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BDS

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

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

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

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Species Reviews: The fifth species review appears in this issue. Others are in the process of being written so if anyone is considering writing a review of their favourite species, please contact the Editor first.

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Cover Illustration: Male of *Brachytron pratense*. Photograph by Mark Tyrrell.

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INSTRUCTIONS TO AUTHORS

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

- Word processed manuscripts may be submitted in electronic form either on disk or by e-mail.
- Manuscripts should be one and a half spaced, on one side of the page only and with margins at least 25mm on both sides and top and bottom. Footnotes should be avoided.
- Use of these terms is acceptable: ‘exuvia’ for cast skin (plural: ‘exuviae’); ‘larva’ (instead of ‘naiad’ or ‘nymph’); ‘prolarva’ to designate the first larval instar.
- Dates in the text should be expressed in the form: 24 July 2010.
- References cited in the text should be in the form ‘(Longfield, 1949)’ or ‘...as noted by Longfield (1949)’. All references cited in the text (and only these) should be listed alphabetically at the end of the article in the following forms:
  - Hammond, C.O. 1983. *The Dragonflies of Great Britain and Ireland* 2nd Edition (revised by R. Merritt), Harley Books, Colchester, 116pp.
  - Longfield, C. 1949. The Dragonflies of the London area. *The London Naturalist* **28**: 90-98.
- Titles of journals should be written out in full.
- Figures, plates and tables should be presented on separate, unnumbered pages.
- Legends for figures, plates and tables should be presented together in sequence on separated, unnumbered pages.
- The legend for each table and illustration should allow its contents to be understood fully without reference to the text.

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

SCIENTIFIC AND ENGLISH NAMES OF BRITISH ODONATA

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

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

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

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First discovery of larvae of the Downy Emerald *Cordulia aenea* (L.) in Ireland and the species' use of lakes in treeless blanket bog in Connemara, Co. Galway.

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Summary

The Downy Emerald *Cordulia aenea* is reported from Connemara, Co Galway, Ireland. Larvae were recorded in seven lakes and sightings of adults were made in the vicinity of the breeding sites. The association of *Cordulia aenea* with woodland is questioned as all the Connemara sites are in open, treeless, blanket bog. These new records increase substantially the number of known sites for the species and provide a new understanding of the habitat requirements of *C. aenea* in Ireland.

Introduction

The Downy Emerald *Cordulia aenea* is one the rarest and least recorded of the resident Irish dragonflies. Until now it was thought to be confined to a few lakes and ponds in the south-west of Ireland in Killarney National Park, Co. Kerry and Glengarriff Wood and Nature Reserve, Co. Cork (Fig. 1) (Nelson & Thompson, 2004). An unconfirmed 1992 record of *C. aenea* from the Connemara region of Co. Galway has suggested that the species existed, undetected, elsewhere in Ireland. Here we present definitive proof of its presence in Connemara by documenting the discovery of larvae for the first time in Ireland and sightings of adults.

History in Ireland

The confused, early history of *Cordulia aenea* in Ireland is described in Nelson & Thompson (2004). Although it was first reported in the first half of the nineteenth century (Sélys, 1846), confirmation that it was resident in Ireland was not obtained until 1946 (Graves, 1947). This and the few subsequent reports came from the region of Killarney, Co Kerry (within the area of the present National Park). In 1978, *C. aenea* was discovered at Dromdour, Glengarriff, Co Cork (Goyvaerts, 1979). The species was recorded from several lakes and ponds in Killarney National Park during the 1980s (Merritt *et al.*, 1996) and, again, during the recording period for DragonflyIreland (2000-2003) (Nelson & Thompson, 2004). Records were received also during DragonflyIreland from the Glengarriff site, apparently the first since it had been discovered there (Nelson & Thompson, 2004). Since the end of DragonflyIreland, *C. aenea* has continued to be reported from both Killarney National Park and Glengarriff.

Two specific pieces of work have been undertaken since 2004. Brian Nelson (BN) carried out a survey of the species, including a search for larvae, within Killarney National Park and a pond was created at Glengarriff to provide additional habitat for the species (Clare Heardman, pers. comm.). Nevertheless, *C. aenea* remains one of the most poorly recorded of the Irish dragonflies. The records have been sporadic and, prior to the information presented in this paper, have all been of adults, larvae not having been found at any of its presumed Irish breeding sites. This has hampered understanding of the habitat of the species in Ireland and, consequently, made it difficult to devise effective conservation measures to protect it.

Observations

Cordulia aenea in Connemara, Co Galway

Matthew Tickner (MT) observed several dragonflies which he considered were *Cordulia aenea* on 23 May 1992 sheltering around a rocky outcrop (L711461) on the Toombeola to Clifden road across Roundstone Bog, Co Galway. The description, location and timing of the record did not tally with the other species of Irish dragonfly expected to be flying at this time of year (Hairy Hawker *Brachytron pratense* (Müller) and Four-spot Chaser *Libellula quadrimaculata* L.). However, MT did not wish to claim the record without independent confirmation. Nevertheless the record was given sufficient credence to be mentioned in Merritt *et al.* (1996), although it was not mapped. It was treated in a similar way in Nelson & Thompson (2004) as, despite searches in the area, there had been no further reports.

Independent and definitive confirmation of the occurrence of *C. aenea* in Connemara has recently come to light. In June 1995, Stephen Evans (pers. comm.) visited Lough Nalawney (L695416; approx 5 km south of the 1992 report) on botanical fieldwork and saw and photographed an adult *C. aenea*. The record card was unfortunately not received by DragonflyIreland until after

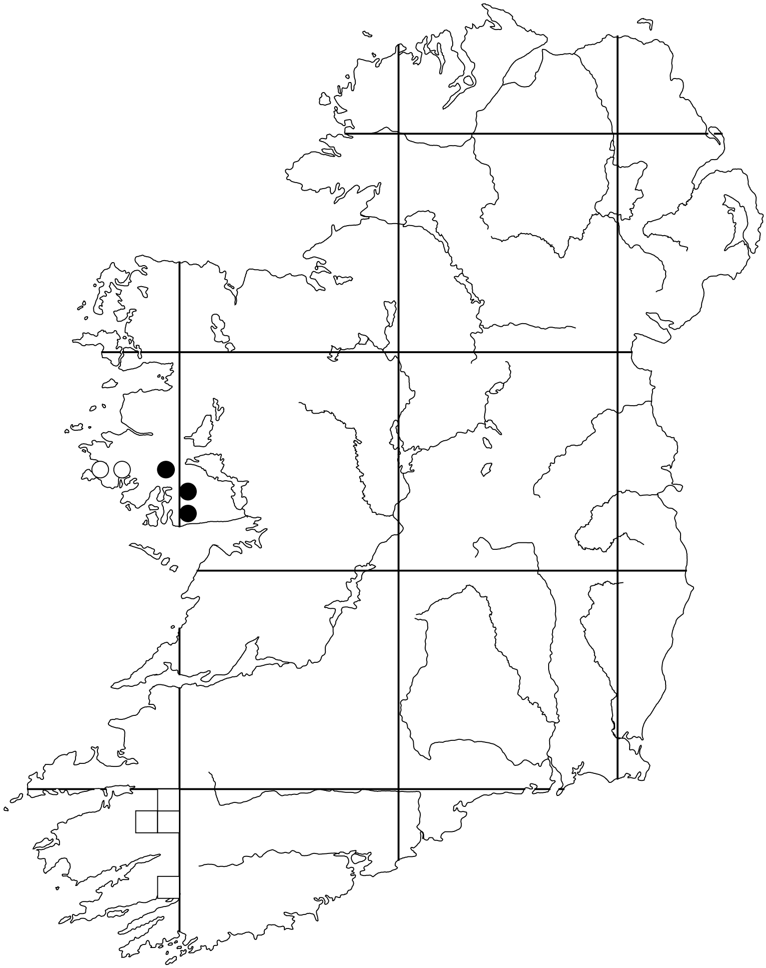


Figure 1. Distribution of *Cordulia aenea* in Ireland plotted by hectad. The closed circles represent the records from 2009 and 2010, the open circles the earlier records from Connemara and the open squares the records mapped in Nelson & Thompson (2004).

the project had been completed. This record was mentioned and mapped in Cham (2004) but the full details were not given. The supporting photograph, supplied with the record card, confirmed the identification. In 2009 and 2010, *C. aenea* was reported again in Connemara but in more easterly localities. These new records include the first larvae of *C. aenea* found in Ireland and greatly increase the number of known sites for the species.

Records in Connemara 2009 — 2010

Sixteen larvae of *C. aenea* were captured by Tom Drinan (TD) during a research study of the invertebrates of oligotrophic and dystrophic lakes in the Connemara Bog Complex Special Area of Conservation, Co. Galway (SAC: 002034). The larvae were caught using activity traps and sweep netting in seven lakes in the Seecon and Bovroughaun regions, south-west of Oughterard, between 16 April and 3 September 2009 (Table 1; Figs. 1, 2). Specimens were identified by TD and confirmed by BN using the keys and descriptions in Norling & Sahlén (1997), Brooks & Lewington (2002) and Cham (2007). The antennal character and teeth on the labium, plus the dark stripes on the thorax, are the most diagnostic features of the *C. aenea* larva. The larvae also have a long-legged, 'spidery' appearance (Plate 1) that helps in separating them in the field from the larvae of *L. quadrimaculata*, which are also common in these lakes. Voucher specimens have been retained by TD, and will be deposited in the Museum at the Department of Zoology, Ecology and Plant Science, University College, Cork and in the National Museum of Ireland, Dublin.

All seven lakes are relatively small (Plates 2, 3) with very similar habitat types present in each. The largest lake (unnamed NW of Lough Seecon (E)) (Plate 2) has an area of 3.93 ha and the smallest lake (unnamed SSE of L. na hAille) has an area of 0.53 ha. Their altitudes range from 80 to 150 m, apart from one which is at 233 m. The pH of the lakes ranges from 4.85 to 5.87 and the conductivity from 58.35 to 76.38 µS/m. The macrophyte communities are dominated by Reed *Phragmites australis* (Cav.) Trin. ex Steud., Bulbous Rush *Juncus bulbosus* L., Bogbean *Menyanthes trifoliata* L., Floating Bur-reed *Sparganium angustifolium* Michx., Bog Pondweed *Potamogeton polygonifolius* L., Yellow Water-lily *Nuphar lutea* L., Water Lobelia *Lobelia dortmanna* L. and Pipewort

A B

Plate 1. (A) larva and (B) exuvia of *Cordulia aenea*. Photographs by Steve Cham.

Eriocaulon aquaticum (Hill) Druce. The majority of the specimens were found in dense layers of decaying Purple Moor Grass *Molina caerulea* L. leaf litter in sheltered pockets of the lake shore underlain by peat.

In May 2010, Ger O'Donnell, who was unaware of the larval records, reported adults of *C. aenea* in the same general area of Connemara. Three adults were seen in open and exposed blanket bog on the edge of Lough Ahalia North (L967402) on 14 May. The lake is large and has treeless shores (although small lake islands have stunted woodland). This lake is perhaps too large to be a breeding site but the status of the species needs to be investigated. Finally, adults of *C. aenea* were seen by Joe Adamson (pers. comm.) on 10 June near Lettercraffroe Lough. Three adults were initially identified hawking along a forest track at the edge of a conifer plantation, approximately 200m southwest of Lettercraffroe Lough (M056369). They were frequently observed alighting on Bracken *Pteridium aquilinium* (L.) Kuhn and Bramble *Rubus fruticosus* agg. L. in a dry ditch dominated by Feathery Bog-moss *Sphagnum cuspidatum* Ehrh. ex Hoffm. between the forest track and the forest edge. More adults were observed along a kilometre stretch of the forest track further to the northwest and it was estimated that approximately 12 individuals were observed in total.

Habitat used in Ireland

Table 1 lists the lakes and ponds that are presumed or confirmed breeding sites for *C. aenea* in Ireland and describes three characteristics considered important features of *C. aenea* habitat (Cham *et al*., 1995; Cham, 2004):

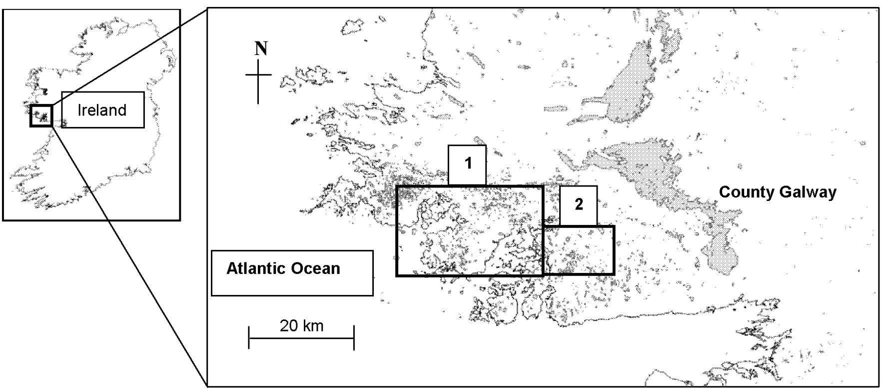
- the nature of the leaf litter,
- openness of the shoreline and
- the proximity to broad-leaved woodland.

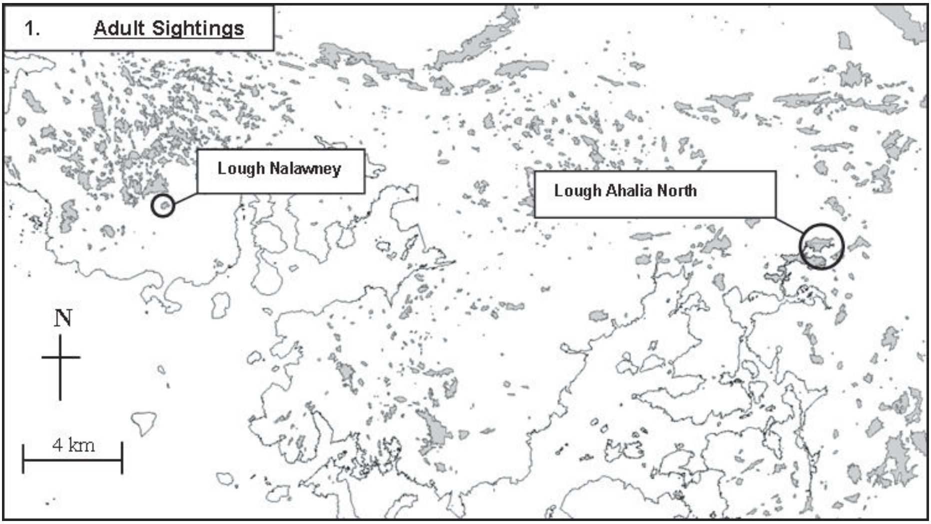
Photographs of three of the Irish sites (Lough Doo, Lough Beg and Dromdour) can be seen in Nelson & Thompson (2004). Only one of the Irish sites, Lough Doo, has woodland growing on the shore. The other lakes in Kerry and Cork have no woodland on their shores but all have some broad-leaved woodland within 200m of the shore. All sites in Connemara where larvae were found are small lakes and ponds in open blanket bog, although two are now surrounded by plantations of Sitka Spruce *Picea sitchensis* (Bong.) Carrière. There is no broad-leaved woodland within several kilometres of any of these sites. Similarly, Lough Nalawney and Lough Ahalia North are located in open, treeless landscapes. The available litter in the Connemara lakes consists mainly of undecayed *Molinia caerulea*. In Lough Beg the leaf litter is mostly Great Fen Sedge *Cladium mariscus* (L.) Pohl and *M. caerulea*, and is restricted to a few areas of the lake. Most of the accessible lake bed is bare, soft peat. The substratum of the small pond north of Lough Beg and the lake at Ladies' View is also mainly soft peat with small amounts of litter, which again is mainly derived from *M. caerulea*. The nature of the leaf litter at Dromdour is not known but is likely to be mainly *Phragmites australis* and *M. caerulea*, which are the dominant plants on the edge of the pond (see illustration on p410 in Nelson & Thompson, 2004). Lough Doo is the only Irish site that is known to have significant accumulations of leaf litter.

Discussion

The discovery of *Cordulia aenea* larvae in Connemara provides information on the nature of the breeding sites used by this dragonfly in Ireland that has not been available before. It questions the widely-held view that the species is only found in wooded landscapes. This discovery, therefore, opens the possibilities that *C. aenea* is less rare in Ireland than currently understood and its distribution is more extensive.

The habitat characteristics of the newly-discovered Irish sites would appear to be contrary to the commonly-stated association between *C. aenea* and broad-leaved woodland. The limited evidence available until now suggested that, in Ireland, *C. aenea* was found in lakes and ponds similar to those used in Great Britain (Nelson & Thompson, 2004) and that the rarity of the species was due to the rarity of this habitat in Ireland. In Great Britain, *C. aenea* is associated with still waters (ponds, lakes and, occasionally, canals) in or close to woodland (Brooks & Lewington, 2002; Cham *et al.*, 1995). It is recognised that sites occupied in Scotland are in more open situations than in southern England, but the presence of ancient deciduous woodland nearby is considered particularly important (Merritt *et al.,* 1996; British Dragonfly Society, 2004). Cham (2004) found that 85% of all *C. aenea* records in the British Dragonfly Society's national





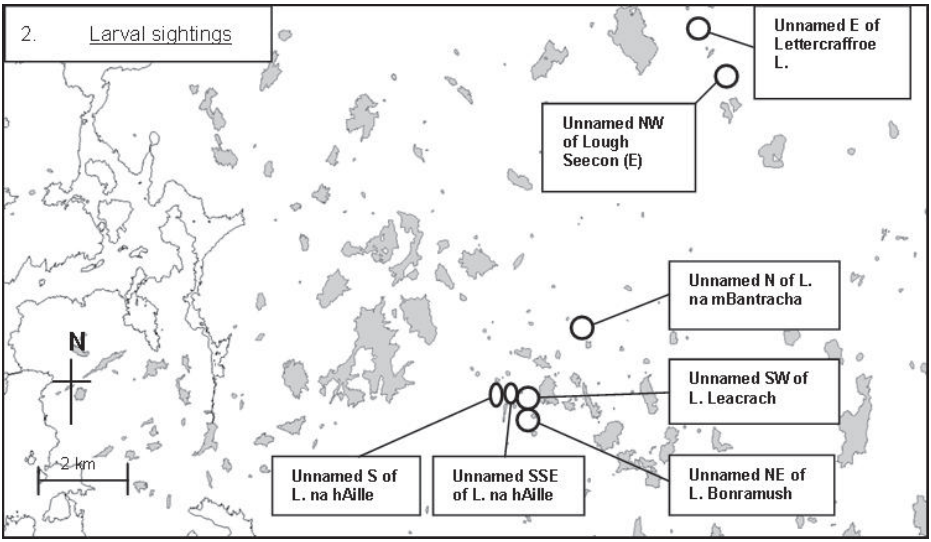


Figure 2. The locations of adult (1) and larval (2) sightings of *Cordulia aenea* from Connemara in the west of Ireland.

Table 1. Location and habitat characteristics of breeding and presumed breeding sites of *Cordulia aenea* in Ireland. Full details of the records from each of the sites are in the DragonflyIreland database which is available online through the Irish National Biodiversity Data Centre (2010)

Site and grid reference	Status of *Cordulia aenea*	Principal habitat surrounding site and % of shore with woodland	Distance to nearest broad-leaved woodland	Characteristics of lake bed
Co. Kerry				
Lough Beg, V894812	Adults in several years; territorial behaviour	Wet heath; 0%	Oak woodland 25m to south	Soft peat with localised accumulations of *Cladium* and *Molinia*
Pond north of Lough Beg V894813	Adults in several years; territorial behaviour	Wet heath; 0%	Oak woodland 180m to south	Soft peat with localised accumulations of *Cladium* and *Molinia*
Lough Doo, V953861	Adults in several years; territorial behaviour	Broad leaved woodland (oak and alder), wet heath and fen; 80%	0m	Tree leaf litter; localised accumulations of *Phragmites*
Lake at Ladies' view, V904804	Adults, recorded twice	Wet heath with scattered birch trees on <5%	Oak woodland 110m to east	Soft peat with localised accumulations of *Molinia*
Co. Cork				
Dromdour, V904571	Adults recorded in several years	Ungrazed wetland, rank grassland and broad-leaved woodland (oak dominated); 0%	10-15m to east and north; 60-150m on west and south	Not known
Co. Galway				
Unnamed NW of Lough Seecon (E), M077361	Larvae	Blanket bog; 0%	>1km	Soft peat with localised accumulations of *Molinia*
Unnamed E of Lettercraffroe L., M073374	Larvae	Blanket bog; 0%	>1km	Soft peat with localised accumulations of *Molinia*
Unnamed N of L. na mBantracha, M046309	Larvae	Blanket bog; 0%	>1km	Soft peat with localised accumulations of *Molinia*
Unnamed SW of L. Leacrach, M033294	Larvae	Blanket bog; 0%	>1km	Soft peat with localised accumulations of *Molinia*
Unnamed SSE of L. na hAille, M029297	Larvae	Blanket bog; 0%	>1km	Soft peat with localised accumulations of *Molinia*
Unnamed S of L. na hAille, M027297	Larvae	Blanket bog;0%	>1km	Soft peat with localised accumulations of *Molinia*
Unnamed NE of L. Bonramush, M033291	Larvae	Blanket bog; 0%	>1km	Soft peat with localised accumulations of *Molinia*
Lough Ahalia North, L967402	Adults, once 2010	Blanket bog; 0%	>1km	Not known
Lough Nalawney, L695416	Adult, once 1996	Blanket bog; 0%	>1km	Mainly rock and rock debris; localised accumulations of *Phragmites* and *Cladium*

Plate 2. Unnamed lough north of Loch na mBantracha, Co. Galway

Plate 3. Unnamed lough northwest of Lough Seecon (E), Co. Galway

database were from "sites within, or in very close proximity to woodland." This figure would have been higher if only proved breeding sites were included in the analysis (Cham, 2004). It is not stated in Cham (2004) if Irish sites were included in the analysis or what was defined as close proximity, but only one Irish site, Lough Doo, would seem to meet this definition. Most of the Irish sites and, in particular, all those where larvae have been found, are in open, treeless landscapes, with no broad-leaved woodland within several kilometres. This is not just a recent phenomenon as the blanket bog areas of Connemara have been deforested for many centuries (Whilde, 1994).

Woodland provides the adults with hunting habitat and (Cham *et al.*, 1997) also appears to be important in providing substrate for the larvae in the form of leaf litter (Brooks & Lewington, 2002). The larvae of *C. aenea* rest during the day amongst coarse, undecayed leaf litter and the most common source of this is broad-leaved trees (Cham *et al.*, 1995; Cham, 2004). Management advice in Great Britain stresses the need for trees to be provided on the edge of breeding sites (British Dragonfly Society, 2004). Cham (2004) also highlights the need for undisturbed conditions, as *C. aenea* larvae take several years (two to four) to develop. Pond dredging has resulted in the local extinction of the species from breeding ponds in Epping Forest, Essex.

Ireland is the least wooded area in Europe and less than 1% of the country consists of natural or semi-natural broad-leaved woodland (Martin *et al.,* 2010). It has been natural to hypothesise that the rarity and distribution of *C. aenea* in Ireland is due to the lack of suitable habitat. The historic distribution of the species has linked it to two of the most wooded parts of Ireland (Killarney and Glengarriff) (Perrin & Daly, 2010), where the presumed breeding sites appear to conform to the general description of the British sites. In reality, the only Irish site which does conform to this is Lough Doo. The other lakes and ponds at Killarney and Glengarriff all have woodland within a short distance, but none have trees directly on their shore and, consequently, do not receive large amounts of falling tree leaves. The two early Connemara records were of adults seen on treeless, blanket bog in one of the least wooded parts of Ireland (Whilde, 1994). This disparity between the perceived notions of what constitutes *C. aenea* habitat and the reality of what is utilised on the Connemara blanket bogs has undoubtedly hampered the search for this population.

It has taken almost 20 years to confirm the veracity of the enigmatic record by MT. One of the reasons for this has been the lack of knowledge of the larval habitat of *C. aenea* in Ireland. It can now be stated that *C. aenea* occupies two types of site in Ireland. The most common is open ponds or small lakes in treeless, blanket bog or wet heath, with accumulations of undecayed grasses and marginal aquatic plants. The second, rarer type of site is, like the majority in Britain, lakes or ponds within or close to woodland. Finally, it shows that the close association between *C. aenea* and woodland is much less evident in Ireland than in southern Britain, and the Connemara records give hope that more sites for this still rare Irish dragonfly remain to be found.

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References

Brooks, S. & Lewington, R. 2002. *Field guide to the Dragonflies and Damselflies of Great Britain and Ireland*. 2nd ed. British Wildlife Publishing, Hook, Hampshire. 160 pp.

Cham, S. 2004. The Downy Emerald — an enigmatic dragonfly. *British Wildlife* **16**: 108-119.

Cham, S. 2007. *Field Guide to the larvae and exuviae of British Dragonflies*. *Volume 1: Dragonflies (Anisoptera)*. British Dragonfly Society, Peterborough. 75 pp.

Cham, S., Brooks, S. J. & McGeeney, A. 1995. Distribution and habitat of the Downy Emerald Dragonfly *Cordulia aenea* (L.) (Odonata: Corduliidae) in Britain and Ireland. *Journal of the British Dragonfly Society* **11**: 31-35.

Goyvaerts, P. 1979. *Cordulia aenea* (Odonata: Corduliidae) a new county record. *Irish Naturalists' Journal* **19**: 329.

Graves, P.P. 1947. Odonata at Killarney. *Irish Naturalists' Journal* **9**: 61-63.

Martin, R., Oxbrough, A., Gittings, T., Kelly, T. C. & O' Halloran, J. 2010. New records and rare invertebrate specimens recorded during a decade of forest biodiversity research in Ireland. *Antenna* **34**: 111-118.

Merritt, R., Moore, N. W. & Eversham, B. C. 1996. *Atlas of the dragonflies of Britain and Ireland*. ITE research publication no. 9. HMSO, London. 149 pp.

Nelson, B. & Thompson, R. 2004. *The Natural History of Ireland's Dragonflies.* MAGNI Publication No 013, National Museums and Galleries of Northern Ireland, Belfast. 454 pp.

Norling, U. & Sahlén, G. 1997. *Odonata, Dragonflies and Damselflies*. - *In* Nilsson, A. (ed.): The Aquatic Insects of North Europe **2**: 13-66. Apollo Books, Stenstrup, Denmark.

Perrin, P.M. & Daly, O.H. 2010. *A Provisional inventory of ancient and lomg-established woodland in Ireland*. Irish Wildlife Manuals, No. 46. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland. 71pp.

Sélys Longchamps, E. de. 1846. Revision of the British Libellulidae. *Annals and*

Magazine of Natural History **18**: 217-227.
Whilde, T. 1994. *The Natural History of Connemara*. Immel Publishing, London. 336 pp.

Web Sites

British Dragonfly Society. 2004. The Downy Emerald *Cordulia aenea:* Draft Management Fact File. www.dragonflysoc.org.uk/mffcoaenfull.htm (accessed 1 October 2010).
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Species Review 5

The Hairy Dragonfly *Brachytron pratense* (Müller)

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Summary

Perrin (1999) published a review of *Brachytron pratense* as part of the Collective Knowledge Project of the British Dragonfly Society, which formed the first in depth study of this species. The intervening eleven years have seen several published studies and many local atlases that have contributed to the knowledge of the ecology and breeding habitats of this rare species. The present review summarises the current knowledge of *B. pratense* in terms of lifecycle, phenology and habitat requirements. The adults and larvae are described in the context of other aeshnid species and differences noted.

Introduction

The genus, *Brachytron* is monophyletic and was first described by Evans in 1845. Its only described species is *Brachytron pratense*, with the type specimen from Denmark. Müller first described *Libellula pratensis* in 1764 but failed to identify males and females as the same species and the female became *Libellula hafniensis* (Askew, 2004). *Brachytron* belongs to the family *Aeshnidae* and the subfamily *Brachytoninae*. There are a number of genera and species in the *Brachytroninae* but only three representatives in Europe, i.e. *B. pratense* and *Caliaeschna microstigma* (Schneider) in the tribe Brachytronini and *Boyeria irene* (Fonscolombe) in the tribe Gomphaeschnini (Davies & Tobin, 1985; Askew, 2004). The common English vernacular name for *B. pratense* is Hairy Dragonfly, but Hairy Hawker is also used to describe its family connections with the *Aeshnidae*. In Ireland, it is called the Spring Hawker in recognition of its early emergence (Nelson & Thompson, 2004).

Description

Larvae

The larvae (Plate 1) are very distinctive among aeshnid species, with particularly small eyes, a long, waisted labium and short legs. The head tapers sharply at the back. The presence of a lateral spine on abdominal segment 5 along with a spine on the top of segment 9 is diagnostic (Smallshire & Swash, 2004).

Plate 1. Final instar larva of *B. pratense*.

Adults

Adults of both sexes are characterised by hairy thoracic and abdominal areas, giving rise to the common English vernacular 'Hairy Dragonfly'. It shares this feature with two other early emerging anisopteran dragonflies, Four-spotted Chaser *Libellula quadrimaculata* and Downy Emerald *Cordulia aenea*. The hairs act as insulation, keeping the thorax and flight muscles warm in the variable temperatures of early spring, when this dragonfly emerges.

Males differ from other aeshnid males in that the abdomen is not waisted. In the immature or pre-flight emergent stages, this can make sexing difficult. However, females have small or completely absent antehumeral stripes, whereas in males the antehumeral stripes are highly conspicuous, being long and bright yellow, contrasting with a brown thorax. Both sexes have paired, tear-drop shaped markings down their abdomen. These are blue in males and yellow in females.

B. pratense can readily be separated from other aeshnids by a number of characteristic feature (Plates 2, 3):

a) long thin brown pterostigma, about 4mm in length.
b) long anal appendages, exceeding the length of abdominal segments 9 & 10.
c) hind wings that lack the sharply angled hind margin typical of other aeshnids.
d) a small central spot on the first abdominal segment.
e) green side of thorax divided by two complete black stripes.
f) hairy thorax and abdomen.

Plate 2. Adult male *B. pratense*. The arrows indicate four of the main characteristic features, i.e. the pterostigma, the anal appendages, the margin of the hind wing and the first abdominal segment.

Lifecycle

The ovipositing female inserts eggs into decomposing plant debris floating on the water's surface. The appearance of the eggs is not well described in the literature. However, they can be considered similar to other endophytic ova of aeshnid species such as Emperor Dragonfly *Anax imperator*. After 3-4 weeks, the eggs hatch and the larvae emerge into flying adults after 2-3 years, or in some cases such as in small ponds, after one year (Nelson & Thompson, 2004).

During pond dipping, larvae will often be found clinging to floating, decaying stems of bulrush, reedmace or sticks and are very sedate in nature. They will often release their hold on the stem and can be found "playing dead" in the

Plate 3: Close-up of the head and thorax of a preflight emergent male, showing the thoracic (arrow) and abdominal hairs and the two black lines intersecting the pale side of the thorax (arrow). These features are characteristic of this species among aeshnids.

detritus at the bottom of the net. This defence mechanism, along with their sedate nature, makes them well adapted to living alongside fish. Hunting is via touch. Their slow movement and small eyes limit their ability to see and catch fast moving prey, while their short legs make walking a slow process.

Final instar larvae enter diapause in the winter preceding emergence, although active larvae have been found in November. Activity resumes in mid March, in preparation for emergence in April or May (pers. obs.)

Adults emerge in the early morning, any time from mid March in the south of the UK to early June further north. Emergence is highly synchronous and 50% of the population have been observed to emerge within the first week (Tyrrell, 2006). First flights are often around midday, although they can be earlier during warm early spring days. Emergence is often low down on sedges, iris, etc. and often on broken stems of dead plants such as Reedmace (Plate 4). Due to low plant growth in early spring, the tip of the abdomen can often be found close to the water. As the emergence season progresses, exuviae can be found higher up the stems as plant growth proceeds and safe purchase can be obtained by the relatively small larval legs. Tyrrell (2006) measured the length of exuviae at emergence and found no difference between the sexes, with an average length of 39.6mm. Males and females emerge at the same time (Tyrrell, 2006), which is typical of a spring species (Corbet, 1999).

Adults leave the breeding site to undergo maturation, returning about two weeks later during typical, variable spring weather (Tyrrell, 2006). In warm stable springs, this can be shorter. During this time away from water, they can be found flying in woodlands or along hedgerows hunting for insect prey, often some distance from the breeding site.

Adult densities tend to be low at the breeding site. However, this can mask the true breeding population. Tyrrell *et. al.* (2006) report that 77 exuviae were collected at one site during one season and Nelson and Thompson (2004) report 55 exuviae found at one site in Ireland.

Males are highly territorial and this can partly explain the low adult density

Plate 4. *B. pratense* emerging on a dead stem of Reedmace (*Typha sp.*).

Plate 5. *B. pratense* copulating low down in grasses close to the water. Note the two black lines intersecting the lime green side of the thorax in both sexes.

A

B

Plate 6. Ovipositing females. A) Using a decaying sedge leaf close to the water's margin, 1800 hrs. B) Ovipositing into an accumulation of dead stems of Common Club Rush *Schoenoplectus lacustris,* in dull cloudy weather.

seen at most sites. On establishing territory, they will hunt for ovipositing females by zig zag flights low down through emergent reeds. They readily clash with *Libellula quadrimaculata* and *Anax imperator,* and will easily reject the latter from their territory despite the size differences. Copulation (Plate 5) occurs in low grasses at the breeding site, close to the water. Pairs will often give away their location by wing rustling. The pair will separate within 30-40 minutes and the female will oviposit alone (Plate 6), usually into decomposing plant debris floating on the water's surface, often close to the margin. Living stems can also be used, but generally only when decaying matter is absent, for example in slow flowing rivers and canals. Females tend to oviposit in the early morning or late afternoon, or during weather not conducive to male territorial activity. This reduces the chances of harassment from males.

Distribution

Brachytron pratense is a western, central and eastern European species, its distribution stretching from Ireland eastwards as far as the Urals (Fig. 1). To the north it just reaches into southern Scandinavia. In southern European countries its distribution is disjunct and in the Iberian peninusal there are only a very few records (Dijkstra, 2006). In Belgium and Luxembourg it is protected and is classed as Vulnerable in north Belgium and as Critically Endangered in south Belgium and Luxembourg (Grand & Boudot, 2006).

In the UK, *B. pratense* has a mainly southern and eastern distribution, with significant populations in southern Wales, Anglesey and southern Scotland (Fig. 2).

The distribution of *B.pratense* in Great Britain & Ireland has changed markedly

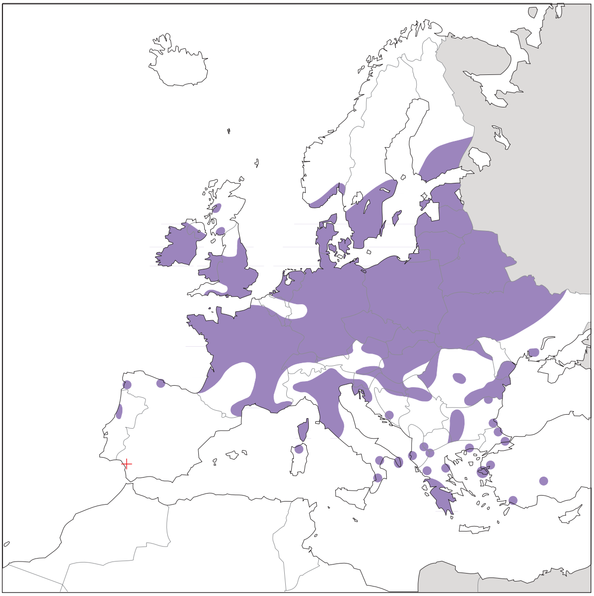

Figure 1: Distribution of *B. pratense* in Europe. From Dijkstra (2006).

over the last thirty years. In Hammond (1983), the distribution map shows a predominant presence on the south coast, around Sussex and Kent, with scattered records from south Wales and elsewhere. By 1997 and the publication of Merritt *et.al.* (1997), colonies had expanded in East Anglia and records began to appear from inland counties such as Cambridgeshire, although it was still largely absent from these counties.

It is now found in coastal areas around Norfolk, Suffolk, Sussex, Essex, Hampshire, Somerset and south Wales. It is also widely distributed in several inland counties such as Cambridgeshire, Northamptonshire, Bedfordshire and Surrey. Thus its distribution has changed significantly and this species now occupies a stronghold in the midlands in addition to the traditional coastal sites.

In Ireland, it is recorded in all counties, but can be highly localised (Nelson & Thompson, 2004), and the highest density of records is in the north midlands. Comparing the situation in Ireland in 1997 with the current records, shows only limited changes that may be more to do with increased recording than species expansion.

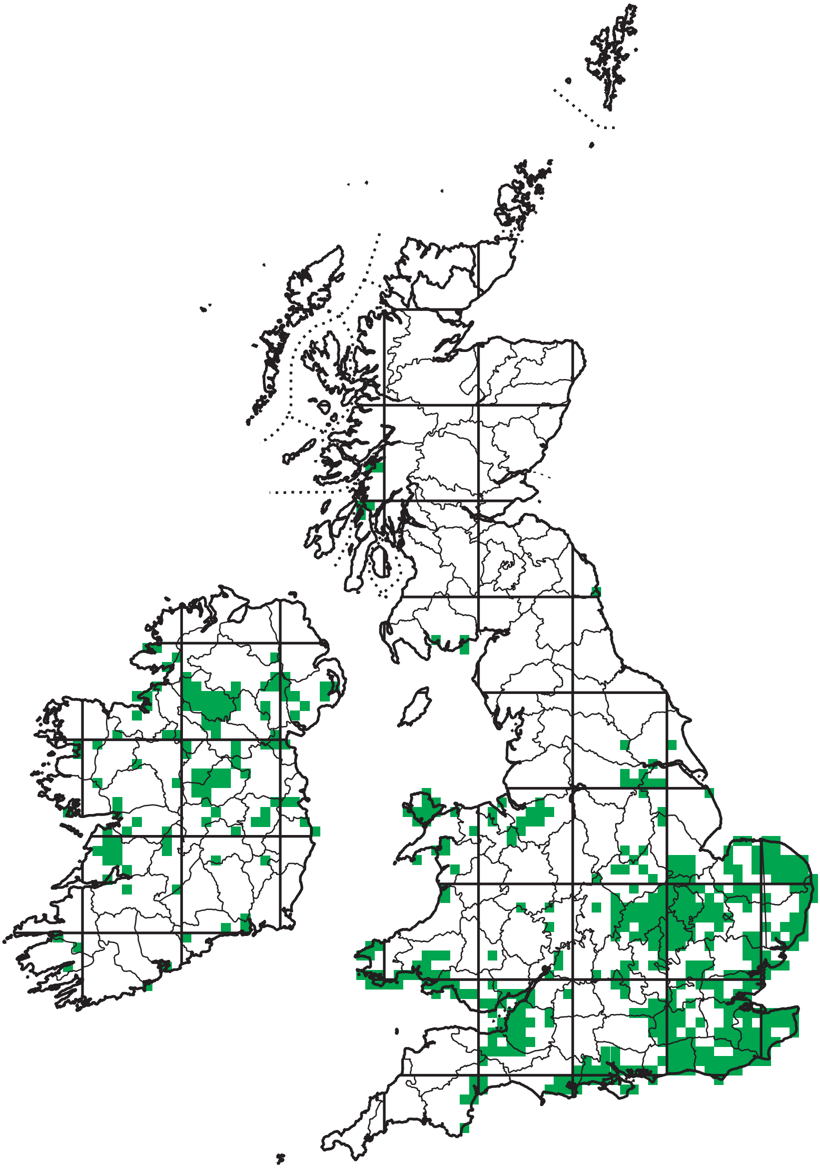

Figure 2. Current recorded distribution of *B. pratense* in Great Britain and Ireland. The green dots are recorded presence at 10km resolution. Data taken from the DRN database held in the NBN Gateway. The map boundaries show Vice Counties.

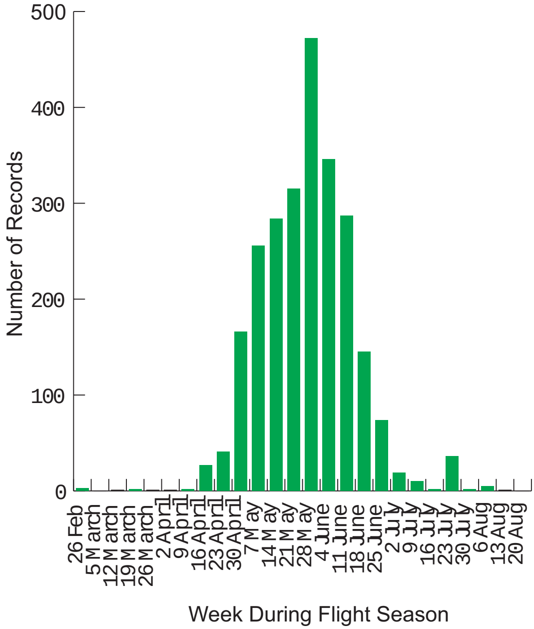

Figure 3. Adult flight period for *B. pratense* across the UK using data from the British Dragonfly Society Dragonfly Recording Network, covering the period 2000-2009, held on the NBN Gateway.

Phenology

Brachytron pratense has a locally short flying season. It is the first large dragonfly to emerge in early spring. Adults have been recorded from early March in warm springs However, these are the extreme and records this early are unusual. Nationally, its recorded flight season can extend to 166 days (Fig. 3), although this inevitably includes the extremes of early and late sightings. Locally, the flight season has been recorded at 75 days in Northamptonshire (Tyrrell, 2006) and 57 days in Bedfordshire (Cham, 2004). Tyrrell (2006) estimated average adult lifespan as between 25-35 days.

It is not until the end of April and early May that emergence occurs in any great numbers. Peak adult activity is at the end of May, with a steady decline towards early July. As males are territorial, it is important that habitat is available and that clashes with other species are minimised. At the peak of the flying season, its main territorial competitor is *Libellula quadrimaculata* and these two species clash often. By the time *Anax imperator* is at territory, numbers of *B. pratense* are in rapid decline.

In Poitou-Charentes in south-west France, the picture is similar, with the first recorded emergence on 5 March and the last on 19 June. Flying adults decrease in numbers from mid-July (a little later than in England) with the latest record on 19 September (Rochelet & Jourdet, 2009).

Habitat

Brachytron pratense favours sites with a rich complex of submerged and emergent plants. Breeding sites include coastal marshes, dykes, drainage ditches, slow flowing rivers and canals, mature gravel pits, grazing meadows and fens. In all cases, sites are characterised by abundant vegetation. They are associated with plants such as Common Club Rush *Schoenoplectus lacustris*, sedges *Carex* spp., Reedmace (*Typha* spp.), Reed Sweetgrass *Glyceria maxima*, reed *Phragmites* spp., rush *Juncus* spp., Hornwort *Ceratophyllum* spp., Milfoil *Myriophyllum* spp., Frogbit *Hydrocharis morsus-ranae*, Water Soldier *Stratiotes aloides*, Water Plantain *Alisma* spp., Arrowhead *Sagittaria sagittifolia* and bur-reeds *Sparganium* spp. The wide variety of vegetation reported in local studies of *B. pratense* suggest that its presence is more related to a rich variety of plants rather than to specific plants. This indicates a good, healthy mature wetland site – *B. pratense* is not found in new wetland habitats with absence of plants or only limited coverage. We have already seen how both larval and ovipositing stages are dependent on dead and decaying vegetation, and the wider variety of plants at a site leads to more of this material. It is a requirement that breeding sites are undisturbed and not regularly cleaned of such material – such clearance will limit this species' breeding opportunities and larval habitat and may cause its decline. Water bodies tend to be stagnant, although *B. pratense* has been recorded breeding in slow flowing, eutrophic rivers such as the River Nene in Northamptonshire (Emary, pers. comm.). While such sites may at first appear not to meet the above criteria, with waters uncluttered by dead material, they too tend to have a rich assemblage of surface, submerged and emergent vegetation. Perrin (1999) showed that suitable sites tend to have neutral to mildly alkaline pH, with only occasional occurance in mildly acidic pH. In Ireland, *B. pratense* avoids acidic sites (Nelson & Thompson, 2004). This is in broad agreement with sites being eutropic or mesotropic with high nutrient levels encouraging high levels of plant growth.

As adults emerge in early spring, their maturation period needs to be in areas where insect food is in abundance; this means that breeding sites tend to be close to woodlands or hedgerows, providing good hunting territory. In coastal marshes, fenland and grazing meadows, woodlands are not common and sites are more open. In these areas, *B. pratense* favours sites with dense grasslands around the breeding site. However, adults can be found some distance away in woodlands (Mendel, 1992), returning to the water to breed.

In all habitats, *B. pratense* is never the only species of odonate found. Its presence indicates not only a rich and healthy wetland habitat, but also a rich odonate assemblage. In Ireland it is often associated with *Coenagrion pulchellum* and *Aeshna grandis* (Nelson & Thompson, 2004). In the UK it is commonly found with *C. pulchellum*, *Sympetrum sanguineum* and *Lestes sponsa*. In riverine habitats it is also found alongside *Libellula fulva* in central lowland England (pers obs.), a species that favours slow-flowing, eutropic, muddy lowland rivers.

Regional Summaries

Brachytron pratense in Norfolk is predominantly found associated with grazing marsh dyke systems and fen areas (Plate 7). Often these grazing marshes and fens lie adjacent to the main river systems in the area or next to the main broads. The vast majority of Norfolk breeding records come from these marshes and fens, where this species can be found in any water body from small turf ponds to wider drainage dykes, but dykes 3-5m wide seem to be the best.

Grazing marshes tend to be extensive areas with moderate to low stocking densities, whilst fen areas vary from narrow strips around some broads to larger expanses criss-crossed by a network of dykes (Pam Taylor, pers comm.).

In Sussex, post war changes in farming practices have impacted this species around the coastal marshes. The recent return to more traditional grazing methods via the Countryside Stewardship scheme has benefited *B. pratense*. In areas where grazing has ceased, *B. pratense* is no longer found (Belden *et.al*, 2004).

Plate 7. Typical grazing marsh habitat at Upton Marshes, Norfolk. Photograph by Pam Taylor.

Plate 8. Typical gravel pit habitat for *B. pratense* showing lush emergent vegetation and plenty of trees. Ditchford Lakes and Meadows Nature Reserve, Northamptonshire.

Brook & Brook (2009) report that *B. pratense* favours linear sites such as ditches, dykes and canals in the north Kent marshes, and rivers such as the Great Stour and Medway.

The Gwent Levels near Newport, South Wales provide a variety of habitat types, with lagoons, wetland grasses and saltmarsh. In this area, *B. pratense* prefers slow moving water bodies, such as canals, ponds and ditches, provided there are emergent and some surface covering plants in reasonably clean water (Jones, 2008).

The colonies in Dumfries and Galloway are the subject of a Local Species Action Plan, in recognition of their rarity in this area of Scotland. These sites are ponds and lochs close to the coast (Mearns, 2000).

In the 1960s, the growth in gravel pits (to provide hardcore for the construction of the major motorways) along the main river systems in the East Midlands, for example in Cambridgeshire and Northamptonshire, was of great benefit to this species. In their early successional periods, such sites are not suitable for *B. pratense* as vegetation is sparse, with a lack of grasslands and woodlands. As they have matured, and often been protected in the form of managed nature reserves, the colonisation of the gravel pits by many wetland plant species has slowly provided ideal breeding habitat for *B. pratense* and they now arguably represent the best breeding sites in the UK (Plate 8). While in many marsh and fenland sites, adults are reported in single figures, in many gravel pits over 20 adults have been reported at the same time (Tyrrell *et. al.* 2006). In these counties, as colonies of *B. pratense* expand, they have moved into some of the river systems, such as the River Nene in Northamptonshire (Plate 9).

Plate 9. Riverine habitat for *B. pratense.* River Nene at Stanwick Lakes.

In Ireland, *B. pratense* is a lowland species associated with mesotropic fenland and inland pools and lakes. It is also found in coastal wetlands such as dune pools and coastal ditches. In common with lowland sites in England, it is also found in slow-flowing streams and rivers. Very exposed sites lacking vegetation and acidic sites are avoided (Nelson & Thompson, 2004).

Conclusions

In his introduction, Perrin (1999) hoped that his paper on *Brachytron pratense* would stimulate further research and study of this important species. This review has brought together a number of subsequent published studies of the behaviour of *B. pratense* in the UK, as well as information on its current distribution, habitat requirements and phenology, and has shown that our understanding of this species has increased considerably.

At the same time, colonies of *B. pratense* have expanded from predominantly coastal locations, as recorded pre-1997, to include many inland sites such as slow flowing rivers and mature gravel pits. This expansion is a strong sign of the success of *B. pratense* in colonising new areas. It is currently increasing its range in the midlands (Tyrrell & Brayshaw, 2004) and is being seen at still more new sites every year (M. Piper, pers. comm.). This pattern points to a successful future for *B. pratense* in the UK.

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References

Askew, R. R. 2004 *The Dragonflies of Europe* (2nd ed.). Harley Books, Colchester. 308 pp.

Belden, P. A., Downer, V. J., Luck, J. C., Prendergast, H. D. V., & Sadler, D. 2004. *The Dragonflies of Sussex: A guide to their distribution and conservation*. Essedon Press, Forest Row, East Sussex. 81 pp.

Brook, J. & Brook, G. 2009. *Dragonflies of Kent*. Kent Field Club. 128 pp.

Cham, S. A. 2004. *Dragonflies of Bedfordshire*. The Bedfordshire Natural History Society, Bedford. 139 pp.

Corbet, P. S. 1999 *Dragonflies: Behaviour and Ecology of Odonata*. Harley Books, Colchester. 892pp.

Davies, D. A. L. & Tobin, P. 1985. The Dragonflies of the World: A systematic list of the extant species of Odonata. Vol. 2 Anisoptera. *Societas Internationalis Odonatologica Rapid Communications (Supplements)* No. 5. 151 pp.

Dijkstra, K-D. B. 2006. *Field Guide to the Dragonflies of Britain and Europe*. British Wildlife Publishing, Gillingham. 320 pp.

Grand, D. & Boudot, J.-P. 2006 *Les Libellules de France, Belgique et Luxembourg.* Biotope Mèze (Collection Parthénope). 480 pp.

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

Mendel, H. 1992. *Suffolk Dragonflies*. Suffolk Naturalists' Society.

Merritt, R., Moore, N. W. and Eversham, B. C. 1997. *Atlas of the dragonflies of Britain and Ireland*. HMSO, London. 149 pp.

Nelson, B. and Thompson, R. 2004. *The Natural History of Ireland's Dragonflies*. The National Museums & Galleries of Northern Ireland, Belfast. 454 pp.

Perrin, V. L. 1999 Observations on the distribution, ecology and behaviour of the Hairy Dragonfly *Brachytron pratense* (Müller). *Journal of the British Dragonfly Society* **15**: 39-45.

Rochelet, B. & Jourde, P. 2009. *Brachytron pratense* (Müller, 1764). In: *Libellules du Poitou-Charentes*. Poitou-Charentes Nature, 255 pp.

Smallshire, D. & Swash, A. 2004. *Britain's Dragonflies*. WILDGuides, Old Basing, Hampshire. 168 pp.

Tyrrell, M. 2006 Observations on emergence and duration of adult life of the Hairy Dragonfly *Brachytron pratense* (Müller). *Journal of the British Dragonfly Society* ***21*****:** 43-46.

Tyrrell, M. & Brayshaw, S. 2004. Population expansion of the Hairy Dragonfly *Brachytron pratense* (Müller) and other breeding dragonflies of the Nene Valley in Northamptonshire. *Journal of the British Dragonfly Society* ***20***: 51-60.

Tyrrell, M., Brayshaw, S., Emary, C., Sutcliffe, D. & Showers, J. 2006. *The Dragonflies of Northamptonshire*. Northants Dragonfly Group, Raunds, Northamptonshire. 80 pp

Web Sites

Jones, B. 2008. http://www.dragonfly-days.co.uk/dragonflies.html

Mearns, R. 2000. *Hairy Dragonfly: Local Species Action Plan*. Dumfries and Galloway Council. http://www.dumgal.gov.uk/CHttpHandler.ashx?id=559&p=0

NBN Gateway 2010. http://www.searchnbn.net/searchengine/search.jsp?tab=1&pg=1&searchTerm=brachytron (accessed 20 December 2010).

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A review of the distribution of Odonata in the Macaronesian Islands, with particular reference to the *Ischnura* puzzle

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Summary

The Macaronesian Islands, comprising five archipelagoes in the North Atlantic Ocean (Azores, Madeira, Savage Islands, Canary Islands and Cape Verde Islands), do not harbour many species of Odonata. Acknowledged records of 20 species (7 Zygoptera, 13 Anisoptera) are known today from Macaronesia. However, a unique mixture of one endemic and 19 species that originated from three continents makes these islands a very attractive travel destination for odonatologists. In this study, the existing literature on the occurrence of Odonata in Macaronesia is summarised and evaluated. Special account is given concerning the historical development of the knowledge of the distribution of *Ischnura* species in Macaronesia.

Introduction

The Macaronesian Islands consist of five groups of islands of volcanic origin in the North Atlantic Ocean that were formed during the Miocene Age, roughly 20 to 3 million years ago. Politically, the Macaronesian Islands belong to three countries: Portugal, Spain, and Cape Verde. These five archipelagoes are, from north to south: The Azores (Portugal); Madeira with the island of Porto Santo and the Desertas Islands (Portugal); the Savage Islands (Portugal), administratively part of the Madeira Autonomous Region; the Canary Islands (Spain); and the Cape Verde Islands, which achieved independence from Portugal in 1975 (Fig. 1).

The Macaronesian Islands are characterised botanically by the natural occurrence of *Laurisilva* forest at higher altitudes, from 300 m up to approximately 1,300 m above sea level. It is dominated by evergreen, glossy-leaved hardwood trees that predominantly are members of the Lauraceae family. In Madeira it covers about 16 % of the island and its contribution to biodiversity is extremely high with over 500 endemic invertebrate species being associated with the *Laurisilva*. As all these archipelagoes were never part of a continent, the level of endemism is very high and several distinct plant and animal communities have developed. Other native plants and animals reached the islands via long-distance dispersal.

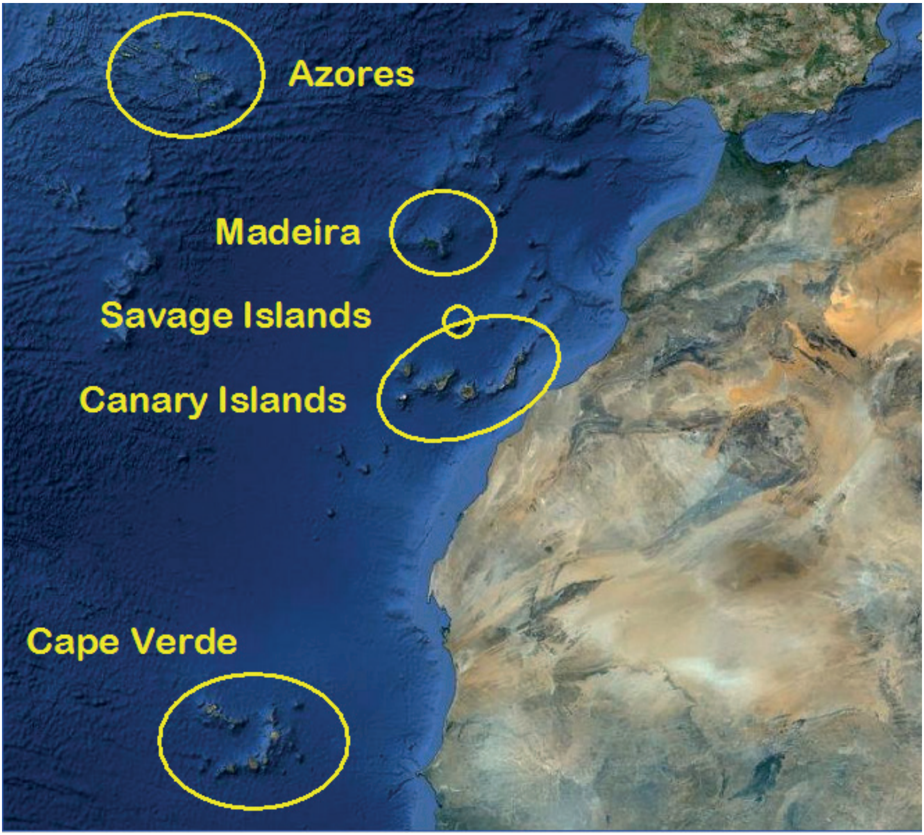

Figure 1. Overview of the Macaronesian region with the five archipelagoes. North faces up. The distance from the Azores to the Cape Verde islands is about 2,300 km. © 2011 Google – Grafiken ©2011 TerraMetrics, NASA.

Regarding the Odonata, this scenario becomes clearly visible: In Macaronesia we find one endemic species, *Sympetrum nigrifemur* (Plate 1), alongside 19 other species that originated from three continents – Europe, Africa and America. Hence, although the absolute number of odonate species on the Macaronesian archipelagoes is not very high, this unique mixture makes these islands a most attractive travel destination for odonatologists and other nature lovers. Consequently, the number of odonatological publications that pertain to the Macaronesian Islands is relatively high, compared to other regions where many more species are present.

In this study I give a review of today's knowledge on the occurrence and the distribution of Odonata in Macaronesia (Table 1). Several publications already exist that have summarised, annotated and discussed the existing literature and other recording data from Macaronesia, and these have been considered in this review. However, these publications either pertain only to certain countries or archipelagoes (e.g., McLachlan, 1882; Navás, 1906; Ferreira & Weihrauch, 2005; Ferreira et al., 2006; Aistleitner et al., 2008) or to a particular species (Cordero Rivera et al., 2005b; Lorenzo Carballa et al., 2009; Malkmus & Weihrauch, 2010). In this paper, a general, up-to-date overview of all Macaronesian Islands is presented. A special account is given of *Ischnura* in these archipelagoes, and the development of knowledge of the occurrence and distribution of *Ischnura* species in Macaronesia is provided chronologically in sections entitled 'The *Ischnura* puzzle'.

Plate 1. Male *Sympetrum nigrifemur*, the only Macaronesian endemic odonate. Ponds near Erjos, Tenerife, Canary Islands. 21 March 2006. Photograph by Mike Averill.

The Azores

Considering the prevailing climatic conditions it is not surprising that the Odonata found on the nine islands of the Azores – from west to east: Flores, Corvo, Faial, Pico, São Jorge, Graciosa, Terceira, São Miguel and Santa Maria (Fig. 2) - is species poor. Only four species, two zygopterans and two anisopterans, have been recorded (Table 1). Although the occurrence of Odonata in the Azores had been mentioned during the 19th century (Drouët, 1861; Guerne, 1888), the first records of three of the four Azorean species – *Ischnura pumilio*, *Anax imperator* and *Sympetrum fonscolombii* - were only listed in 1933 (Navás, 1933). However, it should be noted that, earlier, Sampaio (1904) erroneously mentioned *Libellula grandis* as common on the island of Terceira, but his detailed drawing proves

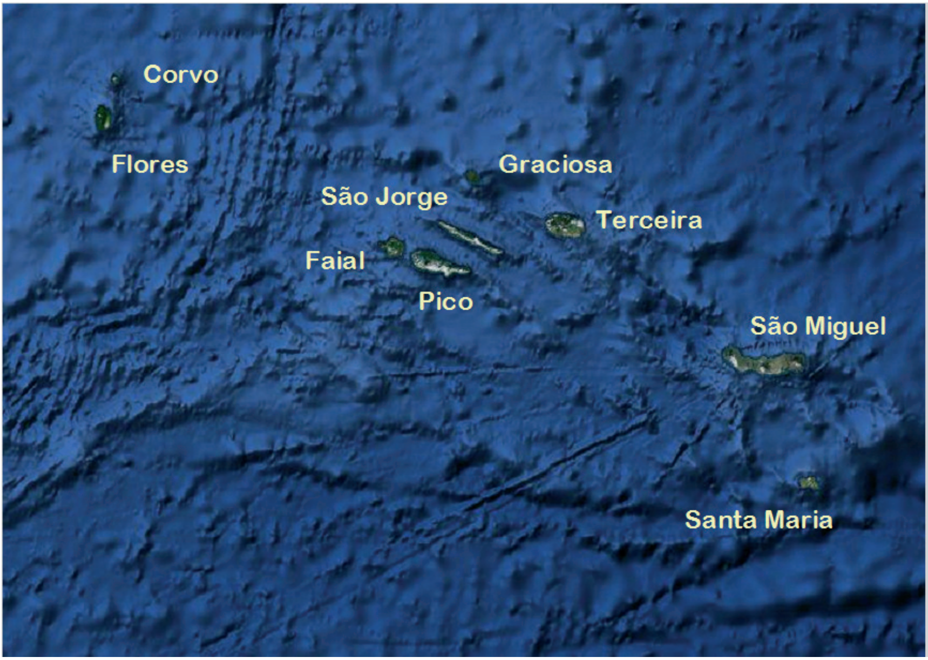

Figure 2. Names and position of the nine islands of the Azores Archipelago. North faces up. São Miguel is about 63 km long. © 2011 Google – Grafiken ©2011 TerraMetrics, NASA.

that he had actually described *A. imperator*.

The *Ischnura* puzzle, part I

The fourth Odonata species from the Azores belongs to a population unique in the world. Its occurrence there was first published by Valle (1940), who identified 63 specimens collected during 1938 on five Azorean islands as *Ischnura senegalensis*, and added, with an exclamation mark, that all of these specimens unfortunately were females but that due to the shape of the pronotum he regarded the identification as safe. Gardner (1960) judged a series of larvae collected during 1957 in Santa Maria and Flores as belonging to *I. senegalensis* as well. However, Belle (1982) had the opportunity to recheck ten of Valle's specimens, which were stored in the Zoological Museum of the University of Helsinki, and found that they "proved to belong to another species as judged by the very small vulvar spine" (Belle 1982). To shed more light on this mysterious case, Jean Belle travelled to the Azores in 1988 and searched three islands for this damselfly. In Pico, he captured more than 30 female specimens but again a male of the species was not encountered. The true identity of this enigmatic

Table 1. Checklist of Odonata in the archipelagoes of the Macaronesian Islands and their probable origin (Af, African; Am, American; Eu, European; ME, Macaronesian endemic). Some additional taxa that have been reported from Macaronesia in the odonatological literature have been omitted in this checklist but are discussed in the text. Status: ●, established species or regularly occurring migrant; ○, only single records; M, typical migrant with only sporadic occurrence, or recorded in a clearly migrating situation; ?, status as yet unclear or questionable.

	origin	Azores	Madeira	Savage Islands	Canary Islands	Cape Verde
Lestes pallidus	Af					●
Ischnura hastata	Am	●				
I. pumilio	Eu	●	●			
I.saharensis	Af		**?**		●	
I. senegalensis	Af				**?**	●
Pseudagrion glaucescens	Af					**?**
Platycnemis subdilatata	Af				○	
Anax ephippiger	Af		**M**		**M**	**M**
A. imperator	Eu/Af	●	●	**M**	●	●
A. parthenope	Eu		○		●	
Crocothemis erythraea	Af				●	●
Orthetrum chrysostigma	Af				●	
O. trinacria	Af				●	●
Pantala flavescens	Af					●
Sympetrum fonscolombii	Af	●	●		●	●
S. nigrifemur	ME		●	**M**	●	
Tramea limbata	Af					○
Trithemis annulata	Af				●	●
T. arteriosa	Af				●	**?**
Zygonyx torridus	Af				●	●

species was unravelled only when Belle's specimens from Pico were compared by Jan van Tol with the collection in the former National Museum of Natural History in Leiden, The Netherlands (today named 'Naturalis'), and were identified as the American species *Anomalagrion hastatum* (Belle & van Tol, 1990), a taxon that today is referred to the genus *Ischnura* and the species listed as *Ischnura hastata* (Say, 1839). Furthermore, Belle & van Tol (1990) were the first to hypothesize that the Azorean *I. hastata* belonged to a parthenogenetically reproducing population. This finding, which is unique within the whole order, was later analysed and substantiated in detailed studies by Cordero Rivera *et al*. (2005a, b) and has reached an according significance in evolutionary biology. Based on the case of *I. hastata*, Sherratt & Beatty (2005) discuss the concept of 'geographic parthenogenesis', which proposes that, due to the different selection pressures that organisms face, the parthenogenetic form of a species is more likely to occur in areas such as higher latitudes and altitudes and on islands. If a species can include both sexual and parthenogenetic forms, on arriving on a remote island it is possible that the latter is favoured, at least initially, owing to the difficulty of finding mates.

The Madeira Archipelago

The Madeira Archipelago consists of the two main islands of Madeira and Porto Santo and the three small Desertas Islands (in Portuguese *Ilhas Desertas*) – from north to south: Ilhéu Chão, Deserta Grande and Bugio (Fig. 3). The Desertas Islands are no more than a chain of long and narrow, uninhabited rocks in the sea, lacking permanent freshwater, and therefore are not colonised by Odonata. Madeira and Porto Santo are permanently inhabited or regularly visited by six odonate species (Ferreira & Weihrauch, 2008): *Ischnura pumilio* (the only zygopteran), *Anax ephippiger*, *A. imperator*, *A. parthenope*, *Sympetrum fonscolombii* and *S. nigrifemur* (Table 1).

The first Odonata species from Madeira was reported by Bowdich (1825: 169), referring to an "*Aeschna* approaching *grandis*, and greatly resembling the species figured by Roesel, t.2, Insect. Aquat. tab. ii fig. 1", i.e., *A. imperator*. The occurrence of *I. pumilio* in Madeira was first mentioned by Rambur (1842: 278): "*Agrion pumilio* ... il se trouve aussi à Madère". Selys & Hagen (1850: 396) wrote "A Madeire on trouve *Libellula striolata*…", which is the first indication of the occurrence of *S. nigrifemur* on Madeira. The first record of *S. fonscolombii* was given by Hagen (1865) and, in a footnote, Gardner (1963) mentions that in February 1958 he collected specimens of *A. ephippiger* in Porto Santo. However, the first published record of *A. ephippiger* in Madeira itself was by Smit (1998) during a mass influx of the species in spring 1998. The last odonate addition to the Madeiran fauna is *A. parthenope*, which was recorded for the first time on 30 August 2005 in Porto Santo (Pelny, 2006) and on 5 October

Figure 3. Names and position of the five islands of the Madeira Archipelago. North faces up. Madeira is about 45 km long. © 2011 Google – Grafiken ©2011 TerraMetrics, NASA.

2008 in Madeira (Malkmus & Weihrauch, 2010). From the Desertas Islands, only records of migrating *S. fonscolombii* (Gardner, 1968) and *S. nigrifemur* (Malkmus & Weihrauch, 2010) have been published.

Of particular interest is a gomphid species that in the 19th century was noted on three occasions to occur in Madeira. Selys & Hagen (1858: 138) refer to a specimen reported by T. Vernon Wollaston by the name *G. lucasii*. Hagen (1865), who drew up this paper for Wollaston, based on his Madeiran Neuroptera material (McLachlan, 1882), writes "I have not seen the *Gomphus* taken by M. Hartung in Madeira, and deposited in the collection of Professor Heer; it is probably *G. simillimus*". On the other hand, Selys (1887: 66) writes: "Gomphus sp? - D'après une larve de Madère. Probablement le *G. Lucasii* d'Algérie", indicating that here he explicitly refers to a larval gomphid specimen. This may be regarded as contradictory to the interpretation of McLachlan (1882), Gardner (1963) and Ferreira *et al*. (2006), who all consider the reported *Gomphus* from Madeira to pertain to a single adult specimen, because neither Selys & Hagen (1858) nor Hagen (1865) alluded to a larval specimen. However, Selys' indication (Selys, 1887) may simply have been a mistake and, as the true identity of the lost gomphid specimen(s) is unclear, it was consequently deleted from the

Madeiran checklist by Ferreira *et al*. (2006) and Ferreira & Weihrauch (2008).

The *Ischnura* puzzle, part II

A particular case has been discussed in detail by Ferreira *et al*. (2006) and here I repeat the chronology of events, which Reinhard Jödicke and I had prepared together for that publication: There is an, as yet unidentified second, *Ischnura* species in Madeira, in addition to *I. pumilio*. It was first mentioned by Selys & Hagen (1850), who referred to a species labelled *Agrion Maderae* (nom. nud.) in the collection of Rambur that had been acquired by Selys. For many years further information was sparse. Hagen (1865) wrote that he did not know the "A. Maderae" of Selys, while Selys (1876) listed the locality "Madeire?" for *I. graellsii* – the first speculation about the identity of the Madeiran species. McLachlan (1882) stated that his knowledge "of this African species as Madeiran is based solely on 1 ♂ and 1 ♀ in De Selys's collection. The ♂ is from Rambur's collection, and is labelled by him "*Agrion maderae*", an unpublished name; it is in bad condition, but is certified as *senegalensis* by De Selys". Selys (1887) himself was unsure because he first (p. 46) put a question mark behind Madeira as a locality for *I. senegalensis* but later (p. 66) he added it to the list of records: "Madère, d'après une exemplaire de la collection Rambur". Although Le Roi (1915) doubted the occurrence of a species in Madeira that is absent from northwestern Africa, this identification seemed to be confirmed when Gardner (1963) reported the species in a footnote on a series of *I. senegalensis* captured during an expedition to the island of Porto Santo in February 1958. Unfortunately, the specimens from the collection of Selys are lost today, and the series of Gardner has not yet been located.

Based on the knowledge of the distribution of *Ischnura* spp. in Macaronesia at that time, Ferreira *et al*. (2006) exhaustively discussed the case and came to the conclusion that "the identity of the enigmatic ischnuran in Madeira is most probably *I. saharensis*". From today's viewpoint, only five years later, I would not dare to go that far. When considering the new findings in Macaronesia (see 'The *Ischnura* puzzle, part III') all that can be said is that the true identity of a second *Ischnura* species from Madeira can only be unravelled by the examination of Gardner's – as yet not traced - series caught in 1958 in Porto Santo, or by catching new specimens of the same species from the Madeira Archipelago.

The Savage Islands

The Savage Islands (in Portuguese *Ilhas Selvagens*), comprising three large and 18 small islands of volcanic origin, are situated almost centrally between Madeira, 230 km away, and the Canary Islands 165 km away. The archipelago consists of two groups of islands: the northeastern group, including the main island of Selvagem Grande and three small islets, and the southwestern group, including Selvagem Pequena, Ilhéu de Fora and a group of ten very small, rocky islets. Due to its marine biodiversity, a unique flora with ten endemic species and a breeding ground for many avian species, especially shearwaters (*Calonectris* spp.), the Savage Islands were converted stepwise into a nature reserve by the Portuguese government from 1971 onwards. There are no human inhabitants on the islands, with the exception of two permanent wardens on Selvagem Grande, and access is allowed to authorised visitors only.

The Savage Islands, like the Desertas Islands, lack freshwater except for ephemeral puddles after rainfalls, and the presence of Odonata is restricted to visits by migrating individuals (Table 1). Observations of only two species have been published: Báez (1985: 39) observed an *Anax* cf. *imperator* during a visit to Selvagem Grande in 1976, and Malkmus & Weihrauch (2010) list three records of *Sympetrum nigrifemur* from the same island: One is a specimen in the Museo Municipal do Funchal that was collected by Weinreich on 24 July 1963; the other two were observations by M.J. Biscoito during October 1984.

The Canary Islands

There are 14 species of Odonata that can be considered today for the checklist of the seven Canary Islands (Table 1) – from west to east: El Hierro, La Palma, La Gomera, Tenerife, Gran Canaria, Fuerteventura and Lanzarote (Fig. 4). Probably the first publication that contained any reference to dragonflies was published by Bory de St.-Vincent (1803: 369) who listed three species from Tenerife: "75. Demoiselle rouge. *Libellula rubicunda*. L. 77. Demoiselle déprimée. *Libellula depressa* ? L. 78. Demoiselle variée. *Libellula variegata*. Fab. Drury T. II. *Pl. XLV, fig*. 1." As for item 76, only a fourth "Demoiselle ...." is listed without any additional information. From Bory's list, today only the observation of *Crocothemis erythraea*, under the synonym *L. rubicunda*, can be acknowledged as a first record from the Canaries. An observation of *Libellula depressa*, that Bory himself had added a question mark to, and otherwise has never been reported from the Canaries, was already regarded as doubtful by McLachlan (1882) and Navás (1906). The same applies to *Palpopleura lucia* (Drury), a common southern African species listed by Bory under the synonym *Libellula variegata*. Consequently, Báez (1985) deleted these two species from the checklist of the Canary Islands.

A comprehensive opus on the natural history of the Canary Islands, edited by Philip Barker Webb and Sabin Berthelot and issued to subscribers in 106 parts between 1835 and 1850, is the second publication with reference to Canarian Odonata. The section on "Neuroptera" (Webb & Berthelot, 1837-1840: 82 f.) was actually worked on by Gaspard Auguste Brullé and includes five odonate species.

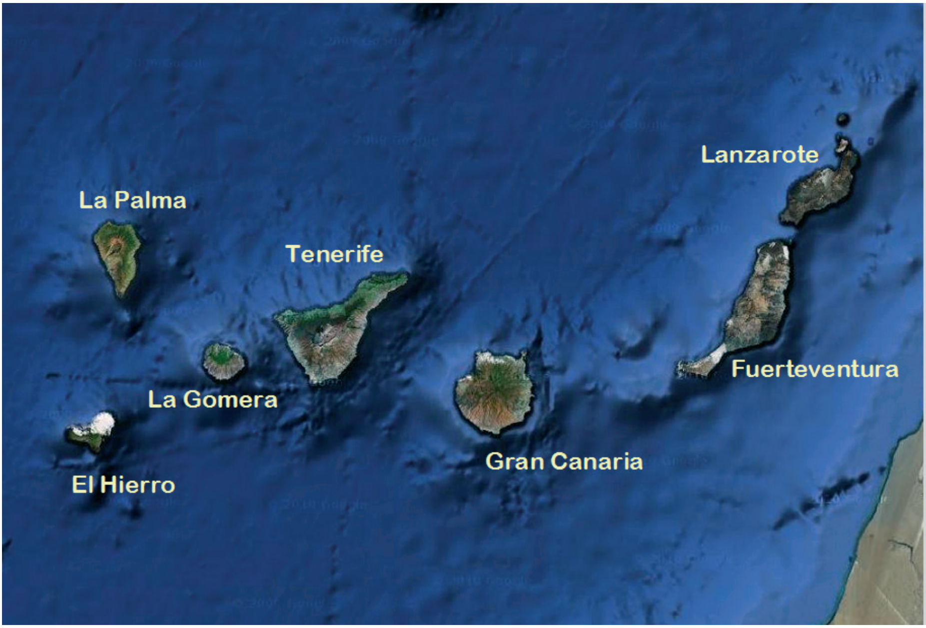

Figure 4. Names and position of the seven Canary Islands. North faces up. Tenerife is about 81 km long. © 2011 Google – Grafiken ©2011 TerraMetrics, NASA.

Unfortunately I was not able to check that book personally and therefore have to rely on McLachlan's (1882) information here, who credits the following species to Webb & Berthelot (1837-1840): *Anax imperator* (sub *Aeschna formosa*), *C. erythraea* (sub *Libellula ferruginea*), *Orthetrum chrysostigma* (sub *Libellula olympia*), *Sympetrum nigrifemur* (sub *Libellula vulgata*) and *Trithemis arteriosa* (sub *Libellula rubella*). Therefore, the mention of *A. imperator* and *T. arteriosa* has to be regarded as the first records of these species from the Canary Islands. The first mention of *S. nigrifemur* for the Canaries was previously credited by Malkmus & Weihrauch (2010) to Selys (1884) ("Je donne ce nom aux exemplaires que j'ai reçus de Madère et probablement à ceux des Canaries"). However, as the record by Webb & Berthelot (1837-1840) clearly occurred earlier, the credit should be attributed to them. Indeed, they were the first to record this species anywhere in the Macaronesian Islands. As for *O. chrysostigma*, the first record from the Canaries cannot be awarded with certainty. Thus Burmeister's (1839: 857) description of the species was based on a specimen from Tenerife ("Von Teneriffa, in v. Winthem's Sammlung"), whereas Webb & Berthelot's mention of the species occurred virtually simultaneously (Webb & Berthelot, 1837-1840).

Anax parthenope was first listed for the Canaries by Brauer (1866: 61) from Tenerife, and Hagen (1867: 31) refers to a specimen of *A. ephippiger* in his collection, which was taken at sea, three German miles (22.6 km) off the coast of the Canaries: "…auch ich besitze ein Stück mit der Signatur: im atlantischen Meere drei Meilen von den canarischen Inseln von Afrika kommend gefangen." However, the first record of *A. ephippiger* from the islands themselves is listed by Navás (1906) from Tenerife. The first documented Canarian record of *S. fonscolombii* pertains to three females collected by the Rev. Alfred Edwin Eaton on 6 December 1880 in Gran Canaria near Las Palmas (McLachlan, 1882) and *Zygonyx torridus* was first mentioned from the Canaries in the species' description by Kirby (1889), which amongst others was based on a male from Tenerife.

Hence, at the end of the 19th century, nine anisopteran species were known that plausibly occurred in the Canary Islands and this status remained unchanged for more than a century. During that period, merely occasional faunistic studies were published that increased the knowledge of the distribution of species on single islands or on their phenology (e.g., Brauer, 1900; Valle, 1935; Lieftinck, 1949; Belle, 1982; Peters, 1988; Bemmerle, 2005; Brauner, 2007). It was only in the first decade of the 21st century when Boudot *et al.* (2009) reported the occurrence of two more anisopterans in Fuerteventura, which probably can be traced back to a recent expansion from the African continent: *Orthetrum trinacria* and *Trithemis annulata*. Both species were recorded in July 2003 by Mike Crewe, a British tour guide, during a birdwatching trip (Clarke & Crewe, 2003). It has to be noted though that a record of *O. trinacria* in Fuerteventura had been signalled already in October 2000 in another birdwatching trip report on the internet (Hill, 2000). However, although I was able to contact Mike Crewe during the editing of the atlas by Boudot *et al*. (2009), I did not succeed in contacting Paul Hill in order to verify – however absolutely plausible - that record.

As regards the occurrence of Zygoptera on the Canary Islands, three species from two genera have to be taken into account, of which one pertains to a single specimen only: Kalkman & Smit (2002) detected a male of *Platycnemis subdilatata* in the collection of the Zoological Museum of Amsterdam, labelled "Canary Islands, Tenerife, Puerto de la Cruz, 28 March 1971, J.H. Stocks". Kalkman & Smit (2002) regard a mislabelling of the specimen as unlikely and discuss potential ways how this Maghreb endemic may have reached Tenerife over a distance of approximately 500 km. As I have already experienced the unforgettable incidence of dust-bearing *Calima* winds from the Sahara in the Canaries, like Kalkman & Smit (2002) I regard a wind-borne transport of this individual as absolutely plausible.

The *Ischnura* puzzle, part III

The first record of any zygopteran species from the Canary Islands was reported by Valle (1955), referring to four males and one female of *Ischnura* that had been collected by Håkan Lindberg on 1 March 1949 near Aldea San Nicolas in Gran Canaria and which were classified by Valle (1955) as pertaining to *Ischnura senegalensis*. Belle (1982) gave notice of many individuals of another species, *Ischnura saharensis*, from the south of Gran Canaria, including several collected specimens in February 1981, and listed that species as new to the fauna of the Canary Islands. However, in the same publication, Belle already doubted the correctness of Valle's (1955) determination of *I. senegalensis* from Gran Canaria. This doubt was substantiated by Hämäläinen (1986), who checked Valle's specimens in the collection of the Zoological Museum of the University of Turku, Finland and found that they were in fact misidentified *I. saharensis*. Since then, *I. saharensis* was unanimously regarded as the only zygopteran species that occurred in the Canaries and has been reported from all other islands of the archipelago except El Hierro (e.g., Bacallado Aránega, 1984; Bemmerle, 2005; Brauner, 2007).

However, with respect to a recent finding, this seemingly clear-cut situtation now has to be scrutinised again. According to Rosa Ana Sánchez-Guillén and Adolfo Cordero Rivera, University of Vigo, Spain (pers. comm.), preliminary results from DNA analyses of a specimen that was collected near Taganana in Tenerife have confirmed the presence of *I. senegalensis* in the Canary Islands. Hopefully, that intriguing record will be published with more details soon. Considering this new finding, records of *Ischnura* species from the Canaries should be regarded critically and the collection of a – preferably male - voucher specimen for any new record is strongly recommended.

The Cape Verde Islands

The southernmost archipelago of Macaronesia comprises the Cape Verde Islands (in Portuguese Cabo Verde), a cluster of ten islands and nine small islets, which are divided into two groups: The Windward Islands (Ilhas de Barlavento) - Santo Antão, São Vicente, Santa Luzia, São Nicolau, Sal and Boa Vista and the Leeward Islands (Ilhas de Sotavento) - Maio, Santiago, Fogo and Brava (Fig. 5). Compared to the other Macaronesian Islands, only little is known about the occurrence of Odonata in Cape Verde. Today's knowledge has been reviewed thoroughly by Aistleitner *et al*. (2008), supported by recent studies by Martens (2010) and Martens & Hazevoet (2010), and the information I give here is based chiefly on these papers.

Records of 14 species of Odonata have hitherto been published from the Cape Verde Islands (Table 1). The first two species from Cape Verde are listed by Calvert (1894) and were collected in São Vicente, near Porto Grande, the deep-water port of Mindelo, during the U.S. solar eclipse expedition to West Africa

Figure 5. Names and position of the ten Cape Verde Islands. North faces up. Santiago is about 57 km long. © 2011 Google – Grafiken ©2011 TerraMetrics, NASA.

1889-1890, when the U.S.S. Pensacola called there from 10 to 12 November 1889. During the time of steam navigation, Porto Grande was an important port of call with a coal station. However, both of the species listed by Calvert (1894), viz *Pseudagrion glaucescens* and *Brachythemis leucosticta*, have not been confirmed for more than 100 years and therefore have to be regarded critically. *Pseudagrion glaucescens* belongs to a large African genus that underwent many taxonomic changes during the 20th century. Furthermore, Calvert mentions an acephalic, unclassified male *Pseudagrion* specimen from the same site. As regards *B. leucosticta*, this taxon was recently split by Dijkstra & Matushkina (2009) into two cryptic, but clearly separable, species, *B. leucosticta* s.str. (Burmeister, 1839) and *B. impartita* (Karsch, 1890). Only a check of Calvert's (1894) missing male specimen could resolve which of the two species he referred to when he mentioned "*Libellula* (*Cacergates*) *unifasciata* Oliv. (*leucosticta* Burm.)". Since Cape Verde is situated in the overlapping zone of both species, I have deleted this unconfirmed ancient record from the checklist until further notice. It is strongly advised that all of the addressed specimens listed by Calvert (1894) should be checked, if the material can be traced; probably they are stored in the Smithsonian National Museum of Natural History in Washington, D.C.

From the same locality, Porto Grande, Kirby (1897) mentioned two species collected by Ernest Edward Austen during a stopover on 26 December 1895 of the cable S.S. Faraday on its way to the Lower Amazon, which he accompanied as a scientific representative of the British Museum to make collections from the Amazon. These are *Crocothemis erythraea* and *Pantala flavescens*, both of which are first records for Cape Verde. The next records of Odonata were by Leonardo Fea, an Italian explorer and zoologist, during a visit to Cape Verde in 1898. The eight species observed or collected by Fea were published by Martin (1908) without any additional data. With the exception of *C. erythraea* and *P. flavescens* they are all first records for Cape Verde: *Ischnura senegalensis*, *Anax imperator* (sub *A. formosus*), *Orthetrum trinacria*, *Trithemis annulata* (sub *T. rubrinervis*), *T. arteriosa* and *Zygonyx torridus* (sub *Pseudomacromia torrida*). Several specimens collected by Fea in Cape Verde were checked additionally in the collection of the Natural History Museum in Genoa, Italy (Aistleitner *et al*., 2008): *I. senegalensis* (Boa Vista, February 1898), *C. erythraea* (ditto), *O. trinacria* (ditto), and *T. annulata* (São Nicolau, November 1898). However, *T. arteriosa* has not been substantiated by any further records and hence has to be regarded critically.

Sympetrum fonscolombii was first mentioned from Cape Verde by Lobin (1982), referring to an observation by E. Bauer and B. Traub on 1 January 1979. The three other species on the checklist of Cape Verde are credited as first records to Aistleitner *et al*. (2008): *Lestes pallidus* (São Vicente, 14 December 2000, leg. Eyjolf Aistleitner), *Anax ephippiger* (Maio, 24 January 2002, leg. E. Aistleitner) and *Tramea limbata* (Boa Vista, 2 January 2001, leg. E. Aistleitner and Uli Aistleitner). In conclusion, 11 species definitely occur today on the islands of Cape Verde but records of additional species are likely in the future.

The *Ischnura* puzzle: synopsis

In the **Azores**, two *Ischnura* species have widely established populations: *I. hastata* (a worldwide unique parthenogenetic population) and *I. pumilio*.

In **Madeira** and **Porto Santo**, *I. pumilio* has established populations. During both 19th and 20th centuries, records of at least one other *Ischnura* species have been made in the Madeira archipelago but it is not known whether this species still exists there today and its true identity is unknown. However, potential candidates are, with decreasing probability, *I saharensis*; *I. senegalensis*; *I. graellsii*; *I. fountaineae* and *I. hastata*.

In the **Canary Islands**, *I saharensis* has established populations on most or even all of the islands. The occurrence of *I. senegalensis* in Tenerife has been confirmed by genetic analyses but its status in the Canaries is completely unclear.

The potential occurrence of the highly vagrant pioneer species *I. pumilio*, in the Canaries cannot be excluded *a priori*.

In the **Cape Verde Islands**, *I. senegalensis* is the only *Ischnura* species present but it does not occur frequently nor is it widely distributed.

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References

Aistleitner, E., Barkemeyer, W., Lehmann, G. & Martens, A. 2008. A checklist of the Odonata of the Cape Verde Islands. *Mitteilungen des Internationalen Entomologischen Vereins*, *Frankfurt a.M*. **33**: 45-57.

Bacallado Aránega, J.J. (ed.) 1984. *Fauna (marina y terrestre) del Archipiélago Canario*. Gran Biblioteca Canaria 13. Edirca, Las Palmas de Gran Canaria. 358 pp.

Báez, M. 1985. *Las libelulas de las Islas Canarias*. Enciclopedia Canaria 28. Aula de Cultura del Excmo. Cabildo Insular de Tenerife, Santa Cruz. 48 pp.

Belle, J. 1982. Odonata collected in the Canary Islands. *Entomologische Berichten*, *Amsterdam* **42**: 75-77.

Belle, J. & van Tol, J. 1990. Anomalagrion hastatum (Say), an American damselfly indigenous to the Azores (Odonata, Coenagrionidae). *Tijdschrift voor Entomologie* **133**: 143-147.

Bemmerle, B. 2005. Zygonyx torridus auf La Gomera, Kanarische Inseln (Oodnata: Libellulidae). *Libellula* **24**: 249-256.

Bory de St.-Vincent, J.B.G.M. 1803. *Essais sur les isles fortunées et l'antique Atlantide, ou précis de l'histoire générale de l'archipel des Canaries*. Baudouin, Paris. 522 pp. + 2pp. errata.

Boudot, J.-P., Kalkman, V.J., Azpilicueta Amorín, M., Bogdanović, T., Cordero Rivera, A., Degabriele, G., Dommanget, J.-L., Ferreira, S., Garrigós, B., Jović, M., Kotarac, M., Lopau, W., Marinov, M., Mihoković, N., Riservato, E., Samraoui, B. & Schneider, W. 2009. Atlas of the Odonata of the Mediterranean and North Africa. *Libellula Supplement* **9**: 1-256.

Bowdich, T.E. 1825. *Excursions in Madeira and Porto Santo, during the autumn of 1823,* *while on his third voyage to Africa*. George B. Whittaker, London. xii + 278 pp., pls 1-22.

Brauer, F. 1866. *Reise der Oesterreichischen Fregatte Novara um die Erde, in den Jahren 1857-1859 unter den Befehlen des Commodore B. von Wüllerstorf-Urbair.* Zoologischer Theil, Band 2: Entomologie. Abtheilung 1 (4): Neuropteren. Vienna. 104 + 1 pp., pl. I-II.

Brauer, F. 1900. Über die von Prof. O. Simony auf den Canaren gefundenen Neuroptera und Pseudoneuroptera (Odonata, Corrodentia et Ephemeridae). *Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften in Wien*, *Mathematisch-Naturwissenschaftliche Classe*, *Abtheilung I*, **109**: 464-477.

Brauner, O. 2007. Winterbeobachtungen von Libellen auf La Gomera und La Palma, Kanarische Inseln (Odonata). *Libellula* **26**: 213-232.

Burmeister, H. 1839. *Handbuch der Entomologie*. pp. 757-1050: Zweiter Band. Besondere Entomologie. Zweite Abtheilung. Kaukerfe. Gymnognatha. (Zweite Hälfte; vulgo Neuroptera.). Enslin, Berlin.

Calvert, P.P. 1894. Order Pseudoneuroptera. pp. 582-586 in: Riley, C.V. (ed.) Scientific results of the U.S. eclipse expedition to West Africa, 1889-‘90. Report upon the Insecta, Arachnida, and Myriopoda. *Proceedings of the United States National Museum* **16** [1893]: 565-590, pl. LXX.

Cordero Rivera, A., Lorenzo [Carballa], [M].O. & Andrés, J. 2005a. Endosymbiont-induced parthenogenesis in a diplo-diploid damselfly? Tagungsband der 24. Jahrestagung der Gesellschaft deutschsprachiger Odonatologen, Freising, 18.-20. März 2005: 25.

Cordero Rivera, A., Lorenzo Carballa, M.O., Utzeri, C. & Vieira, V. 2005b. Parthenogenetic Ischnura hastata (Say), widespread in the Azores (Zygoptera: Coenagrionidae). *Odonatologica* **34**: 1-9.

Dijkstra, K.-D.B. & Matushkina, N. 2009. Kindred spirits: “Brachythemis leucosticta”, Africa’s most familiar dragonfly, consists of two species (Odonata: Libellulidae). *International Journal of Odonatology* **12**: 237-256.

Drouët, H. 1861. *Eléments de la faune Açoréenne*. J.B. Baillière et Fils, Paris. 245 pp.

Ferreira, S. & Weihrauch, F. 2005. Annotated bibliography of odonatological literature from continental Portugal, Madeira, and the Azores (Odonata). *Libellula* **24**: 109-128.

Ferreira, S. & Weihrauch, F. 2008. Odonata. In: Borges, P.A.V., Abreu, C., Aguiar, A.M.F., Carvalho, P., Jardim, R., Melo, I., Oliveira, P., Serrano, A.R.M. & Vieira, P. (eds) *A list of the terrestrial fungi, flora and fauna of Madeira and Selvagens archipelagos*: 294. Direcção Regional do Ambiente da Madeira and Universidade dos Açores, Funchal and Angra do Heroísmo. 438 pp.

Ferreira, S., Grosso-Silva, J.M., Lohr, M., Weihrauch, F. & Jödicke, R. 2006. A critical checklist of the Odonata of Portugal. *International Journal of Odonatology* **9**: 133-150.

Gardner, A.E. 1960. Odonata from the Azores and Madeira. *Boletim do Museu Municipal do Funchal* **13** (41): 119-122.

Gardner, A.E. 1963. Report on the insects collected by E. W. Classey and A. E. Gardner expedition to Madeira in December 1957 (With special reference to the life-history of Sympetrum nigrifemur (Selys)). Part III. Odonata. *Proceedings of the South London Entomological and Natural History Society* **1962**: 62-85, pls III-VI.

Gardner, A.E. 1968. Notes on insects collected in Madeira in 1966. *Boletim do Museu Municipal do Funchal* **22** (102): 35-37.

Guerne, J. de. 1888. *Excursions zoologiques dans les Iles de Fayal et de San Miguel (Açores)*. Gauthier-Villars et Fils, Paris. 110 pp., 1 pl.

Hagen, H.A. 1865. The Neuroptera of Madeira. *The Entomologist's Monthly Magazine* **2**: 8-11, 25-28, 59-62, 75-81.

Hagen, H.[A.] 1867. Notizen beim Studium von Brauer's Novara-Neuropteren. *Verhandlungen der Zoologisch-Botanischen Gesellschaft in Wien* **17**: 31-62.

Hämäläinen, M. 1986. Note on misidentification of the first Zygoptera material from the Canary Islands. *Notulae Odonatologicae* **2**: 131-132.

Kalkman, V.J. & Smit, J.T. 2002. Platycnemis subdilatata Sel. new to the Canary Islands (Zygoptera: Platycnemididae). *Notulae Odonatologicae* **5**: 128.

Kirby, W.F. 1889. A revision of the subfamily Libellulinae, with descriptions of new genera and species. *Transactions of the Zoological Society of London* **12**: 249-348, pls LI-LVII.

Kirby, W.F. 1897. List of the Neuroptera collected by Mr. E.E. Austen on the Amazonas etc. during the recent expedition of Messrs. Siemens Bros. Cable S.S. 'Faraday', with descriptions of several new species of Odonata (Dragonflies). *Annals and Magazine of Natural History* (6) **19**: 598-617, pls XII-XIII.

Le Roi, [O.] 1915. Odonaten aus der algerischen Sahara von der Reise des Freiherrn H. Geyr von Schweppenburg. Mit einer Übersicht der nordafrikanischen Odonaten-Fauna. *Deutsche Entomologische Zeitschrift* **1915**: 609-634.

Lieftinck, M.A. 1949. On a small collection of Odonata from Teneriffe and La Palma. *Tijdschrift voor Entomologie* **91**: 6.

Lobin, W. 1982. Libellen (Insecta, Odonata) von den Kapverdischen Inseln. In: Groh, K. (ed.) Zum Auftreten einiger, bisher von den Kapverdischen Inseln nicht oder wenig bekannter Tiergruppen (Articulata und Vertebrata). *Courier Forschungsinstitut Senckenberg* **52**: 255-256.

Lorenzo Carballa, M.O., Beatty, C.B., Utzeri, C., Vieira, V. & Cordero Rivera, A. 2009. Parthenogenetic Ischnura hastata revisited: present status and notes on population ecology and behaviour (Odonata: Coenagrionidae). *International Journal of Odonatology* **12**: 395-411.

Malkmus, R. & Weihrauch, F. 2010. Verbreitung und Phänologie von Sympetrum nigrifemur auf den Makaronesischen Inseln (Odonata: Libellulidae). *Libellula* **29**: 91-106.

Martens, A. 2010. Ecology of the dragonflies at the westernmost spot of Africa, the island of Santo Antão, Cape Verde (Odonata). *International Journal of Odonatology* **13**: 241-254, pl. IV.

Martens, A. & Hazevoet, C.J. 2010. Dragonflies (Insecta, Odonata) of São Vicente, Cape Verde Islands: 10 species on a desert island. *Zoologia Caboverdiana* **1**: 112-115.

Martin, R. 1908. Voyage de feu Leonardo Fea dans l'Afrique Occidentale. Odonates. Annali del Museo Civico di Storia Naturale di Genova (Ser. 3) **3**: 649-667.

McLachlan, R. 1882. The Neuroptera of Madeira and the Canary Islands. *Journal of the Linnean Society*, *Zoology* **16**: 149-183.

Navás, L. 1906. Catálogo descriptivo de los Insectos Neurópteros de las Islas Canarias. *Revista de la Real Academia de Ciencias Exactas*, *Físicas y Naturales de Madrid* **4**: 687-706, 1 pl.

Navás, L. 1933. Voyage de MM. L. Chopard et A. Méquignon aux Açores (Août-Septembre 1930). III Névroptères et Pseudo-Névroptères. *Annales de la Société Entomologique de France* **102**: 19-20.

Pelny, H.-J. 2006. Erster Nachweis von Anax parthenope auf dem Madeira-Archipel (Odonata: Aeshnidae). *Libellula* **25**: 27-30.

Peters, G. 1988. Libellen (Odonata) von den Kanarischen Inseln. *Entomologische Nachrichten und Berichte* **32**: 39-40.

Rambur, M.P. 1842. *Histoire naturelle des insectes*. Névroptères. Roret, Paris. xvii + 534 pp.

Sampaio, A. da Silva, 1904. *Memória sobre a Ilha Terceira*. Imprensa Municipal, Angra do Heroísmo. 876 pp.

Selys Longchamps, E. de, 1876. Synopsis des Agrionines. Suite de la 5me legion: Agrion. Bulletins de l'Academie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique (II) 41: 247-322, 496-539, 1233-1309.

Selys Longchamps, E. de, 1884. Révision des Diplax paléarctiques. *Annales de la Société Entomologique de Belgique* **28**: 29-45.

Selys Longchamps, E. de, 1887. Odonates de l'Asie Mineure et revision de ceux des autres parties de la faune dite Européenne. *Annales de la Société Entomologique de Belgique* **31**: 1-85.

Selys Longchamps, E. de & Hagen, H.A. 1850. Revue des Odonates ou Libellules d'Europe. *Mémoires de la Société Royale des Sciences de Liège* **6**: i-xxii, 1-408, pls 1-11.

Selys Longchamps, E. de & Hagen, H.A. 1858. Monographie des Gomphines. *Mémoires de la Société Royale des Sciences de Liège* **11**: 257-720 [Separatum published 1857].

Sherratt, T.N. & Beatty, C.D. 2005. Island of the clones. *Nature*, *London* **435**: 1039-1040.

Smit, J.T. 1998. *De Zoogeografie van de libellen en de zweefvliegen van Madeira (Odonata & Diptera; Syrphidae)*. Afstudeerscriptie [final study thesis], Hogeschool van Utrecht, vakgroep Biologie. 40 pp.

Valle, K.J. 1935. Iter entomologicum ad Insulas Canarienses anno 1931 a Richard Frey et Ragnar Storå factum. N:o 5. Die Odonaten der Kanarischen Inseln. *Societas Scientiarum Fennica*, *Commentationes Biologicae* **6** (5): 1-7.

Valle, K.J. 1940. Iter entomologicum et botanicum ad insulas Madeiram et Azores anno 1938 a Richard Frey, Ragnar Storå et Carl Cedercreutz factum. N:o 5. Odonaten von den Azoren und Madeira. *Societas Scientiarum Fennica*, *Commentationes*

Biologicae **8** (5): 1-7.
Valle, K.J. 1955. Zygopteren (Odonata) von den Kanarischen Inseln. *Annales Entomologici Fennici* **21**: 182.
Webb, P.B. & Berthelot, S. 1837-1840. *Histoire naturelle des Îles Canaries*. Tome deuxième. Deuxième partie: Zoologie. Entomologie (Animaux articulés). Béthune, Paris. 119 pp., 7+1 pls.

Web Sites

Clarke, T. & Crewe, M. 2003*. Limosa Holidays Trip Report: The Canary Islands, Fri 4th – Fri 11th July 2003.* http://ww.limosaholidays.co.uk/tripReportDetail.cfm?reportID=174
Hill, P. 2000. *Birdwatching Trip Reports: Fuerteventura, October 2000.* http://www.birdtours.co.uk/tripreports/canaries/fuerte3/fuerteventura.htm

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The damselflies and dragonflies of Holyrood Park, Edinburgh

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Summary

A set of pre-defined transects and scheduled surveys were used to carry out a survey of the Odonata of Holyrood Park in Edinburgh in the summer of 2010. Six species were recorded, with Emerald Damselfly *Lestes sponsa* as an addition and Common Hawker *Aeshna juncea* as a loss since the last survey during 2005. While still present in Holyrood Park, the distribution of Common Darter *Sympetrum striolatum* has greatly declined in the last five years. Dunsapie Loch showed significantly reduced Odonata activity, which may be part of a long-term decline and further study is required to understand the changes observed.

Introduction

The purpose of this paper is to provide an account of the status of Odonata within Holyrood Park, Edinburgh, during the summer of 2010. As such it provides information on the distribution and breeding behaviour of the species based on the methods described below, but with the addition of casual Odonata records acquired from Historic Scotland Ranger Service (HSRS) patrols.

The Historic Scotland Ranger Service (HSRS) survey of the Odonata of Holyrood Park (Checkley, 2005) recorded the presence of Azure Damselfly *Coenagrion puella*, Blue-tailed Damselfly *Ischnura elegans*, Common Blue Damselfly *Enallagma cyathigerum*, Common Darter *Sympetrum striolatum*, Common Hawker *Aeshna juncea* and Large Red Damselfly *Pyrrhosoma nymphula* within the Park boundary. Large Red Damselfly was a local biodiversity action plan priority species (EBAP, 2004) and its confirmed presence was of particular interest.

Prior to this date, the Scottish Wildlife Trust (SWT) invertebrate survey of Bawsinch and Duddingston Loch (Hawkswell & Sommerville, 2003) recorded the presence of Black Darter *Sympetrum danae*, while anecdotal evidence from the Bawsinch management committee suggested that Emerald Damselfly *Lestes sponsa* had been lost from the Bawsinch reserve by summer 2003.

The presence of Odonata is an indicator of good water and air quality at a site and, as such, forms part of any assessment of pond quality (Scottish Environment Protection Agency (SEPA), 2000). Since five years have passed since the last survey, the author, following discussions with Natalie Todman of HSRS, decided to carry out a distribution and breeding behaviour survey of the Odonata populations in 2010.

The aim of the present survey is thus to determine the distribution and breeding behaviour of Odonata within Holyrood Park during the summer season of 2010 and to establish a methodology for the park that can be used for future surveys. Occasional records from HSRS patrols are also noted.

Site Description

Holyrood Park, Edinburgh (Midlothian NT275730) is 263 hectares in extent and contains one natural (Duddingston Loch) and 20 artificial water bodies within its boundaries (Fig. 1). It is designated as a Scheduled Ancient Monument and as a Site of Special Scientific Interest (SSSI), and is managed on behalf of the Scottish Government by Historic Scotland (HS). An additional management agreement between HS and the SWT has allowed the development of the Bawsinch area as a wildlife reserve since 1972.

Plate 1. Hunter's Bog facing north. The open water body in the centre of Hunter's Bog is in the middle distance; St Margaret's Loch can just be seen some way behind it.

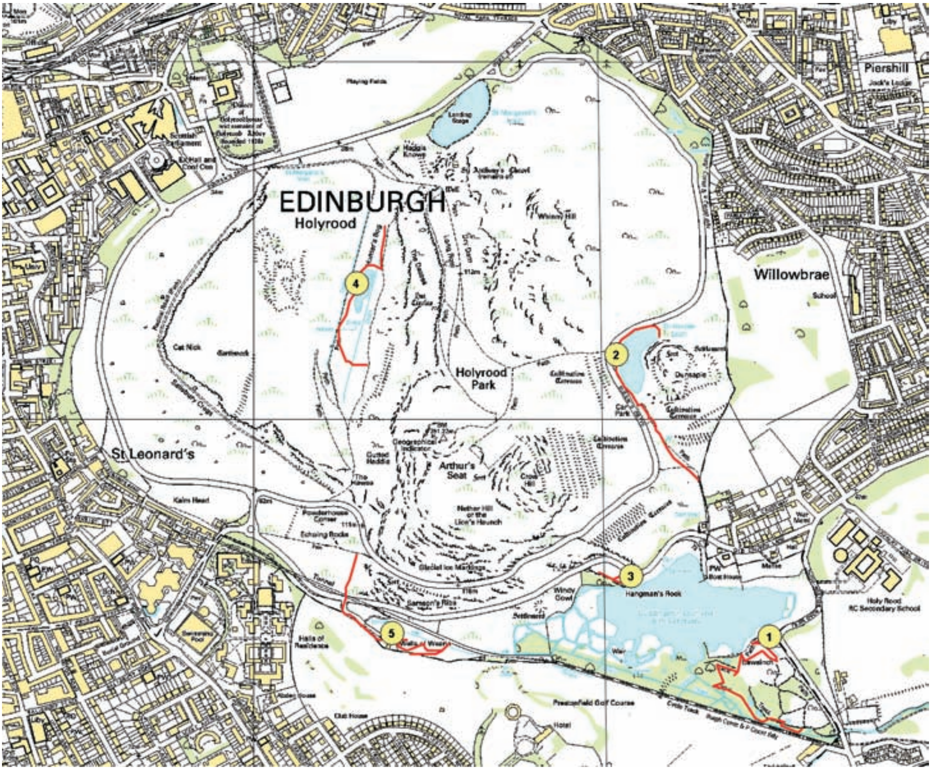

Figure 1. Holyrood Park, Edinburgh (Midlothian NT275730). 1 km grid; north faces up; (yellow circle), survey site number; (red line), survey route. Reproduced by permission of Ordnance Survey on behalf of HMSO.

Methods

The approach adopted was based on the 2005 survey methods (Checkley, 2005) but with the addition of pre-defined transect routes and survey frequencies. This method follows that of Sykes *et al*. (2001) in establishing year on year figures for Southern Damselfly *Coenagrion mercuriale* populations in Hampshire (Sykes, 2001).

Five sites (Bawsinch reserve, Dunsapie Loch, Hangman's Rock, Hunter's Bog and Wells o' Wearie) were surveyed (Fig. 1; Plate 1; Table 1). Time constraints did not allow St Margaret's Loch, the Glebe Meadow, the 4th Wells o' Wearie pond or the west end of Duddingston Loch north from the Innocent railway to Hangman's Rock (Murder Acre) to be surveyed in 2010.

Each of the five sites was visited on seven occasions at, as closely as possible, two-week intervals (Table 2). Due to early season low temperatures and windy conditions the first survey did not take place until 21 May 2010. The last survey took place on 30 August 2010. Surveys were carried out between 10.00 and 16.00 BST and in line with the weather condition parameters employed for the Butterfly Monitoring Scheme (BMS, 2005). Counts were only made under suitably warm and bright weather conditions, when wind speeds were light. The minimum BMS criteria are either 13-17ºC with at least 60% sunshine, or 18+ºC without rain (can be cloudy). These criteria were employed as they coincided with the peak activity of other flying invertebrates.

Table 1. Sites surveyed

Site name	Grid reference	Description
Bawsinch reserve	NT284722	13 artificial water bodies, with unshaded edges, in a mixture of broadleaved plantation and semi-natural woodland. Located on the south side of Duddingston Loch.
Dunsapie Loch	NT280731	Unshaded artificial loch with stone edges and a neutral grassland surround.
Hangman's Rock	NT280725	Unshaded south facing slope of neutral grassland on the north shore of Duddingston Loch.
Hunter's Bog	NT273733	Unshaded artificial water body with a marshy grassland edge.
Wells o' Wearie	NT274723	3 unshaded artificial water bodies with a mixture of tall ruderal and neutral grassland edges.

Table 2. Survey visit dates by survey cycle and survey site

Survey cycle	Hunter's Bog	Wells o' Wearie	Bawsinch	Hangman's Rock	Dunsapie Loch
1	21 May	27 May	21 May	27 May	27 May
2	3 June	10 June	3 June	14 June	10 June
3	12 July	12 July	8 July	12 July	12 July
4	20 July	23 July	23 July	23 July	23 July
5	29 July	29 July	3 Aug	29 July	29 July
6	12 Aug	12 Aug	19 Aug	12 Aug	13 Aug
7	25 Aug	25 Aug	30 Aug	25 Aug	25 Aug

Table 3. Counting method by survey site

Survey site	Counting method employed	Time allowed (hours)
Bawsinch reserve	Slow transect (circa 1-2mph) checking vegetation within 2 metres of the survey path, and a 10 minute static observation of each water body.	3.0
Dunsapie Loch	Slow transect (circa 1-2mph) checking vegetation within 2 metres of the survey path, with 10 minute static observations at the south end and north end of the Loch.	0.75
Hangman's Rock	Slow transect (circa 1-2mph) checking vegetation within 2 metres of the survey path.	0.5
Hunter's Bog	Slow transect (circa 1-2mph) checking vegetation within 2 metres of the survey path, and a 10 minute static observation from the west side of the open water body.	0.75
Wells o' Wearie	Slow transect (circa 1-2mph) checking vegetation within 2 metres of the survey path. 10 minute static observation of each pond. West Pond observed from pier, mid pond observed from west end, east pond observed from mid point on south side.	1.25

A transect was defined for each site (Fig. 1; Table 3). In addition to the 10 minute observations at each water body, the vegetation for two metres on either side of the transect was examined to determine the presence of any Odonata away from actual or potential breeding sites. Swarovski EL binoculars (8.5 x 42) were used to aid identification. Transect Way Points were identified using Google satellite images, the points chosen coinciding with major features such as water bodies and points where paths changed direction. An Etrex summit GPS unit was employed wherever surrounding vegetation obscured satellite image features. Google latitude and longitude readings were converted to six-figure grid references using the algorithm employed by Veness (2005). Conversions and GPS readings were calibrated against known reference points on the HSRS 1:2500 map of Holyrood Park.

On each visit to each site the following details were recorded: date, time, field observer and weather conditions (percentage of cloud cover, estimated temperature (from BBC weather forecast) and estimated wind speed based on the Beaufort scale).

Survey data

At each site, a count was made of each species, with separate counts made for pairs in the wheel formation and oviposition. When no Odonata were seen, other invertebrate activity was noted as an indicator of weather conditions. Detailed location names, where required, and associated six-figure grid references were determined from the Transect Map and the appropriate Way Point list. Where a species could not be identified positively it was recorded as an unidentified damselfly or dragonfly. When necessary, species identification was confirmed using Brooks & Lewington (2004).

Data analysis was facilitated by mapping the survey records on to a 1:10,000 Ordnance Survey map of Holyrood Park. Record data were mapped using the Ordnance Survey coordinate system supplied as part of the HS implementation of the ESRI Arcmap application (version 9.2). Maps were produced as Windows bitmap files by using the ESRI Map Explorer application (version 2.0, Service Pack 1).

Detailed survey records are held by the author, HSRS, the British Dragonfly Society (BDS) Scottish Recorder and the SWT. Records, summarised at an effective 1 kilometre square resolution, have also been input by the author to the BDS online recording system.

Survey Observations

Six species of odonate were recorded in Holyrood Park in summer 2010 (Table 4). Azure Damselfly, Blue-tailed Damselfly, Common Blue Damselfly, Common Darter, Emerald Damselfly, and Large Red Damselfly were noted, with Common Blue being by far the most abundant and Azure Damselfly being the least. Breeding behaviour was noted during the survey for all but Azure Damselfly. No species was recorded at all five sites (Table 4). The most productive site in terms of abundance of Odonata was Bawsinch, from where almost 72% of the total number of identified species records (227 out of 316) was obtained during scheduled surveys (Table 4). This site also had the highest peak count for four species: Azure Damselfly (only two individuals), Blue-tailed Damselfly, Common Blue Damselfly and Large Red Damselfly (Table 5). The highest counts for Common Darter and Emerald Damselfly were made at the Wells o' Wearie, with a single Common Darter seen in Bawsinch. Emerald Damselfly was also present in Hunter's Bog.

Table 4. Survey total counts by species and site

Species	Hunter's Bog	Wells o' Wearie	Bawsinch	Hangman's Rock	Dunsapie Loch	Total
Azure Damselfly	0	0	2	0	0	**2**
Blue-tailed Damselfly	3	25	50	1	0	**79**
Common Blue Damselfly	9	11	142	14	1	**177**
Common Darter	0	8	1	0	0	**9**
Emerald Damselfly	8	9	0	0	0	**17**
Large Red Damselfly	0	0	32	0	0	**32**
Unidentified damselfly	3	13	55	6	2	**79**
Total	**23**	**66**	**282**	**21**	**3**	**395**

Table 5. Survey peak counts by species and site

Species	Hunter's Bog	Wells o' Wearie	Bawsinch	Hangman's Rock	Dunsapie Loch
Azure Damselfly	0	0	2	0	0
Blue-tailed Damselfly	1	15	35	1	0
Common Blue Damselfly	2	5	94	6	1
Common Darter	0	5	1	0	0
Emerald Damselfly	3	6	0	0	0
Large Red Damselfly	0	0	18	0	0
Unidentified damselfly	1	6	37	4	2

Table 6. Range of flying periods by species noted during survey

Species	Flying period
Azure Damselfly	8 July 2010 only date recorded
Blue-tailed Damselfly	21 May 2010 to 12 August 2010
Common Blue Damselfly	21 May 2010 to 12 August 2010
Common Darter	03 August 2010 to 25 August 2010
Emerald Damselfly	20 July 2010 to 25 August 2010
Large Red Damselfly	21 May 2010 to 08 July 2010

Table 7. Survey breeding behaviour summarised by site

Species	Hunter's Bog	Wells o' Wearie	Bawsinch	Hangman's Rock	Dunsapie Loch	Total sites
Azure Damselfly	-	-	-	-	-	0
Blue-tailed Damselfly	-	Yes	Yes	-	-	2
Common Blue Damselfly	-	-	Yes	Yes	-	2
Common Darter	-	Yes	-	-	-	1
Emerald Damselfly	-	Yes	-	-	-	1
Large Red Damselfly	-	-	Yes	-	-	1
Unidentified Damselfly	-	-	Yes	-	-	1

Three species were present on 21 May 2010 in Bawsinch: Blue-tailed Damselfly, Common Blue Damselfly and Large Red Damselfly. No Odonata activity was noted on that day in Hunter's Bog, and the other three sites were not visited until 27 May 2010. Only two species, Common Darter and Emerald Damselfly, were recorded in the latter half of August (Table 6). Peak activity occurred between 3 – 14 June, which accounted for over half of all the records (214 out of 395) (Fig. 2).

All species except the Azure Damselfly exhibited breeding behaviour. However, breeding behaviour was only observed at three sites: Wells o' Wearie, Bawsinch and Hangman's Rock (Table 7). Breeding behaviour was most widely distributed for the Common Blue Damselfly (Fig. 3).

Discussion

The 2005 survey (Checkley, 2005) did not record the presence of Emerald Damselfly in Hunter's Bog and the Wells o' Wearie, although it was seen in both locations in 2006 (BDS records 2003-2008 - Prentice, pers. com.), and breeding behaviour was noted in Hunter's Bog during 2009 (HSRS, Wildlife Log

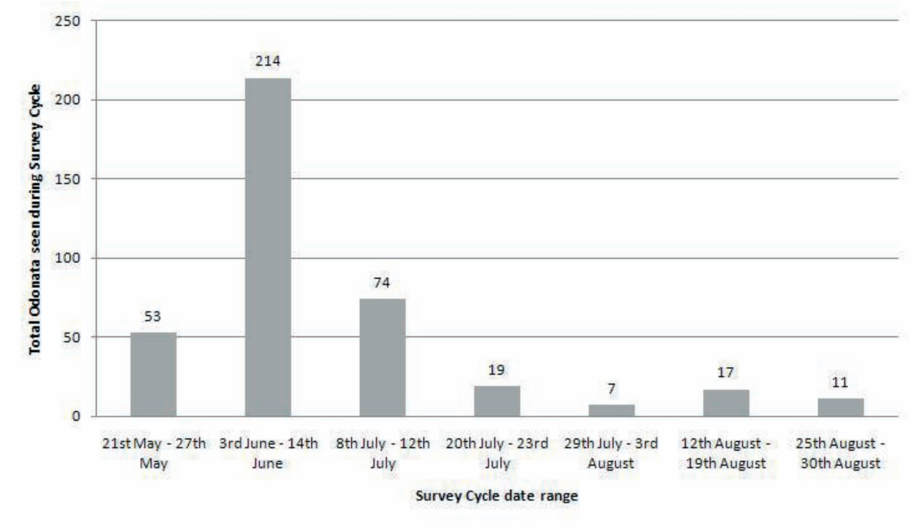

Figure 2. The total number of odonates observed during each survey period in 2010.

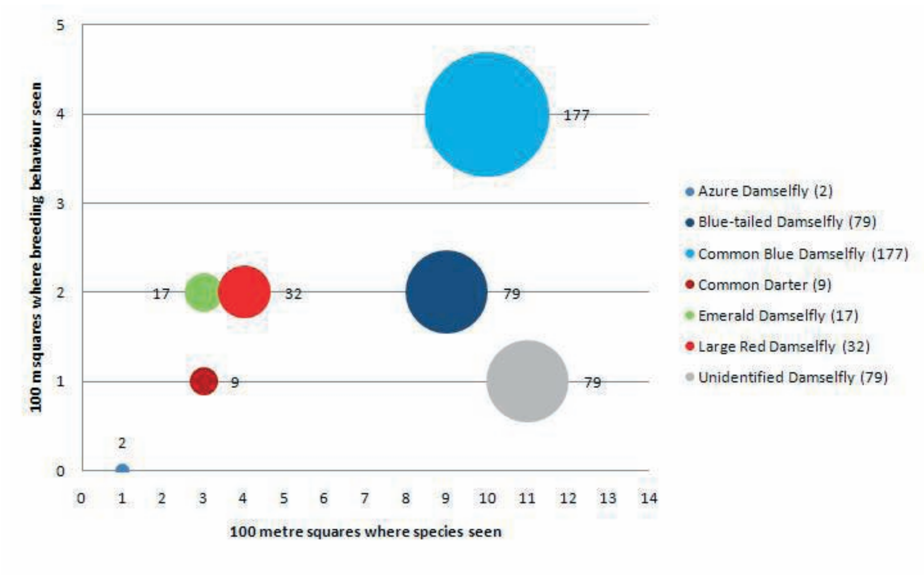

Figure 3. The number of individual species observed in terms of breeding behaviour and occupancy. Breeding activity refers to pairs in the wheel formation as well as oviposition. The numbers indicate species totals; this is also reflected in the size of the dots.

2000 to 2010. unpub.). The continued presence of this species at these two sites is promising, especially the breeding behaviour noted at Wells o' Wearie in the current survey. The distribution of the Common Darter across the sites surveyed has declined since 2005. During that year it was noted in Hunter's Bog, Bawsinch and the Wells o' Wearie, with breeding activity seen in the last two localities. It was last seen in Hunter's Bog in 2008 (BDS, 2010); in Bawsinch in 2010 only a single individual was noted, with no evidence of breeding. The Common Hawker was not recorded during the 2010 survey and there have been no HSRS or BDS records in Holyrood for this species since 2005. The reasons for its disappearance remain unknown.

Dunsapie Loch had no evidence of any Odonata breeding during 2010. The only Damselfly identified in the immediate vicinity was a single Common Blue in the marshy ground south of the loch on 10 June 2010. During the 2005 survey Azure Damselfly was present and a breeding population of Common Blue Damselfly was noted (Checkley, 2005). Furthermore, Saville & Sommerville (1991) noted "50 Common Blue Damselfly at Dunsapie Loch". This loch was mentioned as "a representative example of the freshwater aquatic plant communities in the City of Edinburgh District" in the Arthur's Seat Volcano SSSI citation (Scottish Natural Heritage, 1986) and the cause of this apparent decline is of conservation concern.

SEPA should be invited to check the water quality of Dunsapie Loch and it would be useful to investigate the ecological preferences of the species. A follow-up survey using the same methodology should be conducted in 2015.

Discussion of 2010 casual records

A tandem pair of Azure Damselfly was noted during a 'non-survey' visit to Bawsinch on 10 June 2010. This indicates breeding behaviour for this species in Bawsinch in 2010 but, as it is a casual record, it has not been included in the survey results. A casual record of a single Emerald Damselfly in Hunter's Bog on 17 September 2010 extended the known flight period for this species at this location beyond that recorded during the survey but again, as it is a casual record, it has been excluded from the survey results.

St Margaret's Loch remains unpopulated by Odonata. The explanation for this is likely to be the lack of emergent vegetation and the periodic heavy algal blooms during the summer period.

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References

Brooks, S. & Lewington, R. 2004. *Field Guide to the Dragonflies and Damselflies of Great Britain and Ireland*, revised edition. British Wildlife Publishing, Hook, Hampshire. 160 pp.

Checkley, G. 2005. *Holyrood and Duddingston/Bawsinch Damselflies and Dragonflies 2005*. Historic Scotland Ranger Service, Edinburgh. 11 pp.

Edinburgh Biodiversity Action Plan. 2009. *Edinburgh Biodiversity Action Plan 2004 - 2009*. City of Edinburgh Council, Edinburgh. 99 pp.

Hawkswell, S. & Sommerville, A. 2003. *Invertebrate survey of Bawsinch and Duddingston Loch*. Scottish Wildlife Trust, Edinburgh. 100 pp.

Saville, R.E. & Sommerville, A. 1991. *Invertebrate study of Holyrood Park.* Scottish Wildlife Trust, Edinburgh. 34 pp.

Scottish Natural Heritage. 1986. *Arthur's Seat Volcano SSSI Citation*. Scottish Natural Heritage, Edinburgh. 2 pp.

Web Sites

Butterfly Monitoring Scheme. 2005.http://www.ukbms.org/methods.htm (accessed 30 January 2011).

Scottish Environment Protection Agency. 2000. *Ponds, pools and lochans: Guidance on good practice in the management and creation of small waterbodies in Scotland*. http://search.sepa.org.uk/sepa?action=search&q=lochans June 2000 (accessed 1 November 2010).

Sykes, T. 2001. Hampshire Biodiversity Partnership: Southern Damselfly. www.dragonflysoc.org.uk/dosc/SD.doc (accessed 30 January 2011).

Veness, C. 2005. Movable Type Scripts: Convert between Latitude/Longitude & OS National Grid Reference points. http://www.movable-type.co.uk/scripts/latlong-gridref.html (accessed 2 November 2010).

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Tracking the elusive life of the Emperor Dragonfly *Anax imperator* Leach

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Summary

Whilst the behaviour of adult dragonflies is well known over open water, their behaviour away from water bodies remains relatively unknown. It has been difficult to follow individuals that are either moving more quickly through vegetation than researchers can, or hiding in vegetation. This article describes how radio-tracking was used to collect objective information on local movements of individual dragonflies. The results are discussed.

Introduction

When defending a territory, animals advertise their presence, e.g. by singing in the case of birds, scent marking or howling in the case of some mammals or just being highly visible with their patrolling behaviour, as in dragonflies. Many studies use this easily observed behaviour to build a picture of a species' character and ecological role, because it is often difficult to find animals when they are not being territorial. However, modern tracking techniques which allow researchers to find an animal when they want to, rather than just when the animal is visible, have taught us more about their overall ecology. For example, when chaffinches *Fringilla coelebs* were radio-tracked it was discovered that they used an area 4-8 times larger than their singing territory (Hanksi & Haila, 1988). Knowing the total home range, i.e. "the area traversed by the individual in its normal activities of food gathering, mating and caring for young" (Burt, 1943) and the behaviour when away from the defended territory, provide valuable information when it comes to managing habitat and assessing its impact on different species.

Dragonflies exhibit territorial behaviour similar to that of birds (Corbet, 1957). As in Hanski & Haila's study (Hanksi & Haila, 1988), territories of male dragonflies can be defined by observation (Moore, 1957) but little is known about the movement of these insects away from their territories. Mark-release-recapture can give some insight into small range movements and this has been successfully used in various odonate species (Rouquette & Thompson, 2007; Watts *et al*., 2007; Ward & Mill, 2007; Chin & Taylor, 2009). However, the data from this method can only be collected when they are visible.

Studies on home range show us the total area used by an individual. The movement patterns within the area can further inform us of the dragonfly's activities, such as where the dragonfly forages, where it roosts, whether the same roost is used every night and if other local territories are visited. These are important considerations for conservation, indicating the resources that species need and any potential influences on survival, e.g. if a dragonfly species only forages or roosts in a particular habitat, alteration or destruction of that habitat will affect its survival. Radio-tracking allows animals to be found when they are not so visible, e.g. many animals hide when sleeping, or spend time in thick vegetation to avoid predators. Therefore, a more complete assessment of all their needs can be constructed.

The smallest radio-tags have become progressively smaller over the last 30 years, allowing them to be used to study insects such as crickets (Sword *et al*., 2008), beetles (Negro *et al*., 2008), bees (Wikelski *et al*., 2010) and dragonflies, as in the study of the migratory movements of a North American dragonfly, *Anax junius,* by Wikelski *et al*. (2006). Therefore, we decided to test the potential for using radio-tracking to investigate dragonfly behaviour for an active but generally non-migratory species.

The Emperor Dragonfly *Anax imperator* was considered to be a good species for radio-tracking. *Anax imperator* is one of the largest British dragonflies, so is most likely to be able to tolerate a radio-tag. It is widespread in Southern Britain (Brooks & Lewington, 2004); therefore the study does not endanger this species and, although its territorial behaviour and larval stages are well studied (Corbet, 1957), little is known about its behaviour away from water.

Methods

Five male *Anax imperator* were caught at a small natural pond on Stoborough Heath, Dorset, UK, between 19 July and 9 August 2010, using a large, black mesh insect net. We were unable to age the dragonflies but wing condition varied, suggesting different ages. The radio-tags (PicoPip Ag337 from Biotrack Ltd, U.K.) weighed 0.29g and had an expected battery life of 10 days, which are virtually identical parameters to those of Wikelski *et al*. (2006). To attach the tag, one person held the dragonfly by the wings whilst a second person glued the transmitter to the underside of the thorax (Plate 1), as described by Wikelski *et al*. (2006). Tags were attached using a combination of eyelash adhesive (unbranded, from a local supplier) and superglue (Blackspur superglue) with a fine chalk dusting to accelerate drying. With practice, tagging time took less than 10 minutes. When released, four out of the five dragonflies flew away in less than one minute and the other flew off after 15 minutes.

Dragonflies were manually tracked on foot or by vehicle using a Sika receiver and Yagi antenna (Plate 2). Each dragonfly was located between one and eight times per day, for up to 10 days. When found, the dragonfly's location was recorded to within 10 m, together with its behaviour (e.g. roosting, flying,

Plate 1. Attaching a transmitter (radio tag) to a male A. imperator

Plate 2. Radio-tracking in the field.

fighting) and the weather conditions (temperature, sunny/cloudy, wind direction and speed).

We deployed a datalogging receiver (DataSika) and omni-directional antenna (both from Biotrack Ltd, U.K.) to record presence/absence of our tagged dragonflies at the pond where they were caught and tagged. Plotting signal strength against time allowed us to determine when the dragonfly was active. We also set up a 'LightBug' light-based geolocator (Biotrack Ltd, U.K.) to detect and record light levels and temperature throughout the study. The LightBug was placed in direct sunlight to mimic the temperatures that the dragonfly could experience when basking. These data were compared to the data from the DataSika to indicate the effect of weather variables on behaviour.

Home ranges, distances travelled and movement patterns were analysed using Ranges software (Anatrack Ltd, U.K.). Incremental area analysis was used to assess whether we had collected a sufficient number of locations to describe the home range by plotting the area of the range against the number of locations. Initially, the range size increases quickly but, when the animal has visited all the places it normally uses, 'sampling saturation' is reached and the range no longer continues to increase. However, if the animal is constantly visiting new areas the home range size will continue to increase.

The home range estimate used was Minimum Convex Polygon (MCP), which is a simple and widely used technique (Harris, *et al*. 1990). Whilst there are other more sophisticated home range estimates, they either make assumptions that could not be validated (e.g. contours) or need large numbers of locations that we did not have (Kenward, 2001).

Results

The five tagged adult males were each radio-tracked for between one and 10 days (median of four days), obtaining an average of 17.8 locations per dragonfly (Table 1). Only two were tracked for the full 10 days. Tracking for longer than this was limited by the battery life of these very small transmitters. On one dragonfly, the transmitter failed after four days; another individual was tracked for three days but then we found the tag on the ground, after a period of prolonged rain. The signal was lost from the fifth dragonfly after only one day of tracking, despite intensive searching (Table 1). When dragonflies were flying, they could be detected at 500 m over flat terrain and for one a signal was heard from a distance of 1500 m when the trackers were on a high hill. However, when the dragonfly was in low vegetation, the maximum range was more usually 200 m. Individual dragonflies still exhibited territorial behaviour, dispersal and

Table 1. Summary of radio-tracking data collected for the five individual *A. imperator* and their estimated home ranges.

Dragonfly	Days tracked	Locations collected	Home range size (ha)
1	10	29	83.6
2	10	33	4.3
3	4	16	13.9
4	1	3	4.2
5	3	8	0.2
Average	**5.6**	**17.8**	**21.2**

aggression with the transmitters attached.

Movement and home ranges

Figure 1A shows the contrasting movement patterns and ranges used by the two dragonflies tracked for 10 days each. Dragonfly 1 first moved to the southeast before dispersing west, away from the pond where it was caught. This dragonfly travelled a total distance of 5,016 m, according to our tracking locations, with its final recorded location at a quarry lake 1,448 m from the initial pond. Dragonfly 2 commuted between its daily territory at a pond and various roosting sites in the surrounding heathland. The maximum distance recorded from the pond where it was caught was only 344 m and the total distance travelled was also much less than dragonfly 1, i.e. only 2,640 m. Both of these distances will be underestimates as the dragonflies were not tracked continuously.

The MCP range was a useful statistic to summarise this contrasting behaviour. The range of dragonfly 1 was 83.6 Ha, which is about 20 times larger than that of dragonfly 2 (4.3 Ha) (Table 1, Fig. 1B). However, incremental area analysis (Fig. 1C) showed that these ranges could not be considered ‘home ranges’ because the areas were still increasing at the end of tracking for both dragonflies.

Automated activity logging

The datalogger only detected dragonflies when they were close to the pond where they were caught, i.e. within the detection range of the receiver. Figure 2 shows the signal strength data collected for the maximum continuous period (four days) for Dragonfly 2. Plotting signal strength against time indicates the

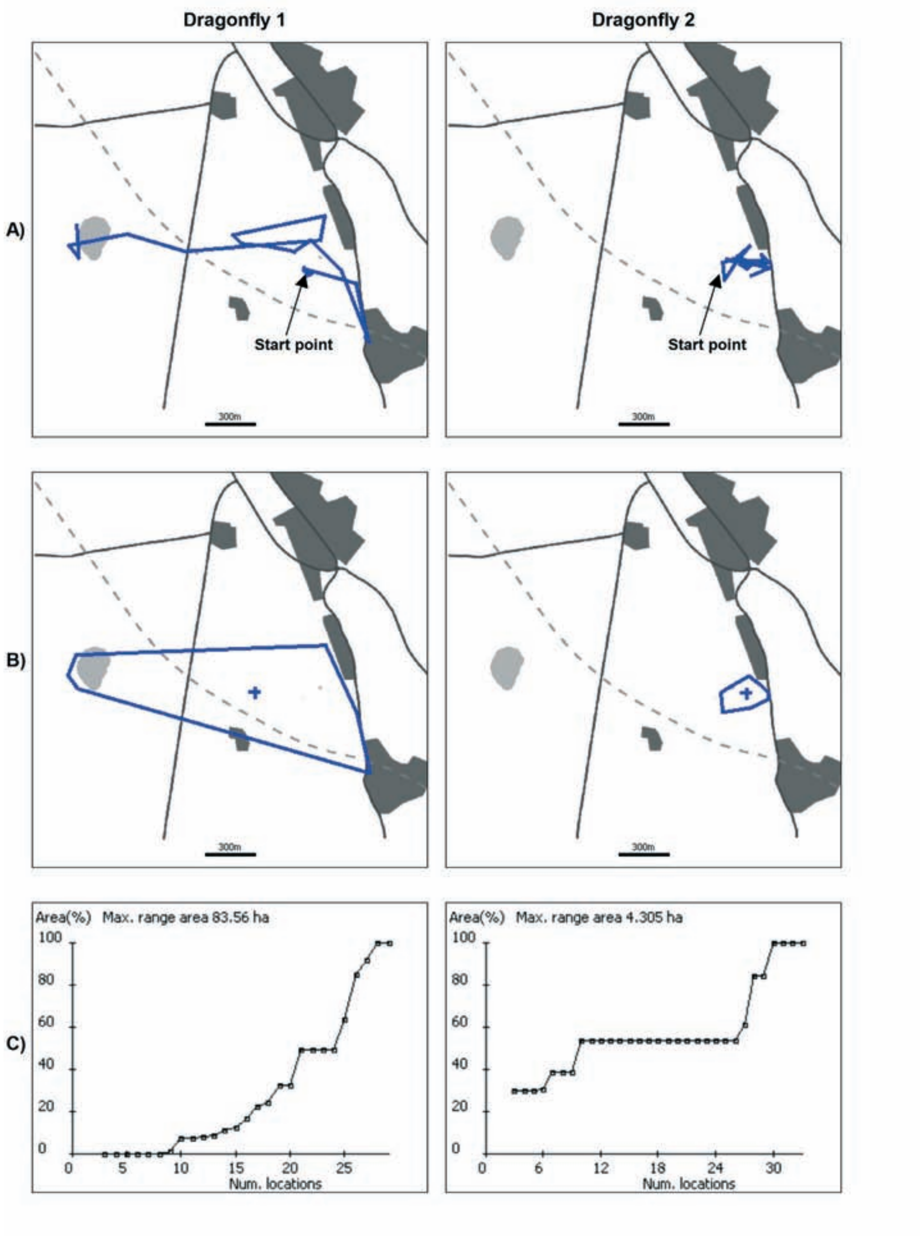

Figure 1. Dragonflies 1 and 2: (A) Movement paths (blue lines), (B) Minimum convex polygon ranges (blue shapes) and (C) Incremental area analysis. In A and B: — roads; - - - railways; ▮ ponds; ▮ urban areas.

activity. The large blocks of points with little variation during the nights of 24-25, 25-26 and 26-27 July 2010 indicate periods of inactivity at or near the pond, whereas patches of high variation in signal strength (e.g. 12.00 – 18.00 on 26 July 2010) indicate periods of activity. Where there are no points then the dragonfly was out of detection range. Thus, during the night of 23-24 July 2010 the dragonfly was not in the vicinity of the pond. Also, late on 24 July 2010, after a period of rest, the dragonfly left the pond in the evening.

Figure 3 shows six hours of signal strength plotted in conjunction with the logged light and temperature data for Dragonfly 2. The flatter sections of the signal strength graph indicate periods of inactivity. It can be seen that these periods of inactivity tended to occur after drops in temperature. However, when the temperature remained low for a period of about two hours after 14.00, the dragonfly became active again between 14.30 and 15.00. Also there was little activity after about 17.00, even though the temperature generally remained high and light levels had also not decreased overall. However, so far there are insufficient data to analyse for correlations. Temperature recorded by the stationary logger in direct sunlight reached over 50°C (at 13.45; Fig. 3). However, it was measuring the amount of possible insolation to which a dragonfly would be exposed at that point, not the shade temperature.

Discussion

In this study *Anax imperator*, although carrying a transmitter, could still defend a territory successfully, as described by Corbet (1957), and could move long distances. The dragonflies could also be located successfully and were often seen, indicating that radio-tracking is a suitable method for short range tracking of dragonflies, as well as for long range tracking (as shown by Wikelski *et al.* 2006). Greater detection distance would be an advantage for any dragonflies that move quickly over long distances; nevertheless the technique proved adequate most of the time in this study. The aim was to keep the tag on the dragonfly for as long as the battery lasted, but this can be difficult when dealing with such small animals and devices, and it is very important to minimise any effect on behaviour. Thus tags sometimes fell off early but that was better than adversely affecting the dragonflies. It would have been useful to be able to track individuals for longer than 10 days but this period is close to the current technological limit. The greatest distance travelled by any individual was just over 5 km over a period of 10 days, which is the same order of magnitude as recorded by Wikelski *et al*. (2006) for *Anax junius* on days when they were not migrating. During migration, *A. junius* sometimes travelled in excess of 100 km in a day (Wikelski *et al*., 2006).

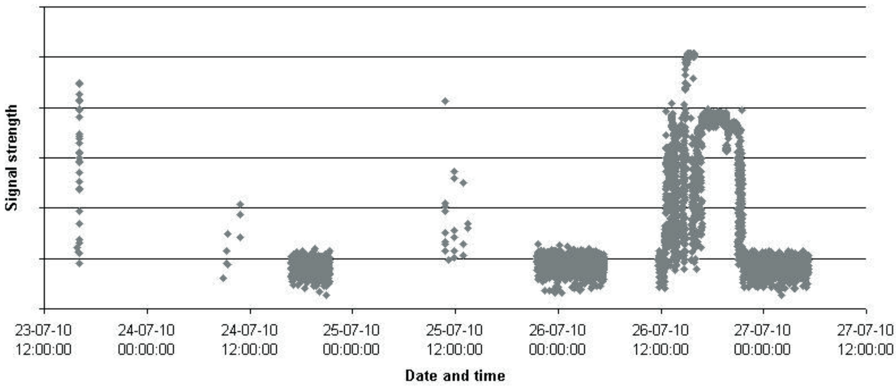

Figure 2. Signal strength during four 24-hour periods collected from the DataSika for Dragonfly 2. Signal strength measured in arbitrary units.

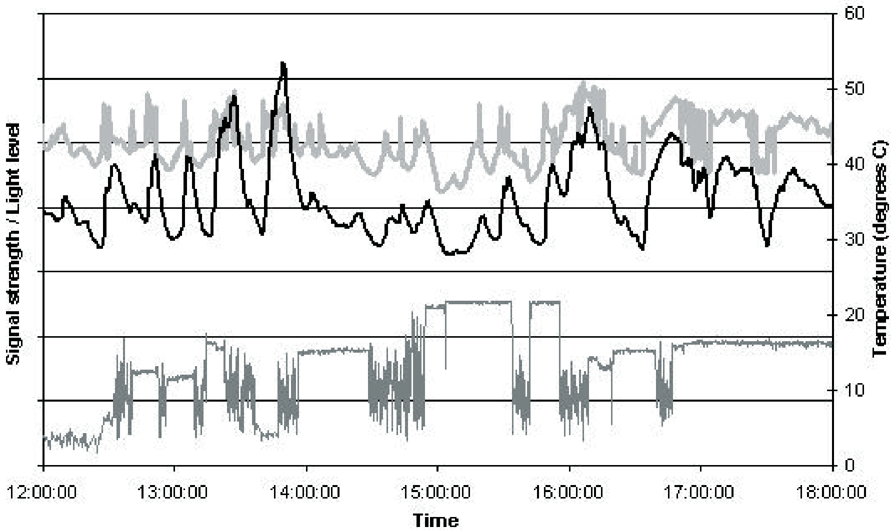

Figure 3. Signal strength (bottom) from the DataSika datalogging receiver, temperature (middle) and light level (top) from a LightBug geolocator for Dragonfly 2 during a six-hour period. Signal strength and light level are measured in arbitrary units.

Although the limit of 10 days prevented us from ascertaining a complete home range, the results were revealing. It was possible to find dragonflies away from their pond territories (e.g. when roosting) and there were differences in their movement behaviour. With such a small sample size, it is impossible to say whether such variation is individual, or different stages in the life cycle that apply to all male *A. imperator*. However, the question is intriguing and future work will need to track more individuals to investigate the extent of the variability and factors that may affect it. Perhaps collecting location points more frequently could achieve a better understanding of the home range within 10 days but the data from Dragonfly 1, which seemed to be constantly moving further away all the time, suggests that this is unlikely. Therefore, these are samples of the dragonfly's ranging behaviour – not a complete home range. Nevertheless, ranges can be compared between individuals if similar numbers of locations are collected over the same number of days. Moreover, such data would allow us to estimate time spent in different habitats that would be impossible to achieve so objectively using other methods.

The results from our datalogging show great promise as a method for recording activity levels at a particular site and relating them to environmental changes. The data can be easily collected to give us insights into the dragonfly's activity patterns that would otherwise require long periods of observation. Having recorded such high temperatures in direct sunlight, future studies should also record shade temperature to see which measurement provides the better correlation with activity patterns. With more data from multiple individuals we could look for broader patterns of activity in relation to the time of day. More than one dragonfly can be logged using this equipment so we could also look at interactions and visits from other tagged males and hopefully tagged females too. Knowing how dragonflies respond to light and temperature could help us understand the effects of global warming on them. As transmitters continue to decrease in size and weight these methods will be able to be used with smaller species.

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References

Burt, W.H. 1943. Territoriality and Home Range Concepts as Applied to Mammals, *Journal of Mammalogy* **24:** 346-352.

Brooks, S. & Lewington, R. 2004. *Field Guide to the Dragonflies and Damselflies of*

Great Britain and Ireland. British Wildlife Publishing, Hook, Hampshire, 160pp.

Chin, K.S. & Taylor, P.D. 2009. Interactive effects of distance and matrix on the movements of a peatland dragonfly. *Ecography* **32:** 715-722.

Corbet, P. S. 1957. The Life-History of the Emperor Dragonfly *Anax imperator* Leach (Odonata: Aeshnidae). *Journal of Animal Ecology* **26:** 1-69.

Hanski, I.K. & Haila, Y. 1988. Singing territories and home ranges of breeding Chaffinches: visual observations vs. radio-tracking. *Ornis Fennica* **65:** 97-103.

Harris, S., Cresswell, W.J., Forde, P.G., Trewhella, W.J., Woollard, T. & Wray .S. 1990. Home-range analysis using radio-tracking data – a review of problems and techniques particularly as applied to the study of mammals. *Mammal Review* **20:** 97-123.

Kenward, R.E. 2001. *A Manual for Wildlife Radio Tracking.* Academic Press, London, UK, 311pp.

Moore, N.W. 1957. Territory in dragonflies and birds. *Bird Study* **4:** 125-130.

Negro, M., Casale, A., Migliore, L., Palestrini, C. & Rolando, A. 2008. Habitat use and movement patterns in the endangered ground beetle species, *Carabus olympiae* (Coleoptera: Carabidae). *European Journal of Entomology* **105:** 105-112.

Rouquette, J.R. & Thompson, D.J. 2007. Patterns of movement and dispersal in an endangered damselfly and the consequences for its management. *Journal of Applied Ecology* **44:** 692-701.

Shreeves, T.G. 1984. Habitat selection, mate location, and microclimatic constraints on the activity of the speckled wood butterfly *Pararge aegerial. Oikos* **42:** 371-377.

Sword, G. A., Lorch, P. D. & Gwynne, D.T. 2008. Radiotelemetric Analysis of the Effects of Prevailing Wind Direction on Mormon Cricket Migratory Band Movement. *Environmental Entomology* **37:** 889–896.

Ward, L & Mill, P. 2007. Long range movements by individuals as a vehicle for range expansion in *Calopteryx splendens* (Odonata: Zygoptera). *European Journal of Entomology* **104:** 195–198.

Watts, P.C., Saccheri, I.J., Kemp, S.J. & Thompson, D.J. 2007. Effective population sizes and migration rates in fragmented populations of an endangered insect (*Coenagrion mercuriale:* Odonata). *Journal of Animal Ecology* **76:** 790–800.

Wikelski, M., Moskowitz, D., Adelman, J.S., Cochran, J., Wilcove, D.S. & May, M.L. 2006. Simple rules guide dragonfly migration. *Biology Letters* **2:** 325-329.

Web Site

Wikelski, M., Moxley, J., Eaton-Mordas, A., López-Uribe, M.M., Holland, R., Moskowitz, D., Roubik, D.W & Kays, R. 2010. Large-Range Movements of Neotropical Orchid Bees Observed via Radio Telemetry. http://www.nysm.nysed.gov/staffpubs/docs/20163.pdf

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