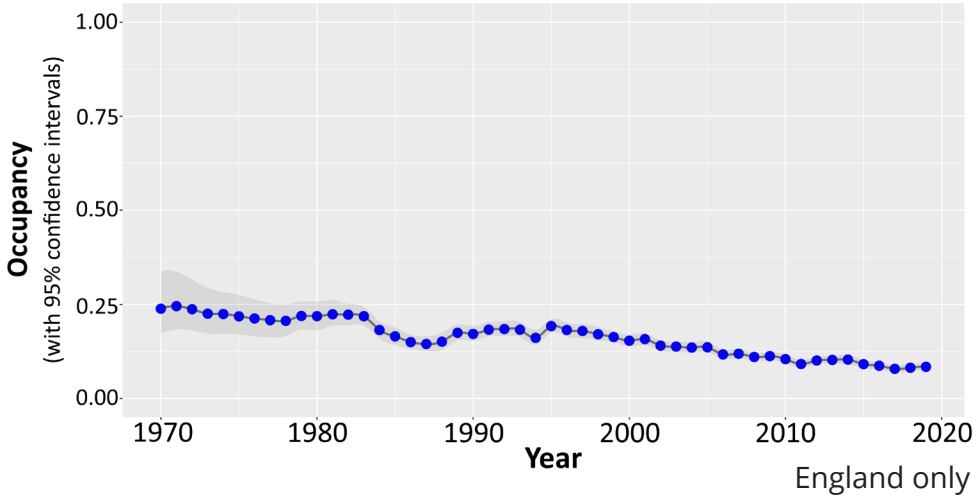
Male Black Darter © Volkmar Becher



Wales only

Common Hawker
Aeshna juncea

This hawker is another species typical of acidic bogs, pools and lakes in moorland or heathland. It is found throughout Ireland, but has a mainly northern and western distribution in Britain. The species has declined in England since 1995, whilst in Scotland there is weak evidence for an increase to 2004, but a decline since, that has returned the species to its previous level. The pattern in Ireland seems to roughly match that of Scotland, but changes in Ireland were not significant. The main causes of decline for this species, particularly in England, are thought to be climate and habitat changes, especially those affecting lowland heathland. In more upland areas, moorlands have also been degraded by the same causes as for Black Darter, especially in Scotland.



England only

Scarce Blue-tailed Damselfly
Ischnura pumilio

This species inhabits seepages, pools and small streams, often associated with heathland or with old mineral workings. It has declined in Britain, most noticeably in England between 1987 and 2001. The species is absent from Scotland, but there has been a decline in Wales since about 1989. As with the two previous species, habitat changes may be the main cause of decline. Reasons include inappropriate habitat management, the desiccation of shallow water areas, reworking or abandonment of quarries and reductions in livestock poaching. The last of these is a likely factor in the species' disappearance from some Dartmoor sites where livestock numbers have been reduced. Scarce Blue-tailed Damselfly has been recorded in Ireland, but records are relatively few and there is no discernible pattern in its trend. It is possibly under-recorded in Ireland, where its habitats are more natural in origin than in Britain, and its populations are more stable. This species is categorised as Near Threatened on the British Red List and Vulnerable on the Irish List.


Male Scarce Blue-tailed Damselfly © Dave Smallshire

Small Red Damselfly
Ceriagrion tenellum

Small Red Damselfly is another species found in seepages, pools and small streams. It declined in England up to 2000, since when its populations have stabilised. It is absent from Scotland and Ireland. The main threat to this species comes from habitat loss. In some locations scrub encroachment and desiccation have led to the demise of local populations. It is a poor flier and weak disperser, so its isolated sites make it vulnerable to local extinctions. It is Nationally Scarce.

Variable Damselfly, Blue-tailed Damselfly and White-faced Darter have all declined significantly in one or more individual countries, but not overall in Britain and Ireland.

Variable Damselfly
Coenagrion pulchellum

This damselfly has a scattered and patchy distribution, but can be locally abundant where found. It has declined in Wales since about 1993 and generally in ROI, but the pattern there is more erratic. By contrast, the species appears to have increased in Northern Ireland between 1976 and 1989. Variable Damselfly is a species prone to site gains and losses over time. Some sites become unsuitable due to eutrophication, succession, or a lack of management. However, it is a mobile species capable of colonising new sites as they become available. It is categorised as Near Threatened on the British Red List.

Blue-tailed Damselfly
Ischnura elegans

Blue-tailed Damselfly is one of our most pollution tolerant species, often being the only damselfly to be found in poor quality waters. It declined in England between 1993 and 2016, most noticeably after 2006. The species has actually increased in Wales, but the main gains were up to 1992, with subsequent losses since. It is possible this species has been affected by the use of neonicotinoid pesticides (Barmentlo *et al.*, 2019). These were introduced in 1991 and the UK area of use is known to have doubled between 1993 and 2013. In 2017 insect conservation charity Buglife reported that 88% of river water samples taken in Britain were contaminated by neonicotinoids and eight rivers in England exceeded recommended chronic pollution levels.

White-faced Darter
Leucorrhinia dubia

White-faced Darter has declined in England. It was last seen in Surrey in the late 1990s and lost from Cheshire in 2003. It is a species of lowland bog pools and depressions with a substantial covering of bog-moss, so vulnerable to drainage, peat extraction and scrub encroachment, as well as climate change. Recent re-establishment projects in northern England, including Cumbria and Cheshire, by the BDS in partnership with other organisations, are helping to redress historic losses. The species is absent from Ireland and categorised as Endangered on the British Red List.

Migrants and recent colonists

Species showing a positive trend

Willow Emerald Damselfly
Chalcolestes viridis

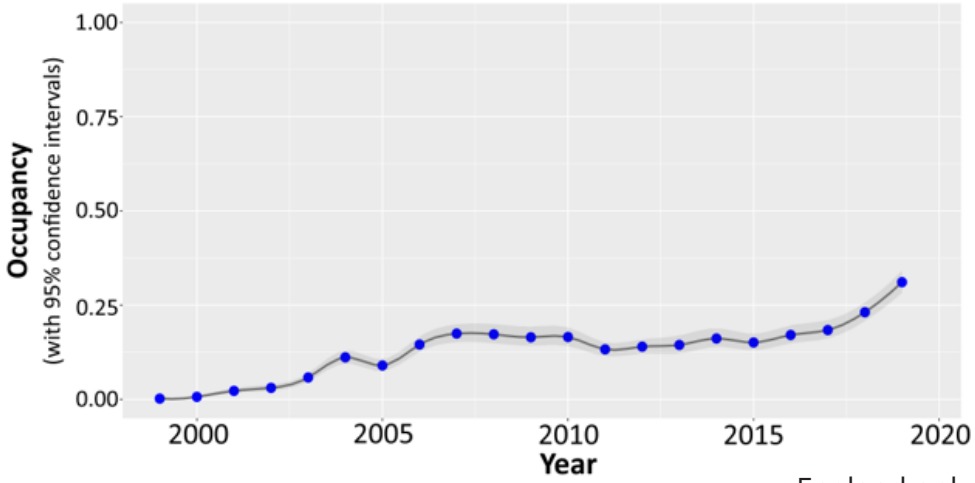
Prior to the start of this century, Willow Emerald Damselfly had only ever been recorded from Britain on two occasions – an adult found in Sussex in 1979, and a shed larval skin found in Kent in 1992. In 2007, a further individual was then reported from south-east Suffolk. Other, undiscovered, individuals were presumably also present in the area, as this immigration event was to lead to successful colonisation of Britain. The species soon became widespread in Suffolk and started appearing in adjacent counties. A steady range expansion averaging around 15–20 km a year has continued since then, and the species is now quite widespread in south-eastern England. A major push northwards was also seen along the east coast in 2019. The most northerly record in Britain is currently from North Yorkshire, while the most westerly sighting is from Warwickshire. Clearly the species is doing well in England, with roughly 20% of recorded monads now estimated to hold the species. It remains unrecorded from Wales, Scotland and Ireland.

Pair of Willow Emerald Damselflies in tandem © Pierre Bornand

Small Red-eyed Damselfly
Erythromma viridulum

Small Red-eyed Damselflies first appeared in Essex in 1999 and the Isle of Wight in 2000. A major influx then took place in 2001 that reached many coastal areas of East Anglia and Kent, with the occasional record as far inland as Bedfordshire. Substantial resident populations soon became established around these various founder sites, and within a few years the discrete populations had started to merge. Further range expansion continued and, after a series of good years, by 2007 much of East Anglia and central and southern England (as far west as Devon) had been colonised. Range expansion then slowed or came to a stop, but since 2015 expansion has picked up again. By 2018, Small Red-eyed Damselflies had reached as far west as Cornwall and parts of south Wales, while they had been seen as far north as Cheshire and just into North Yorkshire. Another significant range expansion then took place in 2019, with records as far north as County Durham.

The initially rapid range expansion and subsequent slowing can be explained using a modelled climate envelope. It was shown by the model that suitable climate conditions were available in south-east Britain prior to the damselfly's arrival so, once the species reached our shores, it spread rapidly to fill the suitable range. Expansion since 2007 has been slower, tracking climate warming. From being absent from Britain just over 20 years ago, the species is now estimated to occur in roughly 30% of recorded monads in England and 10% in Wales. It has yet to reach Scotland or Ireland.



England only

Male Small Red-eyed Damselfly © Dave Smallshire

Southern Migrant Hawker
Aeshna affinis

This species was first recorded in England in 1952, but was then absent for many years. A small influx took place in 2006, followed by a further influx in 2010 that led to colonisation of grazing marshes in the greater Thames Estuary area. Populations were small and localised for the first few years but have since consolidated, so that the species is now quite common in this area. A further immigration into England during 2015 saw records from new counties and may have resulted in additional breeding sites becoming established, for example in north Essex. During 2018–2020, Southern Migrant Hawkers were widely reported from several (predominantly coastal) areas of southern and eastern England, with records also from south Wales in 2019–20. It is still unclear whether these occurrences were the result of fresh immigrations or dispersal from the now thriving Thames Estuary populations; probably both were involved. With many of these 'new' sites seeing repeat sightings over consecutive years, it seems likely that yet more breeding sites have now become established, and Southern Migrant Hawker is presently showing a noticeable positive trend in Britain. This is particularly so in East Anglia and south-east England. The species does, though, remain unrecorded from Scotland and Ireland.

© Marc Heath

Red-veined Darter
Sympetrum fonscolombii

In the historical past, Red-veined Darter was known as an erratic migrant to Britain, being absent for many years but with the occasional obvious influx. Isolated records from Ireland in 1941/42 suggest its status there may have been similar. During the mid-1980s, records then began to increase in frequency in Britain, though the extent to which this was influenced by a growth in recorder numbers remains uncertain. The positive trend has, however, since continued, and nowadays the species is a regular migrant to our area, with substantial influxes taking place roughly every 2–3 years; particularly large invasions occurred in the hot summers of 2006 and 2019. Most records come from England and Wales, though individuals are increasingly reaching Scotland (as far north as the Orkney Islands) and the species is now also regularly noted, if only in small numbers, from Ireland. Spring immigrants often breed to produce a second generation that emerges the same autumn, but these individuals then disperse and are thought to migrate south. Some longer-lasting breeding sites have also become established over the last two decades as a result of spring emergences, though these seem not to be entirely stable and much still remains to be learnt about the detailed breeding biology of this highly mobile species. Red-veined Darter is clearly doing well in Britain at the moment.

Lesser Emperor
Anax parthenope

Lesser Emperor was first recorded in Britain during 1996, and has been seen here annually ever since; the first record for Ireland was in 2000. Although for some years it remained essentially a rare migrant, occasional reports of successful breeding were also received from southern England, though breeding seemed mostly not to persist. A big influx in 2006 saw reports from nearly 60 sites in Britain and five in Ireland, but again it seems that the species did not widely establish itself. After a temporary return to lower levels of immigration, the last 4–5 years have seen records starting to build up again, particularly in England, and with repeat sightings (either annually or every two years) from several sites, it seems likely that regular breeding is now taking place. In very recent times, both 2019 and 2020 have been particularly good years for Lesser Emperor, with reports as far west as County Cork in Ireland and as far north as the Inner Hebrides (though, overall, Irish and particularly Scottish records still remain relatively scarce). The number of sightings at the more regular sites in England has also continued to increase, with repeat sightings now also starting to come from a few sites in south Wales.

In addition to being a regular, though still relatively scarce, immigrant to Britain and Ireland, it appears that Lesser Emperor may at last be becoming an established resident in parts of southern Britain, though much still remains to be learnt about the species' precise status. What is obvious is that the species is showing a definite positive trend.

Vagrant Emperor
Anax ephippiger

This is a long-distance migrant of mainly African and Middle Eastern origin that can occasionally stray far from its core range; (it has even been recorded in Iceland and the Caribbean). The first sightings in Britain and Ireland date back to the start of the twentieth century, but for a long time the species was a great rarity. However, in recent decades, Vagrant Emperor has started to become much more regular in both Britain and Ireland. Several significant arrivals have occurred over the last ten years, mostly in autumn, but also sometimes during late winter or spring. During 2019, some truly remarkable arrivals took place, with records from an unprecedented 100 plus sites in Britain spread over three separate influxes in late winter/early spring, summer and autumn; the first and last of these influxes also reached Ireland to similarly produce the best ever year for the species there. Several instances of oviposition have been recorded in England over the last few years, though there is no proof yet that any breeding attempts have been successful. It has been suggested in the past that regular fluctuations in rainfall in the sub-Saharan regions of Africa, from which many of our Vagrant Emperors probably originate, could lead to cyclic patterns of abundance of the species in western Europe, through influencing population levels in the source areas (Dumont & Desmet, 1990). However, the modern run of significant influxes into Britain and Ireland is rather dramatic and strongly suggests that the species is genuinely now becoming increasingly common in our region. Possibly changes in weather patterns may have increased the chances of an influx, which are typically associated with a strong southerly airflow, and more regular breeding in southern Europe may now also be taking place, boosting numbers available to migrate northwards.

Southern Emerald Damselfly
Lestes barbarus

First recorded in England in 2002, Southern Emerald Damselfly has been slowly developing a foothold as a resident, aided by a low level of continuing immigration, principally along the coast of south-east England. Some early colonies are now extinct, but the species has bred successfully at a site in north Kent for many years, and records continue to come from the locality in Norfolk where the species was first discovered in Britain, though it may not breed there every year. Over the last five years, new breeding sites have been discovered in south Essex, in east Kent, on the Isle of Wight and inland in Buckinghamshire. Despite these positive trends the species remains highly localised in England, and it has not been recorded from Wales, Scotland or Ireland.

Female Southern Emerald Damselfly © Simon Mackie

Dainty Damselfly
Coenagrion scitulum

Dainty Damselfly was recorded from the Hadleigh area of Essex during 1946–1952, but became extinct there after the great coastal floods of early 1953. For over 55 years it was absent from Britain, but successfully recolonised around 2010, when a small population was discovered based around two or three waters in the Isle of Sheppey area of north Kent. This population has remained broadly stable but, significantly, a new site was then discovered in the Sandwich Bay area of Kent during 2019, with some 180 individuals being seen there in 2020. Because of access issues to the extensive tracts of private land in parts of coastal Kent, it is possible that further sites may exist but to date remain undiscovered.

Dainty Damselfly © Marc Heath

Vagrant species

After a long period of relative stability for Britain and Ireland's dragonfly fauna, since 1995 no less than eight species have appeared for the first time ever, and at least two others have appeared after a long gap since any previous records. Some of these species, such as Southern Emerald Damselfly, Small Red-eyed Damselfly, Southern Migrant Hawker and Lesser Emperor, have since gone on to colonise our shores and are described above, clearly showing positive population trends. The exact significance of the arrival of the remaining species is difficult to judge, as the great increase in the number of people interested in dragonflies over the last 30-40 years is bound to have increased the likelihood of any rare stragglers being found and recorded. Some observations are, however, clearly correlated with range changes on the Continent, and again probably reflect positive population trends. Particular attention must be drawn to Scarlet Darter *Crocothemis erythraea*; although there are currently only eleven confirmed British records, experience on the near Continent suggests it may be a potential colonist.

Species new to Britain and Ireland since 1995 currently occurring only as rare vagrants	Year of first occurrence	Recorded in more than one year since 1995?
Scarlet Darter (*Crocothemis erythraea*)	1995	Yes
Banded Darter (*Sympetrum pedemontanum*)	1995	No
Green Darner (*Anax junius*)	1998	No
Winter Damselfly (*Sympecma fusca*)	2008	No
Yellow-spotted Emerald (*Somatochlora flavomaculata*)	2018	No

Species reappearing since 1995 following a long gap without records, but which remain as vagrants	Year of first modern record	Recorded in more than one year since 1995?
Large White-faced Darter (*Leucorrhinia pectoralis*)	2012 there is also one record from 1859	Yes

Species showing a negative trend

Yellow-winged Darter

Sympetrum flaveolum

In contrast to most of our migrant species, which have been appearing with increased frequency and even starting to breed on a regular basis, Yellow-winged Darter is apparently in decline. Although always slightly erratic and unpredictable, British records were not unusual during much of the twentieth century, with the species even having reached Caithness in Scotland during 1945. Obvious invasions were recorded in 1898, 1926, several years during the 1940s, 1953, 1955 and 1995 (note that the absence of records from the 1960s or 1970s could well be an artefact, as dragonfly recording was at a low ebb in Britain during this period). The influx of 1995 was particularly dramatic and a few transitory breeding colonies even became established in England at this time, though these all rapidly died out. The only confirmed Irish records also date back to this influx, when the species was discovered at Tacumshin Lough, County Wexford; other Irish records are not fully substantiated. In recent decades, records from Britain have declined in number. Another small influx took place in 2006, but since then there have been very few sightings indeed, with the last confirmed record being from 2015. Given the erratic nature of past immigrations, this downward trend should not be over-interpreted, but, worryingly, a similar decline has also been noted over much of western Europe. Unlike most of our other migrant species, Yellow-winged Darter is of primarily eastern, rather than southern, European origin and is thus potentially subject to different pressures.

Female Yellow-winged Darter © Christophe Brochard

Comparison of trends across north-western Europe

To help understand the reasons behind trends in Britain & Ireland, it is useful to compare them with those seen in other nearby European countries. The Netherlands has had some form of ongoing dragonfly monitoring in place for some while, and detailed results are now available for 1990 onwards (van Grunsven *et al*., 2020, R. van Grunsven, pers. comm.). Similarly, an analysis of trends in Germany since 1980 has recently been completed (Bowler *et al.*, 2020). Less detailed information is also available from a variety of other countries in western Europe (e.g. Termaat *et al*., 2019). It is informative that, as with Britain & Ireland, most countries are currently reporting more 'winners' than 'losers'.

A group of generalist species can be identified that are increasing significantly in both the Netherlands and Germany as well as in Britain and Ireland. Emperor Dragonfly stands out as showing a strong positive trend in all these areas, with Migrant Hawker also widely increasing. Other species showing a broad increase include a suite of species whose strongholds lie in more southerly regions of Europe, for example Small Red-eyed Damselfly, Lesser Emperor and Red-veined Darter. It is likely that climate change is the main driver for most of these various increases (Ott, 2001), and indeed similar changes can be seen in many other areas of central and northern Europe. Although not so much a generalist, Norfolk Hawker is another species currently showing broad-scale increases in north-western Europe, and here too climate change may in part be involved. It should at this point be noted that certain species (e.g. Migrant Hawker) at first appear to be increasing less strongly in the Netherlands than elsewhere, but this will reflect the shorter time period of their analysis and the fact that some species that are still increasing in Britain and Ireland may now be nearing saturation (i.e. all suitable habitat occupied) in the Netherlands and parts of Germany.

Female Red-veined Darter © Dave Smallshire

As well as the 'southern' species that are becoming increasingly common in northern Europe, there is a group of riverine species, such as Banded and Beautiful Demoiselles, White-legged Damselfly and Scarce Chaser, which are also expanding on a broad front. In addition to climate change, the improvement in water quality that has taken place widely within the EU is probably acting as a driver. It has been shown by van Grunsven *et al*. (2020) that, in the Netherlands, riverine species have increased more rapidly than species with other habitat preferences, though in very recent years the rate of increase has slowed. It is interesting that while Common Clubtail has shown substantial increases on the Continent (over five-fold in the Netherlands and three-to-four-fold in Germany) there is little evidence for this in Britain, perhaps due to the limited availability of suitable river courses.

In addition to species showing a broad positive trend, a number of species can be identified where trends differ between countries, perhaps reflecting the differing geography and climate of the different areas, as well as local environmental and conservation policies. Species showing differing trends within Britain and Ireland obviously fit into this category, but more wide-scale differences are also apparent. Small Red Damselfly has, for example, shown significant increases in the Netherlands and also in Germany (where it has increased almost three-fold since 1995), but has declined slightly or remained stable in Britain over the corresponding time period. Southern Hawker is increasing in Britain, particularly in Scotland and Wales, but is declining slowly in both the Netherlands and Germany. Broad-bodied Chaser is increasing in Britain and the Netherlands but decreasing in Germany, while Scarce Blue-tailed Damselfly is declining in Britain and Germany, while increasing in the Netherlands.

Finally, there are a group of species which are in overall decline not only in Britain & Ireland, but also in the Netherlands and Germany. Although still remaining widespread and common, Blue-tailed Damselfly has shown statistically significant reductions in occupancy both in Germany and in England (though not elsewhere in Britain and Ireland), most notably since about 2005, with a declining trend also apparent in the Netherlands. Although changes are small, that such a ubiquitous damselfly without particularly exacting habitat requirements can be affected serves to highlight some of the threats currently being posed to the environment.

Male Broad-bodied Chaser © Gareth William Tonks

In this case, the use of pesticides such as neonicotinoids, has been shown to have a detrimental effect on the species. These pesticides have been used in both agriculture and pet flea treatments.

By way of larger reductions, of some conservation concern, Emerald Damselfly has in recent years lost roughly 35% of its range in England, Ireland, the Netherlands and Germany, though populations have remained more stable in Scotland and Wales. Common Hawker has declined even more strongly in the Netherlands, having been lost from up to 85% of its range since monitoring began, while in Germany, after a possible slight increase over the period 1980–2000, the species has since declined by around a third. This compares with something like a 60% reduction in England (see the graph on p. 33), though in the other parts of Britain and Ireland the Common Hawker appears more stable or, in Scotland, may even have increased slightly. The third species showing broad scale declines is Black Darter. This has lost something like 60–65% of its German range in the modern era, while in the Netherlands it has lost almost 50% of its range, with the most dramatic changes having been from 2010 onwards. In England the loss has been around 65%, with a substantial decline also apparent in Northern Ireland. In Wales there is also a declining trend, though this is less pronounced (ca. 30%), while in Scotland and Republic of Ireland (ROI) there may have been a small decline since 2000, but overall the species appears broadly stable. Common Hawker and Black Darter, and to a lesser degree Emerald Damselfly, are all linked by being species of moorland or heathland pools and bogs mainly filled by rainwater. Recent trends thus suggest this habitat is now under serious threat in many areas of north-western Europe, though the more northerly and westerly areas of Britain and Ireland appear to have so far escaped the very worst of any such negative pressure (as apparently has Sweden). Although habitat requirements are not entirely identical, this geographical effect might also help explain why species such as Northern Damselfly and also Irish Damselfly (though data is limited here) still seem to be faring OK in Britain and Ireland, whereas they are in significant decline in both the Netherlands and, particularly, Germany.

At this point it is also worth mentioning Yellow-winged Darter. This species has always been an erratic migrant to Britain, but the extent of immigration now appears to be declining. This correlates with a strong decline noted in both the Netherlands and Germany, where the species used to be a more regular migrant and where breeding also used to take place. The species currently seems to be withdrawing eastward, and on the verge of disappearing from many parts of north-western Europe (though not Scandinavia). Whether this will be permanent remains to be seen, but the continuation of low-level immigration on the near Continent at least gives some cause for hope.

Male Northern Damselfly © Dave Smallshire

Comparisons with other taxa

The positive response of many dragonfly species to climate change, and in particular higher average temperatures, is matched by some other species groups.

Butterflies

The State of the UK's Butterflies 2015 report showed that 30% (17 species) had increased in occurrence over the period 1976-2014, with all but two of the trends being statistically robust. However, habitat specialists, as opposed to generalists, had declined by about 70% since 1970. As with dragonflies, responses to climate change in butterflies do not act in isolation. Other factors, such as landscape-scale conservation projects targeting threatened species, have halted, and occasionally even reversed, declining trends. In addition, traditionally migrant species such as Red Admiral are now resident and rare vagrants such as Long-tailed Blue and Scarce Tortoiseshell are now arriving sporadically in larger numbers than previously.

30%

of UK butterfly species increased in occurrence during 1976-2014

70%

decline in occurrence of habitat specialist butterflies during 1976-2014

Red Admiral © Harald Henkel

As described for dragonflies, the effects of climate change on butterflies may be negative, as well as positive. In Britain, although the rate at which southern butterfly species have spread northwards has accelerated significantly over time, there is also evidence that extreme weather events such as droughts could have negative impacts. Climate change is likely to bring more frequent extreme weather events, so the overall consequences for both butterflies and dragonflies are mixed.

Moths

The State of Britain's Larger Moths (Fox *et al*., 2021) reported on changes during a similar period to this review of dragonfly trends. The total abundance of larger moths caught in light-traps across Britain decreased by 33% during 1968–2017. The abundance trends of 427 species included significant decreases in 41% of these (175 species) and increases in only 10% (42 species). However, occupancy modelling of National Moth Recording Scheme records for 1970-2016 showed that 32% of 511 species decreased significantly in distribution, while 37% increased (Randle *et al.*, 2019). More moth species have colonised Britain since 1900 than have become extinct. Many species emerge earlier now than 50 years ago and some have larger and more regular additional generations. Climate change was considered to be the main driver of range expansion. However, there were negative impacts on species adapted to cooler conditions in northern, western and upland Britain: moorland breeding species decreased significantly in distribution, by an average of 13%.

Other insects

The 2020 Parliamentary research briefing 'UK Insect Decline and Extinctions' (Anon, 2020) provides information on other insect groups and, once again, there is a mixed picture. Bees and hoverflies experienced dramatic losses between the 1950s and 1980s, but losses have slowed since the 1990s. A significant decline in abundance of ground beetles was found in 75% of 68 species, and 34 of those species decreased by 30% per decade between 1994 and 2008. The diversity of beetle species also declined. However, over the same period, beetle abundance increased (by 16–57%) in chalk downlands, woodlands and hedgerows. A recent UK study (Outhwaithe *et al*., 2020) found that distributions of freshwater insects such as caddisflies and mayflies decreased during the 1970s–1990s, but recovered in the 2000s to above 1970 levels. Species with increasing distributions tended to be generalists or to have adapted to a warmer climate. This is a similar picture to that presented here for dragonflies, with generalist species like Emperor and Migrant Hawker faring well, but specialists like upland and northern species showing declines.

Male Migrant Hawker © Tony Hisgett

Mammals

The State of the UK's Bats 2017 showed that after historic declines, the latest trends indicated that the populations of bat species that could be monitored were either stable or recovering. However, this was attributed to legislation and conservation action, rather than environmental or climate factors. A more general review of British terrestrial mammals (Mathews *et al*., 2018), the first such review for over 20 years, found the geographical ranges of 18 species had increased since 1995, four had declined; and 22 had remained stable. Over the same period, population sizes had increased in 15 species; nine had declined; and four had remained stable. A lack of data prevented assessment of the remaining species in each case. This review suggested that most of the trends in mammals were driven by habitat changes or human intervention such as culling. Climate was mentioned as a driver of change for only a few species: those that might benefit from warmer winters and those that feed on seeds and berries, where changes in fruiting times could affect food availability. It was found that all of the species most recently introduced to Britain showed an increase in geographical range since 1995 except the Brown Rat, which is stable, and the American Mink, where there are differences between countries. Additionally, all showed an increase in population size except these same two species.

American Mink © tsaiproject, flickr

Birds

The State of the UK's Birds 2020 report presents wild bird indicators for three broad habitat types: farmland, woodland and wetland. The indicators for farmland and woodland birds showed declines of 55% and 27%, respectively, between 1970 and 2019. However, the decline for wetland birds was just 12%, with strong declines in birds of wet grassland, but increases in birds of slow or standing water. This is an intriguing result given the breeding habitat of most dragonflies and the finding that more species increased than declined from 1970 to 2019.

The earlier State of the UK's Birds 2017 report contained a special feature on climate change and birds. It found that species distributions were predominantly moving northwards, but there was also some evidence for shifts to higher elevation. This northwards range expansion of southerly-species is similar to that found for several dragonflies. The 2017 report also showed that colonising bird species such as Cetti's Warbler had spread to cover much of southern Britain, but were still limited by cold winters. This is a similar scenario to that found for Small Red-eyed Damselfly, which spread rapidly after its initial colonisation but, having filled much of the available climate envelope, is now limited in further range expansion by lower temperatures further north.

Changes have been detected in bird distributions across Europe. Of 407 species analysed, 187 (46%) increased significantly and 135 (33%) declined during the 30 years to 2017 (Keller *et al*., 2020). The greatest net gains in species richness occurred in Arctic and Alpine regions, while there were some net losses in the Mediterranean region; these changes were consistent with the effects of climate change. Declining distributions were associated with species of farmland, tundra, mires and moorland, and montane habitat in Central and Southern Europe; however, many species of inland wetlands increased, in part due to better protection.

Drivers of change

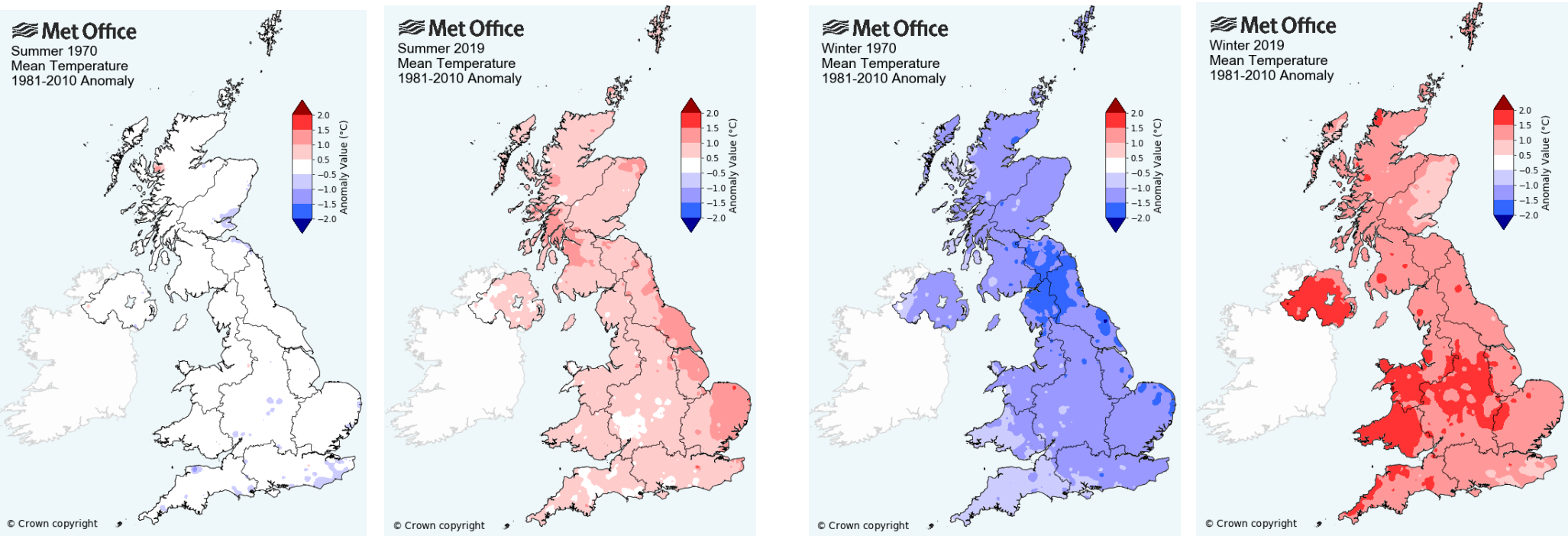
The production of species trends does not reveal the underlying causes. There has been little scientific study to determine the precise causes and their relative impacts on dragonfly populations, although climate change and habitat quantity and quality are clearly important. This assessment of the driving forces behind the observed trends is therefore based principally on expert opinion using what is known of dragonfly biology and ecology.

Climate change

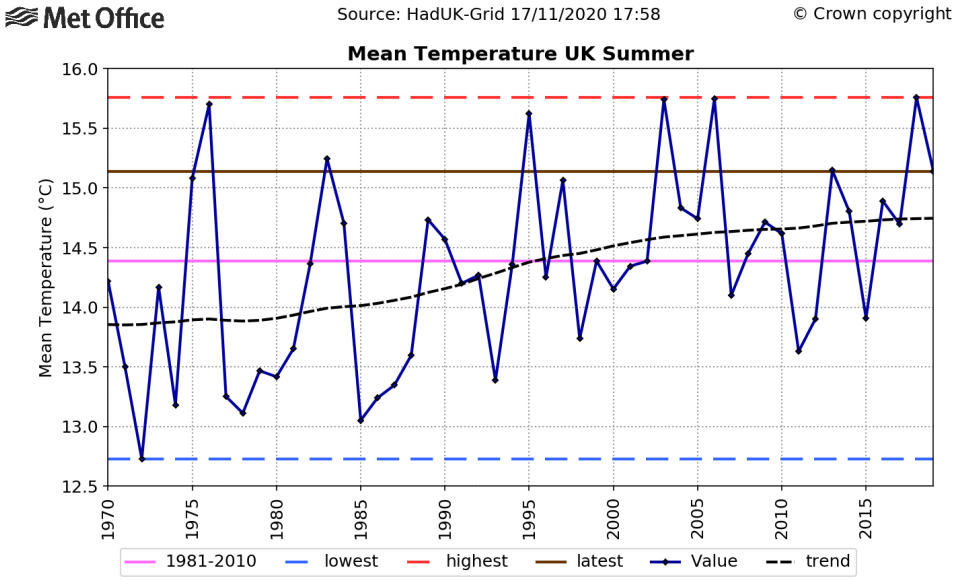
Throughout a half-century of habitat loss, degradation, creation and restoration, this review period has also seen a wide range of wildlife being affected by climate change. The distributions and populations of insects, and especially dragonflies, have been influenced significantly. Of course climate change has taken effect globally, and in Continental Europe as well as in Britain and Ireland there is good evidence of generally increasing temperature and rainfall in both summer and winter. Extreme weather events have become more frequent, producing record high temperatures and rainfall totals. However, there have also been periodic droughts as well as episodes of flooding.

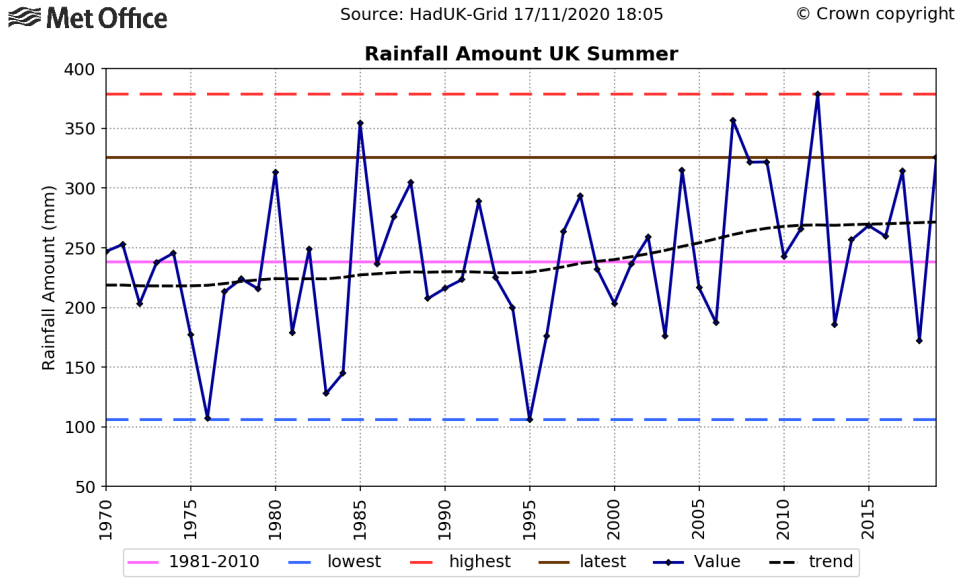
For some species, the changes in their breeding ranges facilitated by these altered environmental conditions have been dramatic, with the less-demanding generalist species faring well. These range expansions have most likely been largely driven by higher summer temperatures (an increase of almost 1°C in the UK during the 50-year period under review), although winter temperatures have also increased (by about 0.6°C), as has rainfall in both summer (by about 23%) and winter (15%). See the graphs on page 50 for more climatic detail. Whilst the effects of increased temperature on a cold-blooded insect can easily be appreciated, especially in a temperate region such as ours, the effects of rainfall are more complex. For example, storm events have caused extreme flooding, with the consequent erosion of sediment and aquatic vegetation, while periodic droughts have caused low water levels or even the desiccation of wetlands. The following paragraphs illustrate the ways in which climate is likely to have affected dragonfly populations.

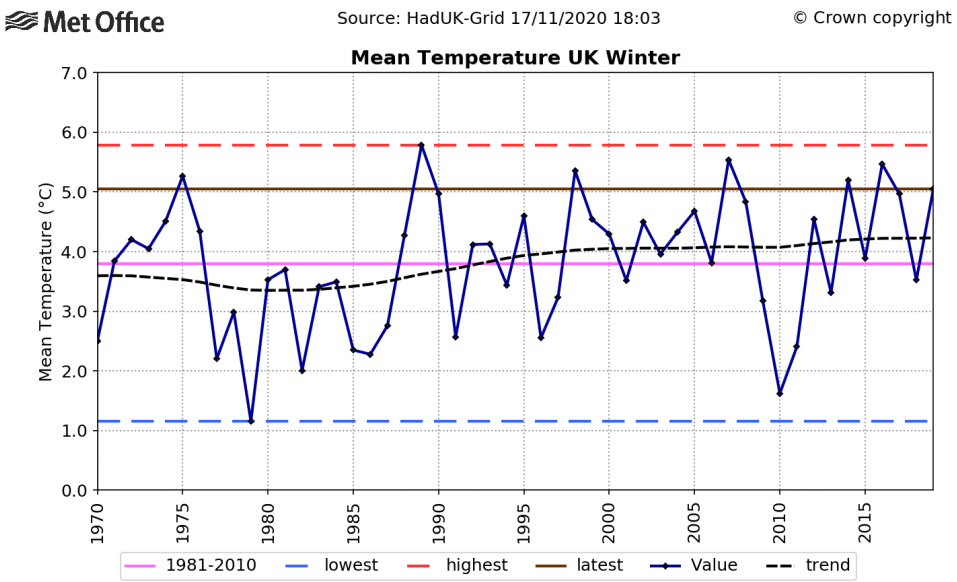
Mean summer and winter temperatures: comparisons between 1970 and 2019 relative to the 1981-2010 mean

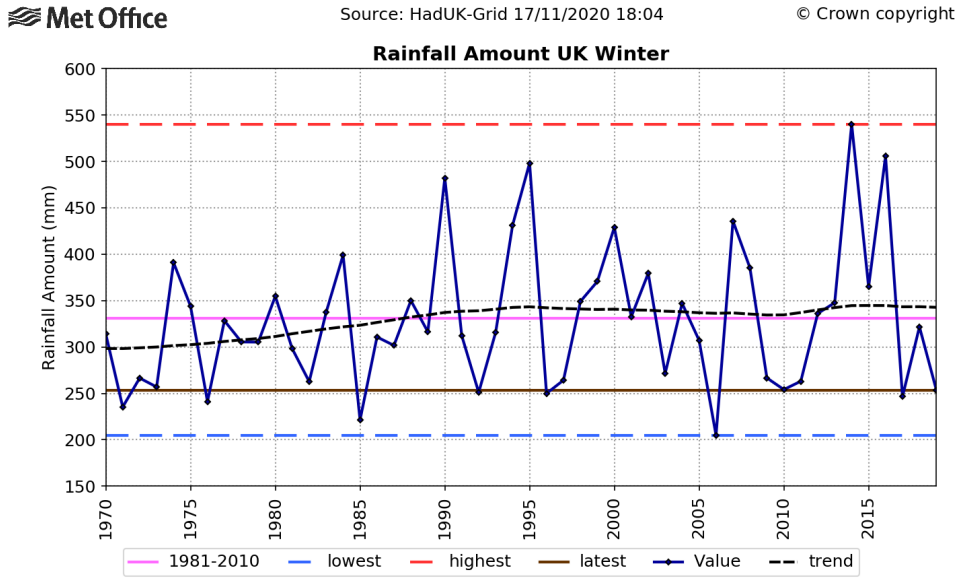


Annual mean temperatures and rainfall in Britain between 1970 and 2019









Warm summer weather increases survival in flying insects such as dragonflies, as well as their prey, thereby increasing populations and hence the likelihood of dispersal events from mainland Europe and range extension within Britain and Ireland. For example, a surge in Lesser Emperor records in late July 2019 (Parr, 2020) coincided with a period of unusual warmth over much of western Europe. The difference between a hot, dry summer and a cool, wet one can mean a large difference in dragonfly populations: hundreds or thousands in good years may be reduced to very low, perhaps undetectable, levels in poor summers. Warmer and drier weather during the flight season also speeds up maturation and generally increases the opportunities for egg-laying by females, as well as the opportunities for dragonfly recorders to be out in the field during optimal conditions. At the start of the flight season, calm, sunny conditions improve the chances of adults emerging successfully from their aquatic larval stage.

Hot winds from the Continent favour immigration, as well as northerly and westerly spread within Britain and Ireland. The establishment of new colonists has also been aided by climatic conditions having already become suitable for many species even before they first arrived. Most notably, this enabled the rapid spread of Small Red-eyed Damselfly in the first decade following its arrival in Britain in 1999 (Cham *et al.*, 2014). Convection currents in hot, calm conditions can aid dispersal by both newly-emerged and mature adults. The dispersal of adults may be triggered by high densities of larvae and adults, resulting from improved, climate-related survival and perhaps also from more concentrated adult populations caused by rain-delayed emergence. All of these factors increase the likelihood of species spreading to, and being found at, new locations.

Water temperature influences the rate of larval development by regulating feeding activity and prey availability; there may also be effects on larval mortality from predation and parasitism. Raised water temperature promotes more rapid larval development, which reduces generation times (voltinism) and alters phenology. By stimulating the earlier emergence of adults (Hassall *et al*., 2007) and shortening their life cycles, semivoltine species (i.e. having two-year life cycles) may become univoltine (one year). In a similar way, univoltine species may become bivoltine (having two generations a year); Red-veined Darter and Scarce Blue-tailed Damselfly are known to respond in this way in Continental Europe, and probably here too. During recent re-establishment projects of two scarce species, Southern Damselfly and White-faced Darter, there was evidence of univoltinism rather than the typical semivoltine life cycle of these species. Others that traditionally exhibited concerted spring emergence after two years as larvae, such as Emperor Dragonfly, may have second waves of emergence later in the summer from larvae little more than one year old, thereby extending the flight periods and hence the chances of detection. On the downside, elevated water temperature also lowers oxygen levels, while high levels of sunlight promote the growth of higher plants and algae.

Immature female Scarce Blue-tailed Damselfly © Dave Smallshire

Periods of drought may cause some wetland sites to dry out completely, both here and on the Continent, which may in turn lead to local extinctions and/or trigger the dispersal of adults and lead to new sites being colonised. Conversely, if re-wetted, sites may soon hold large populations of mobile generalist dragonflies, the larvae of which benefit from the loss of aquatic predators, such as fish and amphibians. Low flows, exacerbated locally by increased abstraction, inevitably increase environmental stress in some watercourses.

The shallower bogs in the western Highlands have become increasingly dry since 2000 and the absence of Azure Hawker since 2014 from Silver Flowe, this species' former outpost in south-west Scotland, is strongly linked to drought. It was especially dependent on shallower pools that have been most affected. However, in other habitats it may be difficult to separate the effects of drought from seral habitat change, especially when ponds or ditches become choked with encroaching vegetation and lose their surface water. This may have affected some sites for Scarce Blue-tailed Damselfly, which favours early successional stages and had a significant negative trend in occupancy. On the contrary, the overall trend for Ruddy Darter, which often breeds in the later stages of natural wetland succession, was significantly positive.

Immature male Azure Hawker © Christophe Brochard

Flood events have increased in frequency, but the effects of these on dragonflies are poorly understood. Flooding brings the possibility of the downstream spread of larvae or eggs, including to otherwise isolated standing waters such as oxbow lakes. On the Continent, this is thought to be behind the range expansion shown by several of the rarer gomphids. However, flash floods can increase mortality during emergence. Silts and gravel beds may be redistributed during high flows, resulting in changes to the quality of larval microhabitats. Flooding may also affect waters indirectly through associated topsoil erosion and deposition, and sewage, silage and agrochemical pollution, leading to eutrophication and toxicity. Near the coast, tidal surges can push saline water further inland in river systems, killing freshwater invertebrates and indirectly affecting dragonfly larvae through the destruction of freshwater aquatic plants and the food chain dependent upon them.

Flooding in Cumbria © Tony Armstrong-Sly

Habitat quality and quantity

Since World War II, a major detrimental impact on dragonfly populations has come from a significant intensification of agriculture – farmland being the major land cover type in Britain and Ireland. This includes field drainage, infilling of ponds and the use of fertilisers and pesticides. During the last 50 years, both widespread and localised species occurring in standing and especially flowing waters have been at risk from pollution from a range of agricultural and urban sources, including industrial effluent and pesticides, and eutrophication from fertilisers, sewage and silage leaks. This is all despite attempts to meet environmental standards.

Direct wetland losses from land drainage thankfully have declined in recent years. Nevertheless, there have been losses resulting from factors such as the afforestation of peat bog; flooding, infilling and reworking after mineral extraction; and natural succession, often exacerbated by a lack of management. The consequent isolation of breeding sites may reduce genetic diversity and increase the risk of local extinctions; this has been identified as a threat to a number of sites for the red listed Southern Damselfly and nationally scarce Small Red Damselfly. The incidence of damage to peatlands by extraction for horticulture has now reduced following campaigns: on average, over 1.5 million cubic metres of peat were extracted annually during 1997-2001, reducing to less than 850,000 cubic metres during 2011-15.

An estimated 75% of ponds were lost from England and Wales between the end of the 19th century and the 1980s, although there have been increases in pond numbers across Britain since then (Williams *et al*., 2010). Many were simply infilled and ploughed over to become little more than depressions within fields, while others were lost to scrub encroachment and subsequent drying. A lack of appropriate grazing management in heathland has resulted in the growth of scrub and localised losses of some dragonfly species. Of particular importance have been some declines and extinctions in the red listed Southern Damselfly, although the advent of the Biodiversity Action Plan for this species brought about research into habitat requirements, remedial management and re-establishment to counteract these losses.

Widespread habitat degradation through acidification and eutrophication has resulted from atmospheric nitrogen and sulphur dioxide deposition, although levels of the latter have declined in recent years. The UK land area where acidity critical loads were exceeded fell by more than two-thirds between 1996 and 2016, although the area that exceeded nutrient nitrogen critical loads only decreased by little more than one-third in this period.

Below, we take a closer look at various aspects of habitat changes, with an emphasis on the situation in England, where the underlying scientific data is most extensive. General trends, however, are likely to be broadly similar over much of Britain and Ireland.

Male Southern Damselfly © Roger Pendell

Water quality

Climate change is likely to have exacerbated the impacts of eutrophication, through increased summer temperatures, changes in rainfall patterns and reduced river flows. Increased run-off during heavy rain has led to higher nutrient loads in waterbodies, while increased temperatures and sunlight, and lower summer river flows are likely to have caused excessive algal growth.

Water quality has generally improved since the 1980s, although not in Ireland. For example, about 55% of river length in England was assessed in 1970 as being in good or better biological and chemical quality (defined as close to 'undisturbed' conditions); this proportion had risen to 70-80% by 2008, although these improvements have not continued subsequently and only 14% of rivers meet Good Ecological Status under the EU Water Framework Directive.

Agriculture is the largest sector responsible for significant water pollution events in England, although the overall number of serious incidents fell by almost two-thirds between 2001 and 2016. Fertilisers, slurry, sheep dip and other pesticides have polluted flowing waters especially, while silage effluent can be up to 200 times more toxic than untreated sewage if it finds its way into waterways. Thankfully, fertiliser use has been moderated in recent years, moves have been made to improve slurry and silage storage facilities and organophosphate sheep dips have been banned in the UK since 1999. Despite the ban on the use of persistent organochlorine insecticides, which finally came in 1984, new and environmentally-damaging compounds have continued to give cause for concern. In particular, neonicotinoid insecticides, used widely in agriculture until an EU-wide ban in 2018, have proved extremely toxic to aquatic organisms (Wood & Goulson, 2017; Yamamuro *et al*., 2019). There is good experimental evidence that prey consumption, mobility and emergence in Blue-tailed Damselfly are adversely affected by the neonicotinoid thiacloprid (Barmentlo *et al*., 2019). It may be no coincidence, therefore, that this species is one of the few whose trend has declined significantly in England.

In England, serious pollution incidents are steadily declining and rivers that were biologically dead are reviving. Phosphorus is the main cause of eutrophication and the top reason for English rivers and lakes not achieving good ecological status. Phosphorus levels in rivers increased from the 1950s to the early 1990s, since when levels have decreased significantly, largely as a result of improvements at sewage treatment works. The main sources of phosphorus are sewage effluent and run-off from agricultural land. Pollutant loads to rivers from water industry discharges have reduced by up to 70% since 1995. Nevertheless, in 2015, water quality issues were the cause of 61% of invertebrate test failures in English rivers, where 26% were judged to be at less than good status for invertebrates. The following year, 86% of river water bodies were judged not to have reached good ecological status, with 55% at less than good status for phosphorus.

Grazing sheep © Karl Norling

Habitat creation and enhancement

In order to negate the losses of farm ponds and drained wetlands, there have been many opportunities to create new habitats for dragonflies. These range from landscape-scale wetlands to garden ponds. The mechanical extraction of peat, clay and minerals has often created deeper flooded waters that generally favour the more widespread generalist species. However, some lowland peat areas have come under nature reserve management and have been restored to valuable wetlands; notable among these are Fenn's, Whixall and Bettisfield Mosses National Nature Reserve spanning the Wales/Shropshire border and Avalon Marshes in Somerset. On nature reserves, wetland conservation or creation is seen as an important goal and dragonflies are increasingly seen as a flagship group worthy of conservation and promotion to visitors. Ponds are excellent for raising awareness of dragonflies and visitor experiences have been enhanced at 'Dragonfly Hotspots' identified by BDS, through the provision of information boards and events.

The BDS has encouraged the creation of garden ponds through its 'Dig a Pond for Dragonflies' booklet. Over 15 years until 2011, the BDS also oversaw the distribution of school pond grants, in memory of Peter Miller. Ponds can be an integral element of Sustainable Drainage Systems (SuDS), although those ponds designed to delay water flow from urban sites may attract breeding dragonflies that are subsequently lost as the ponds dry out.

Many ponds and lakes have been created on farmland in recent decades, with motives that include irrigation, angling and wildlife conservation. The Pond Conservation/Freshwater Habitats Trust's 'Million Ponds Project' helped to create 1023 ponds to benefit Biodiversity Action Plan species across England and Wales during 2008-12 and aimed to create a further 30,000 clean water ponds in the UK by 2020. Following the loss of an estimated 8,000 ponds in Norfolk since the 1950s, the Norfolk Ponds Project has restored over 200 tree-covered farmland ponds since 2014 to high quality, open-canopy ponds dominated by wetland plants, with huge benefits for plants, invertebrates and amphibians, as well as pollinators and farmland birds. In one area, the restoration of nine ponds saw an increase from 13 to 22 dragonfly species, newcomers including the red listed Scarce Emerald Damselfly.

The value of Beavers as landscape engineers in river catchments is gaining recognition (Rosell *et al*., 2005), and there are recent moves to see them re-established in parts of Britain. Their value to dragonflies is recognised in Europe and North America, and is gradually becoming evident here. For example, Small Red Damselfly, a Nationally Scarce wet heathland specialist, was discovered at a Beaver enclosure in Devon in 2019 where the species was previously unknown.

A Norfolk farmland pond recently restored by major tree and sediment removal by Norfolk Ponds Project 2016 © Norfolk Ponds Project

Uplands

Two of the species with significantly declining occupancy trends, Common Hawker and Black Darter, have ranges that are predominantly upland and/or northern in Britain, although in Ireland Black Darter mainly occupies lowland sites and Common Hawker can be found at all altitudes. After climate change, the major drivers affecting upland bogs, lakes and watercourses are atmospheric deposition (via acidification and eutrophication), burning and grazing management.

Notable recent trends include reduced sulphur dioxide and nitrogen deposition, although the 'critical loads' (deposition) and 'critical levels' (gaseous pollutants) which can cause adverse effects can still be exceeded for both in sensitive habitats such as upland and lowland heathland. The area of acid-sensitive habitats that exceeded acidity critical loads fell by more than two-thirds between 1996 and 2016, although the acidification of watercourses may still be a problem, even with reduced sulphur deposition. The proportion of nitrogen-sensitive habitats where nutrient nitrogen critical loads were exceeded decreased from 75% (54,785 km^2) in 1996 to 58% (42,434 km^2) in 2016. This smaller reduction has been due to the smaller proportional reductions in nitrogen deposition, compared to sulphur.

Managed burning, mostly on grouse moors in northern England and Scotland, is associated with increasing dissolved and particulate organic carbon in watercourses draining upland catchments, especially peatland. Burning has for some time been reported as increasing, including on peatlands. Such burning causes organic deposition and changes to water chemistry in upland watercourses, and indirectly changes the composition and diversity of aquatic invertebrates. Therefore, moorland burning has the potential to affect upland dragonflies. The dissolved organic carbon of upland watercourses has been increasing for some time, driven by a combination of burning, reduced sulphur dioxide deposition, increased temperature and fluctuating rainfall (with increases in summer).

Heavy grazing can also cause increases in dissolved organic carbon and especially particulate organic carbon in watercourses, notably on upland peatlands. Numbers of both cattle and sheep increased in the UK and Ireland in response to EU subsidies, peaking in the 1970s and 1990s, respectively; sheep numbers have declined substantially since, while cattle numbers declined by about one-third in the UK, but have been more or less stable in Ireland.

Cairngorms © Manuel Osdoba

Competition

Competition can occur from new dragonfly species as they move into an area, as well as from other species groups. The latter include non-native invasive species (NNIS), the relative influence of which may have changed as a consequence of climate change. The problems caused by NNIS have emerged as a major headache for wetland managers. NNIS such as Signal Crayfish, Demon and Killer Shrimps, Marsh Frog, New Zealand Pigmy Weed and Floating Pennywort threaten native species through predation, competition for food, habitat modification and by spreading disease. A study in Germany (Ott, 2018) found the presence of invasive non-native crayfish to be extremely detrimental to some dragonfly populations, particularly those dragonfly species whose larvae live in the sediment where crayfish hunt. The main crayfish found in the study was Signal Crayfish, but at one site Turkish Crayfish were also noted as predators of dragonfly larvae. Both of these non-native crayfish now occur in Britain.

Signal Crayfish © USFWS - Pacific Region

Conclusions

Dragonfly populations and range in Britain and Ireland are driven essentially by temperature and the availability of suitable habitat. Both temperature and rainfall increased during 1970-2019, while suitable habitats have been created or restored increasingly during that period. Higher temperatures have no doubt benefited adults through reduced mortality and aiding dispersal to new breeding sites. However, they have also increased the risk of wetlands drying out temporarily, despite higher rainfall, but to date there is little if any evidence of local extinctions as a result of this. Rainfall keeps wetlands wet, dilutes pollutants and thereby helps to maintain good habitat quality, although heavy rainfall also increases the risk of pollution events and directly increases adult mortality.

For the most part, these climate changes have benefited dragonflies, especially those generalist species that have spread at both local and national scales. However, a smaller number of specialist, upland and/or northern species are at risk from increasing temperatures, as well as the degradation of moorland bogs through atmospheric deposition, burning and changes in grazing regime. Some of our rarest dragonfly species and their habitats are known to have been affected by afforestation, which, together with the related land drainage, increased shading and acidification, has damaged large areas of bogs and heathlands. Industrial scale peat-extraction, driven by the demands of horticulture and power generation, has added to the losses of these habitats and their dragonflies.

Although the agriculture, forestry and peat-extraction industries have caused direct losses of dragonfly habitats, these have been balanced somewhat by gains from targeted wildlife conservation measures, the creation of ponds and reservoirs and the flooding of worked-out mineral and peat workings. Locally, in earlier times, small-scale mining created wetlands that often held scarce species, but modern mechanical extraction has typically left behind deeper pits that, when flooded, mostly favour the more widespread generalist species.

Therefore, while changes in the climate over the last five decades are likely to have had the greatest influence on dragonflies, these have interacted with a wide range of other factors in complex ways. The principal threats currently are to our rarest species, through habitat loss and degradation, and to our upland/northern species, through the effects of climate change.

Peat cutting © Mark J Handel

Future threats and potential drivers of change

Population growth, climate change (and related sea level rise), non-native invasive species, novel chemicals, plastic pollution, nano-particles and fracking all present potential future threats to water quality, with consequent threats to dragonflies and other aquatic life forms.

Although not currently an issue, the following factors may well have an influence on dragonfly populations in the medium term future.

Sea level changes

Rising sea level and increased storminess caused by climate change pose risks of coastal inundation to areas of national importance for dragonflies such as Norfolk Hawker and Dainty Damselfly (coastal inundation was responsible for the loss of the latter in 1953); Scarce Emerald Damselfly and Southern Migrant Hawker also have significant populations on coastal grazing marshes that might be considered 'at risk'.

Marshland near Walberswick © stephengg, flickr

Accidentally introduced ‘exotic’ dragonflies and damselflies

It has been known for some time that dragonflies can be accidentally introduced into Britain, either as eggs or larvae, along with water plants imported by the horticultural or aquarium trade. Towards the end of the last century, Brooks (1988) listed thirteen non-native species discovered flying in the greenhouses of an aquatic nursery in north London over the course of seven years. For a while such discoveries were treated primarily as a curiosity, but a growing awareness of the potential ecological problems posed by invasive alien species has seen a recent growth of interest in non-native dragonflies. At least 25 exotic species have been reported from Europe (Laister *et al*., 2014), with the dragonflies typically being encountered in aquatic plant nurseries or discovered emerging from domestic aquariums, though there are also a few reports from the wild. In Britain, Marsh Bluetail *Ischnura senegalensis* and Oriental Scarlet *Crocothemis servilia* are currently the species most regularly encountered (Parr, 2010). Several reports, particularly of Marsh Bluetail, are now received each year. The true level of importation must, however, be very much higher than these formal records would suggest.

The aquarium plant trade has grown considerably over the last 50 years, and the internet and e-commerce has boosted the ease with which plants can be disseminated while at the same time making biosecurity issues more difficult to control. The opportunity for accidentally-introduced dragonflies to establish themselves in the wild is thus growing, and with it the potential for direct competition with our native species (including even potential interbreeding). Fortunately, while they may be routed via intermediary countries, at present the majority of imported non-native aquarium plants are ultimately sourced from south-east Asia (Parr, 2010). Any associated dragonflies thus largely comprise sub-tropical species, and no exotic dragonflies have so far succeeded in establishing themselves in Britain and Ireland. However, with ongoing global warming this situation may change. In warmer areas of the New World there are already several examples of Oriental Scarlet having developed self-sustaining local populations as a result of accidental introductions, for example in Florida and Cuba (Paulson, 1978; Ramos, 2000). Any trend to introduce aquatic plants from more temperate areas outside Europe may also lead to exotic dragonfly species ultimately becoming established in Britain and Ireland, and potentially impacting our own native species.

Immature female Marsh Bluetail © Mark J Handel

BDS conservation initiatives and other projects

Recording, surveys, habitat management and re-introductions

When the British Dragonfly Society was first formed by a group of enthusiasts back in 1983, it had two main aims; recording dragonflies and dragonfly conservation. Those aims remain cornerstones of the Society today, but over the last two decades a third aim, to raise awareness of dragonflies, has also become vitally important.

There's an often-quoted statement by Baba Dioum that. . .

"In the end we will conserve only what we love, we will love only what we understand, and we will understand only what we are taught."

This statement resonates within the BDS today as we strive to inform and enthuse as many people as possible about the beauty and importance of dragonflies. The BDS uses many means to achieve this, from education materials for the young, to talks and courses for all age groups, and from conferences to field meetings. Social media obviously plays a huge role in our publicity today, with several Facebook pages, Twitter and websites helping people to identify what they see or photograph. The BDS always tries to encourage observers to record their sightings or get involved in more practical ways to aid the conservation of dragonflies and their habitats.

Common Clubtail © Jonas Myrenås

As part of BDS awareness raising campaigns, the Society has initiated several species-specific citizen science projects. The first was an online recording project for Banded Demoiselle aimed at mapping its spread northwards as the species reached Scotland. The most recent focuses on Willow Emerald Damselfly, mapping its range expansion since the current colonisation began just over a decade ago.

Other species-specific projects are more restricted in scope, with participants signing up to survey particular areas. These projects usually involve species we have particular concerns about, such as Common Clubtail, White-legged Damselfly and, in Scotland, Northern Damselfly, where we hope survey work can be followed by management of existing ponds and the creation of stepping stone ponds between them.

Common Clubtail is associated with clean, slow flowing lowland rivers in England and Wales. Adults are difficult to locate because they spend most of their life in treetops, where they feed, roost and mate. Males will return to the river or canal to hold territories, but are rarely seen there. Females return to water only to deposit their eggs. As a result, records for Common Clubtail have been relatively scarce, making it hard to judge how the species has fared in our pollution-prone and increasingly fluctuating rivers. With concerns raised regarding the impacts of agricultural pollution and human waste water on the health of our rivers, together with changes to riverside habitats, the BDS decided to make an amplified effort to map the current distribution of this species. The survey was timed, over three seasons, for when Common Clubtail was easiest to find - during its synchronised emergence. On warm sunny mornings the larvae, en masse, crawl out of their rivers and sometimes canals, onto the banks. The emerging adults and their discarded exuviae can be found on vegetation, mooring posts and the undersides of bridges.

The Clubtail Count project launched in 2017 and over the three survey years had over 180 participants who adopted a total of 348 km of river in 1km stretches. The project focused on key historic Clubtail breeding rivers and collected over 1,950 records. As a result, the project helped to identify the most important river systems, vital information for safeguarding surviving populations. The data obtained can be used to guide conservation programmes

Volunteer recorders © Andrea Hudspeth

such as local Common Clubtail Biodiversity Action Plans. The project also aimed to identify Clubtail-free zones where there had been historic records, as these could indicate rivers no longer favourable for the species. These results might indicate reduced water quality due to increased pollution or sediment load, destructive dredging, or loss of riparian woodland.

During the Clubtail Count project, concerns were also raised for another mainly riverine species; White-legged Damselfly. The species is believed to be undergoing a significant range shift, with reports of decline in previous strongholds, but increases in its range in the north-west. While this damselfly has previously been considered a riverine species, it is increasingly recorded in still water habitats, such as ponds. Initially, survey participants were asked to add this species to their Clubtail recording, then in 2019 a dedicated species-specific recording project was launched for this damselfly to increase our understanding of how its distribution has changed and how this relates to habitat use.

All of this surveying and recording is necessary to underpin vital conservation work by the BDS and others. A species can only be conserved if we know where it is found and if we can understand its habitat requirements. Once we are aware of these facts, the BDS can work with land managers and other organisations to create, preserve or restore key sites.

In Scotland, three BDS Dragonfly Hotspots, Flanders Moss, Portmoak Moss and Greenhead Moss, are on raised bogs where peatland restoration work has taken place over the past few years. Flanders Moss National Nature Reserve, near Doune, is one of the most southerly known sites for the rare Northern Emerald dragonfly, which is found in sphagnum-filled bog pools and runnels. The site is one of the largest and least damaged lowland raised bogs in Britain and is home to a complex of bog vegetation. To ensure that there continues to be a variety of habitats to suit this rare species, as well as other dragonfly species, the BDS has run a number of volunteer events to create pools, by digging out small ponds and installing peat dams along the drainage ditches. As this has been done over a number of years, the pools are now at differing stages of succession and therefore suit different species of dragonflies. At Portmoak Moss cracks on the edge of the peat dome have been filled in using peat that was extracted when creating new dragonfly pools. This ensures the maximum amount of water stays on the Moss, helping it to stay wet during periods of drought.

Female Northern Emerald © Jo Hood

BDS Dragonfly Hotspots such as these are fantastic places to engage people interested in dragonflies, while many are also important for rare species and habitats. The BDS has run many guided walks and training events for the public and countryside professionals at a number of our Hotspots over the years.

Year round, BDS staff and volunteers respond to requests for advice and support regarding dragonfly habitat management, often from other nature organisations, as well as private landowners. While this support is predominantly provided remotely, face-to-face consultations and site visits are conducted where possible.

Over the past few years the BDS Conservation Officer has provided onsite consultation advice at places such as Telford Millennium NR, where site staff were encouraged to carry out scrub clearance to open up their over-shaded pools. At the Shropshire Hills Discovery Centre, the first English BDS Hotspot, volunteers are carrying out regular wetland management to enhance the site for a wide range of species, under the guidance of the BDS.

BDS volunteers, including County Dragonfly Recorders, often play an important role in this habitat management function of the BDS, acting as local contacts and providing specialist knowledge regarding local species, sites and environmental issues. For example, BDS volunteer Bruce Hyde has been working with landowners and organisations in and around Swanbourne, Buckinghamshire, monitoring local wetland sites and promoting their management for the benefit of dragonflies. This included arranging an onsite meeting with local residents, land owners and the BDS Conservation Officer to explore habitat enhancement opportunities. Each wetland presented a different challenge to rectify problems in order to maximise their suitability for breeding dragonflies, from stabilising water levels to identifying and eradicating sources of pollution.

In Dorset, Kevin Edge and his local outreach team have surveyed ponds at Hengistbury Head and carried out scrub removal to improve their condition, working in partnership with the ranger team at the site.

In Wales, Hampshire and Devon, work has been carried out to create new seepages, open up overgrown runnels and dig new pools and shallow streams to benefit the scarce and threatened Southern Damselfly. More intensive grazing has been encouraged at some sites in order to maintain open, shallow wet areas. Southern Damselfly is endemic to south and west Europe and North Africa. It is threatened throughout its range and in the UK

Pond dipping © Fiona McKenna

declined by 30% during 1960-2000. It occurs in highly-localised, scattered locations in Hampshire, Dorset, Devon, Oxfordshire, Pembrokeshire, the Gower Peninsula and Anglesey. In 2005, it was present in 85 monads in England (29 populations at 13 sites) and Wales (four sites). Research has elucidated the precise habitat requirements; it is primarily a species of shallow, base-rich, slow-flowing runnels and streams in acid heathland, although it also occurs in water meadows in two chalk river valleys. It is listed as Endangered in the British Red List and both the species and its habitats are protected under both European and domestic legislation.

A Southern Damselfly colony at Venn Ottery Common, in the East Devon Pebblebed Heaths, died out after the last sighting in 1990, apparently due to natural succession in the absence of grazing. Remedial habitat management work took place after the establishment of a Devon Wildlife Trust NR, using techniques developed at Aylesbeare Common by the RSPB. The population at Aylesbeare, just 2km to the south-west, had responded well and increased, but natural re-colonisation of Venn Ottery did not happen and studies elsewhere had shown that lifetime movement of mature adults was rarely over 500m. Studies had also shown that the genetic variability was weak in Devon, so it was decided to introduce more diversity from Hampshire, in the hope that the population might eventually mix with that at Aylesbeare. The UK's first licenced dragonfly re-establishment took place at Venn Ottery in 2009 under the auspices of the Biodiversity Action Plan Steering Group and Liverpool University. This was originally planned for 2007, but due to a sudden reduction in water flow the releases were aborted after just 52 adults (17 males and 35 females) had been liberated at Venn Ottery. With better conditions in 2009, 500 adults were released, joining 23 adults that emerged from the 2007

Southern Damselfly © Gilles San Martin

release. Peak counts of 39-98 have occurred in the odd years since 2011, as the species typically has a two-year life-cycle. However, two were seen in 2012, indicating that they had matured in either one or three years, and the species has broken the biennial pattern, with counts of 17-42 in the even years since.

No Southern Damselflies had been seen since 1965 at Hense Moor in the Devon Blackdown Hills, probably due to scrub encroachment over former boggy runnels. Following eight years of scrub control and grazing management under Higher Level Stewardship, the habitat was assessed early in 2015 as being suitable for re-establishment and 460 adult damselflies were transferred under licence from the New Forest in June of that year. Unfortunately, this second translocation targeted under the UK Biodiversity Action Plan failed, presumably due to unsuitable or insufficient micro-habitat to support the species.

Re-introduction projects have also assisted White-faced Darter. The species was lost from former sites in Surrey (1990s) and Cheshire (2003), so with a further former stronghold under threat in Cumbria, the BDS and Cumbria Wildlife Trust initiated a project to reintroduce the species to Foulshaw Moss. This has been a great success. The initial translocation of eggs and larvae took place in 2010 into one of five adjacent ponds. A second translocation, to a second pond, took place the following year. By 2013, emergence at the site had topped 400 individuals, with some adults emerging from two ponds where larvae had not been placed, thereby proving onsite breeding. In 2018, over 2,000 White-faced Darters emerged from the main five ponds at the site, with others elsewhere.

Following the success of this first ever re-introduction of a dragonfly, as opposed to a damselfly, species in the UK, a further project has since been completed in Delamere Forest, Cheshire, and a third initiated in the Solway Firth area.

As recording, surveys and habitat assessments continue to inform our species knowledge, the opportunities to understand and improve conditions for our dragonfly and damselfly species will also continue to grow. Such knowledge can also be helpful in other ways. For example, if protected or vulnerable species or their habitats could be adversely impacted by planning proposals, the BDS will contribute its expert opinions to planning consultations. Similarly, if the BDS becomes aware of potentially damaging habitat management that threatens protected species, the Society will raise concerns and attempt to reach a satisfactory solution.

Male White-faced Darter © David Turrell

Suggested future research

It is no secret that invertebrates receive a smaller piece of the pie when it comes to funding for research, compared to more aesthetically pleasing taxa such as birds and mammals (Titley *et al.*, 2017). Considering that insects are thought to make up over 80% of all known species (Stork, 2018), are key to maintaining functioning ecosystems (Schowalter, 2018) and are, in some places, declining rapidly in abundance (Hallmann *et al.*, 2017), this bias could be disastrous. While Odonata probably get more limelight than many other taxa, due to their bright, pretty colours, there's still much we don't know about their biology, behaviour and ecology.

Climate change is, of course, going to be a major factor determining the survival and distribution of species in years to come, particularly as dragonflies are poikilothermic (meaning their body temperature is regulated by their environment). Even if Paris Agreement emission cuts were met, the world is still predicted to warm by 3°C by the end of the century (Stylianou *et al.*, 2020).

While it can be uncomfortable to think about climate change, it is a factor that needs to be considered when planning long term conservation strategies for species. To do this we need to explore how species might be affected and try to predict what the results will be. Climate, particularly rainfall, interacts with the geology of the land to determine the distribution of wetlands (Cham *et al.*, 2014). We need to predict how the distribution of wetland habitats will change in order to predict the potential future distribution of dragonfly species, which will be highly beneficial when planning future conservation projects.

Female Beautiful Demoiselle © Paul Ritchie

For example, in recent years there has been significant interest in carrying out White-faced Darter re-introduction projects, following the successful re-introduction of White-faced Darters to Fowlshaw Moss, Cumbria. In England, this species is isolated to a few bog pools in lowland peatlands, which can act as donor populations for re-introduction sites. However, these populations are fragile and precious, so we need to be able to guarantee the long term success of re-introduction projects before exploiting them. This includes ensuring that the lowland peat bogs where the species is to be re-introduced will not be lost in the near future as a result of desiccation from changes in seasonal precipitation and increased evapotranspiration caused by increasing summer temperatures (Berry & Butt, 2002).

While all freshwater habitats will be altered to some extent, low lying coastal freshwater wetlands are at risk of being lost altogether as a result of sea level rise. Species such as the protected Norfolk Hawker, which are associated with such habitats, are therefore at risk of losing large areas of their current range. Projected habitat loss, as a result of sea level rise, needs to be considered so that at risk species can be identified and action plans can focus on encouraging range expansion outside of flood risk zones.

When it comes to adapting to the threats presented by climate change, dragonflies have the advantage of flight, which gives many of them a greater dispersal ability and the capacity to adapt by altering their distribution. Dragonfly conservation strategies need to support this process through landscape-scale conservation, ensuring the landscape supports their dispersal and colonisation of new suitable areas of habitat. This requires further research into predicting the future distribution of suitable habitat, and into species' mechanisms of dispersal and colonisation.

Norfolk Hawker © Ouwesok, flickr

Another glaring impact of climate change on the British and Irish dragonfly communities is the accelerated colonisation rate that we are currently witnessing. These colonisations are perfect opportunities to study the dynamics of species' range expansions and the factors that influence a species' movements. Such studies will become increasingly important as more new colonists reach Britain and Ireland.

It is also important that we take a closer look at how dragonfly communities, and their individual species, interact with new colonists. For example, how will species at the southernmost edge of their range, such as Northern Damselfly, interact with species moving into their northern, high altitude, habitats as climate warms. Climate, of course, is not the only factor that has influenced Britain's dragonfly communities over recent years. Habitat destruction, degradation and poor management have often contributed to dragonfly species declines in the UK. If we are to reverse this, we need to carry out efficient habitat restoration, which requires an in-depth knowledge of species' habitat requirements.

This report has highlighted the decline of several dragonflies. More research is needed to understand the underlying causes for each individual species, so that these declines can be addressed, and hopefully, in the future, reversed. It is likely that most factors have more impact on the aquatic habitats of dragonfly larvae, than on the terrestrial environment used by the adults. However, far less is currently known about this stage of the life cycle. Detailed research in the field, rather than the laboratory, is required, with temperature, water chemistry and the structural dimensions of both the waterbody and the plant community all being considered.

The BDS's recent Clubtail Count project reported the loss of the Common Clubtail dragonfly along rivers such as the Avon.

Female Common Clubtail © Christophe Brochard

If we are to identify the causes of localised species extinction, we first need to identify the environmental parameters it requires to survive. This includes, but does not exclude: water parameters (including pollution sensitivity, flow rate, temperature and sediment load), larval habitat preference (for example, sediment and plant structure) and adult habitat availability (in the case of the Common Clubtail this would include distance of deciduous woodland from breeding sites). Similarly, it is important to identify and measure the scale of specific threats and their impact on survivorship, in particular anthropogenic threats, such as plastics and pollution from sewage and agricultural inputs. Plastic pollution has received significant news coverage, but it's prevalence within our freshwater wetlands has only recently been recognised and there is increasing evidence of its capacity to travel through freshwater food chains. Similarly, studies of the impacts of pesticides, such as neonicotinoids, on aquatic organisms are still in their infancy. These pesticides may be banned or strictly controlled in an agricultural environment, but are still freely available to the public in pet flea treatments.

Understanding how a species interacts with its environment and uses different niches during its life cycle could significantly improve our understanding of how to manage wetlands for them. For instance, Norfolk Hawker is often associated with the plant Water Soldier, as adults are often observed using these plants when ovipositing or emerging. However, very little is known about how the larvae use the plant, and the surrounding aquatic environment, throughout the year as they develop. Water Soldier can, in some conditions, undergo rapid growth spurts, which can threaten other nearby vulnerable aquatic plants and result in pressure to control it. Since Norfolk Hawker is a protected species, this needs to be done in a sensitive manner. Having a better understanding of how larvae use the plant would assist in deciding and applying appropriate plant control measures. Norfolk Hawker can also be found at sites that have abundant aquatic vegetation, but lack Water Soldier. Knowledge of how well Norfolk Hawker colonises and utilises these sites would further our understanding of this dragonfly and aid its conservation.

Our understanding of the behaviour of dragonflies is still in its infancy, but a species' behavioural plasticity and adaptability is key to surviving environmental change and thus will be significant in predicting its capacity to deal with novel threats, such as environmental changes and inter-species competition.

Through further scientific research we can piece together a robust understanding of our British species and their ecology. This will assist government bodies, NGOs and charities in producing targeted legislation for the species most under threat, create more efficient species action plans and conservation projects, and guide more effective practical habitat management in the field.

Water Soldier © Jeremy Halls

Get involved - How you can help

Dragonflies and damselflies have existed for over 300 million years. Their ancestors evolved into highly successful wetland predators long before dinosaurs walked the Earth. Over millions of years, dragonflies have spread around the globe and diversified into over 6000 species. Today, however, the ability of dragonflies to survive is being tested like never before.

In Britain, Ireland, and around the world, habitat and climate changes, together with other pressures, are forcing species to adapt quickly or risk extinction. This report illustrates the rapid effect these environmental changes are having on Britain and Ireland's dragonflies. While some species are using the opportunity of a warming climate to move north, others are finding their populations increasingly isolated and more fragmented.

Male Large Red Damselfly © M van Ree

This is where you come in . . .

Watch and record dragonflies

Become a citizen scientist to help us monitor the health of British and Irish species. Get to know which species are in your area and make notes of what you see, where you see them, any breeding activity and the date. Submit your records to either iRecord or, in Ireland, the National Biodiversity Data Centre, where you can also find information about DragonflyIreland 2019-2024. You can find further resources on how to record dragonflies, as well as information about our BDS recording projects, on the BDS website.

Volunteer at local wetland sites

Dragonfly habitats need good management to keep them in top condition. This takes time and a lot of muscle power, so please lend a hand at your nearest BDS Dragonfly Hotspot or wetland nature reserve.

Be a dragonfly-friendly gardener

With the right management, gardens can become an oasis for dragonflies within our increasingly urban landscape. Ponds provide breeding sites while pesticide-free wildflower beds provide valuable foraging grounds, because they attract the insects dragonflies need for food. Visit the BDS website for more information on how to make your garden dragonfly friendly, including how to create a pond for dragonflies.

Champion dragonflies in your area

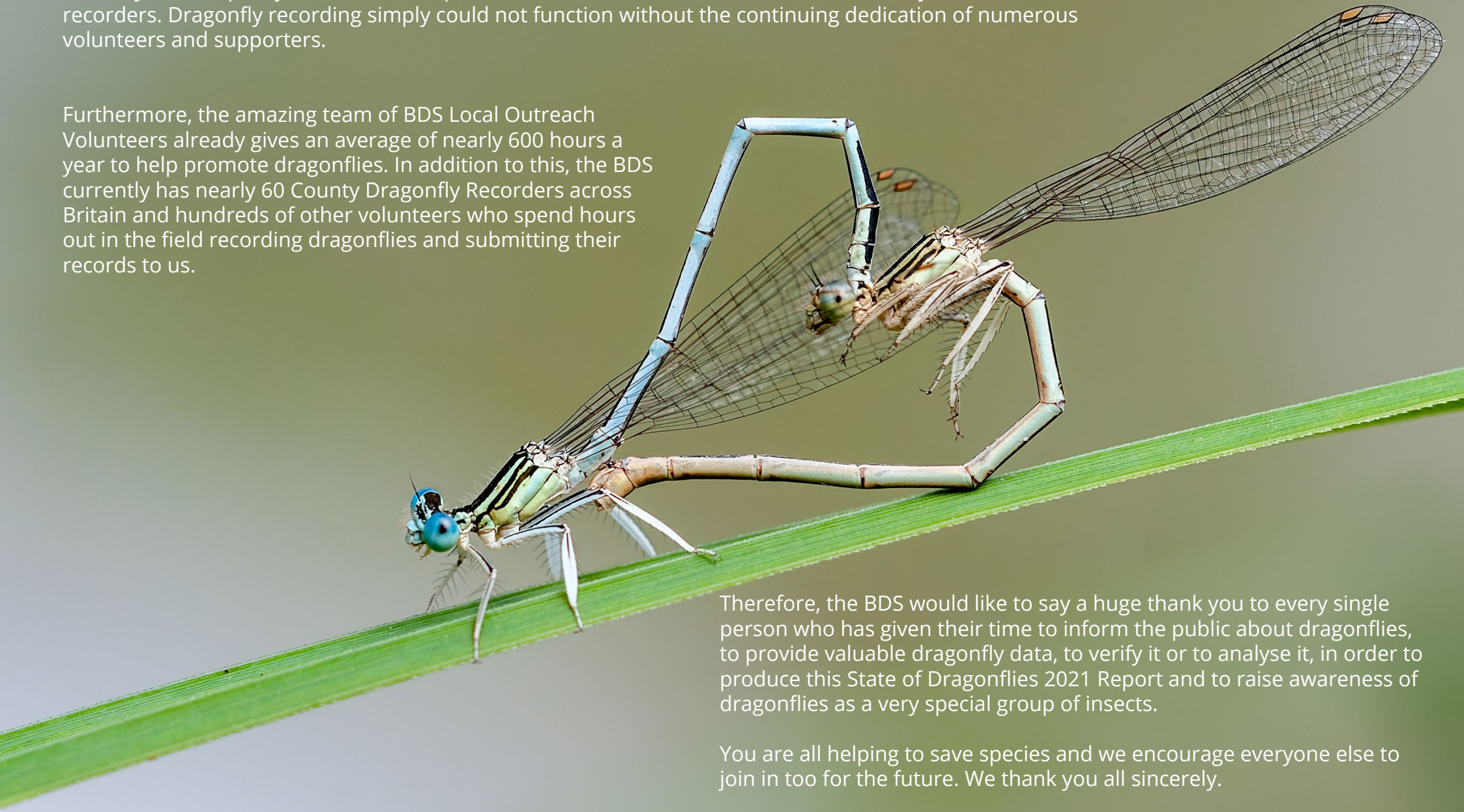
Help us to spread the word about dragonflies so that the whole nation can get to know and love them. Join us as an Outreach Volunteer giving talks, leading dragonfly walks or representing the BDS at events in your local area. Get in touch with us to register your interest in volunteering for the BDS.

Garden pond © Mark, flickr

A Big Thank You!

The 50-year occupancy trends in this report are based on 1.4 million records, collected by some 17,000 individual recorders. Dragonfly recording simply could not function without the continuing dedication of numerous volunteers and supporters.

Furthermore, the amazing team of BDS Local Outreach Volunteers already gives an average of nearly 600 hours a year to help promote dragonflies. In addition to this, the BDS currently has nearly 60 County Dragonfly Recorders across Britain and hundreds of other volunteers who spend hours out in the field recording dragonflies and submitting their records to us.



Therefore, the BDS would like to say a huge thank you to every single person who has given their time to inform the public about dragonflies, to provide valuable dragonfly data, to verify it or to analyse it, in order to produce this State of Dragonflies 2021 Report and to raise awareness of dragonflies as a very special group of insects.

You are all helping to save species and we encourage everyone else to join in too for the future. We thank you all sincerely.

Mating White-legged Damselflies © Jean-Jacques Boujot

About the Editors

Pam Taylor

Pam is a Trustee of the British Dragonfly Society and Convenor of the BDS Dragonfly Conservation Group. Her interest in dragonflies began in 1986 with recording for the first Norfolk atlas. Ten years later she became the County Dragonfly Recorder for Norfolk. Pam has travelled widely in search of dragonflies both here and abroad, and is a member of the Odonata Rarities Committee.

Dave Smallshire

Dave is co-author of both *Britain's Dragonflies*, now in its 4th edition, and *Europe's Dragonflies*. He is a former agroecology policy advisor to Defra and Natural England. He has led dragonfly tours to many countries in Europe and beyond. He is a member and former Convenor of the BDS Dragonfly Conservation Group and the long-standing County Dragonfly Recorder for Devon.

Adrian Parr

Adrian has been the BDS Migrant Recorder since 1991 and is Chair of the Odonata Rarities Committee. His interest in dragonflies goes back nearly 40 years and since 2010 he has been the County Dragonfly Recorder for Suffolk. Adrian is also a member of the BDS Dragonfly Conservation Group.

Glen Affric © Floyd, flickr

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Female Scarce Chaser © Neil Malton

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List of Odonata recorded in Britain and Ireland

The Odonata lists presented below follow the taxonomic sequence of Schorr and Paulson (2013).

Table 1. Category A: resident and/or regular migrant species recorded since 2000

This category comprises species with well-established breeding populations and migrant species that have been recorded regularly since 2000, the latter often attempting to establish temporary breeding populations. (nc = no change in name)

Scientific name	British and Irish name	European common name
Chalcolestes viridis	Willow Emerald Damselfly	Western Willow Spreadwing
Lestes barbarus	Southern Emerald Damselfly	Migrant Spreadwing
Lestes dryas	Scarce Emerald Damselfly	Robust Spreadwing
Lestes sponsa	Emerald Damselfly	Common Spreadwing
Calopteryx splendens	Banded Demoiselle	nc
Calopteryx virgo	Beautiful Demoiselle	nc
Platycnemis pennipes	White-legged Damselfly	Blue Featherleg
Ceriagrion tenellum	Small Red Damselfly	Small Red Damsel
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

Female Southern Emerald Damselfly
© Simon Mackie

Scientific name	British and Irish name	European common name
Erythromma najas	Red-eyed Damselfly	Large Redeye
Erythromma viridulum	Small Red-eyed Damselfly	Small Redeye
Ischnura elegans	Blue-tailed Damselfly	Common Bluetail
Ischnura pumilio	Scarce Blue-tailed Damselfly	Small Bluetail
Pyrrhosoma nymphula	Large Red Damselfly	Large Red Damsel
Aeshna affinis	Southern Migrant Hawker	Blue-eyed Hawker
Aeshna caerulea	Azure Hawker	nc
Aeshna cyanea	Southern Hawker	Blue Hawker
Aeshna grandis	Brown Hawker	nc
Aeshna isoceles	Norfolk Hawker	Green-eyed Hawker
Aeshna juncea	Common Hawker	Moorland Hawker
Aeshna mixta	Migrant Hawker	nc
Anax ephippiger	Vagrant Emperor	nc
Anax imperator	Emperor Dragonfly	Blue Emperor
Anax parthenope	Lesser Emperor	nc
Brachytron pratense	Hairy Dragonfly	Hairy Hawker
Gomphus vulgatissimus	Common Clubtail	nc
Cordulegaster boltonii	Golden-ringed Dragonfly	Common Goldenring
Cordulia aenea	Downy Emerald	nc
Somatochlora arctica	Northern Emerald	nc
Somatochlora metallica	Brilliant Emerald	nc
Leucorrhinia dubia	White-faced Darter	Small Whiteface
Libellula depressa	Broad-bodied Chaser	nc
Libellula fulva	Scarce Chaser	Blue Chaser

Female Variable Damselfly © Dave Smallshire

Scientific name	British and Irish name	European common name
Libellula quadrimaculata	Four-spotted Chaser	nc
Orthetrum cancellatum	Black-tailed Skimmer	nc
Orthetrum coerulescens	Keeled Skimmer	nc
Sympetrum danae	Black Darter	nc
Sympetrum fonscolombii	Red-veined Darter	nc
Sympetrum sanguineum	Ruddy Darter	nc
*Sympetrum striolatum**	Common Darter*	nc

Table 2. Category B: vagrant species

Since 1998 records of these species have been assessed by the BDS Odonata Rarities Committee.

Scientific name	British and Irish name	European common name
Sympecma fusca	Winter Damselfly	Common Winter Damsel
Anax junius	Green Darner	Common Green Darner
Stylurus flavipes	River Clubtail	nc
Somatochlora flavomaculata	Yellow-spotted Emerald	nc
Leucorrhinia pectoralis	Large White-faced Darter	Yellow-spotted Whiteface
*Crocothemis erythraea***	Scarlet Darter**	Broad Scarlet
Pantala flavescens	Wandering Glider	nc
Sympetrum flaveolum	Yellow-winged Darter	nc
Sympetrum pedemontanum	Banded Darter	nc
Sympetrum vulgatum	Vagrant Darter	Moustached Darter

Male Golden-ringed Dragonfly
© Iain Leach

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

** has bred in the Channel Islands.

Table 3. Category C: former breeding species now locally extinct in Britain

Any further records of these species will be assessed by the Odonata Rarities Committee.

Scientific name	British and Irish name	European common name
Coenagrion armatum	Norfolk Damselfly	Dark Bluet
Oxygastra curtisii	Orange-spotted Emerald	nc

Male Keeled Skimmer © Mike Smethurst

Male Southern Migrant Hawker ©Trevor Wilis