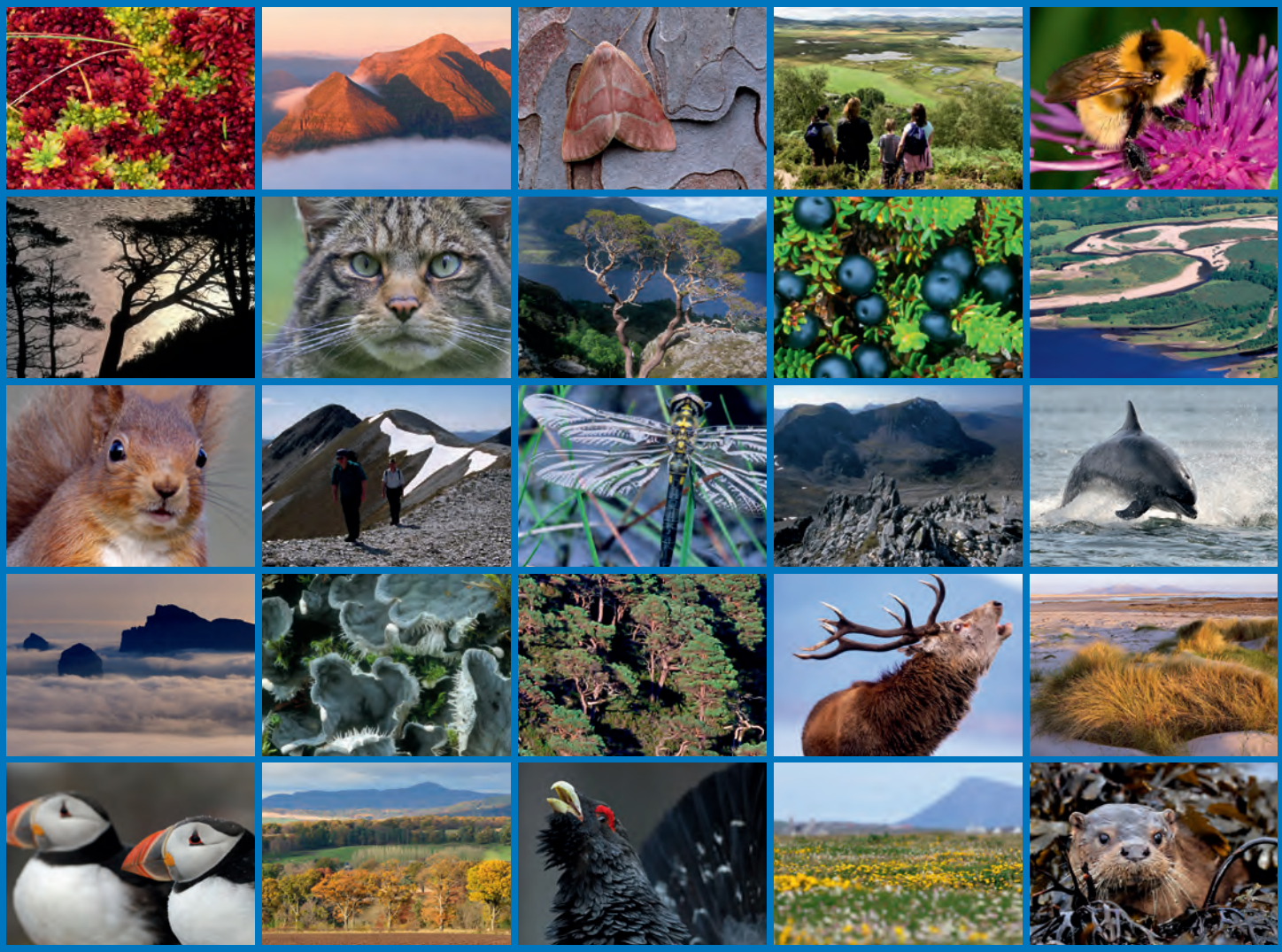
Scottish Natural Heritage
Commissioned Report No. 785

The Scottish Beaver Trial: Odonata monitoring 2009-2014, final report



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The Scottish Beaver Trial: Odonata monitoring 2009-2014, final report

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COMMISSIONED REPORT

Summary

The Scottish Beaver Trial: Odonata monitoring 2009-2014, final report

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Keywords

Scottish Beaver Trial; odonata; hairy dragonfly; *brachytron pratense*; beautiful demoiselle; *calopteryx virgo*; monitoring.

Background

As part of the licence conditions for the beaver reintroduction trial, there is a requirement to monitor populations of two species of Odonata, the hairy dragonfly *Brachytron pratense* and the beautiful demoiselle *Calopteryx virgo.* This was to be carried out within the beaver trial site over a 5-year period, commencing in May 2009, in order to detect possible changes as a consequence of beaver activity. Although the SSSI is of key importance, especially for *B. pratense*, sites in the trial area outside the SSSI were to be included in the programme. Knapdale lochs and their main river systems in the trial area were surveyed in 2009, 2010, 2012 and 2014. This report describes the results of 2014 fieldwork, a summary of the 2009-2014 trial results and an assessment of the possible effects of beavers on Odonata.

Main findings

- For *B. pratense*, 11 water bodies were surveyed by transects, of which seven were within the Knapdale Woods SSSI. Beavers had used eight lochs by 2014.

- There was evidence that *B. pratense* breeds in six of the eight lochs used by beavers. It is likely to breed in the other two lochs as well, where larvae were found in 2013.

- A substantial decline of *Cladium mariscus* and *Schoenoplectus lacustris* has been reported elsewhere as a result of beaver activity. These plants create and trap floating detritus for *B. pratense,* but there has been no detectable effect on dragonfly populations to date. However some areas no longer provide suitable breeding habitat for *B. pratense* and there was a small reduction in numbers in lochs with high beaver usage that do not have heather banks to trap detritus.

- The Dubh Loch suffered substantial change in size and habitat due to dam building. All *B. pratense* exuviae were found amongst the remaining *C. mariscus* in the inundated area, none at the new edge. There are some indications that the population of *B. pratense* may be falling at this site, but it is difficult to be conclusive because of surveying difficulties, small population size and data variability.

- The main changes in *C. virgo* numbers were likely to have been caused by factors such as weather, forest management and the shading of water courses by tree growth. *C. virgo* used the small clearings created by the felling of willow and birch in a limited area at the Loch Linne outflow.

- The trial period of five years has been too short to evaluate the full effects of beaver reintroduction on *B. pratense and C. virgo.* However, potential future effects of continued beaver presence in Knapdale and more widely in Scotland are presented based on evidence to date.

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This project is part of the independent monitoring programme for the Scottish Beaver Trial coordinated by SNH in collaboration with a number of independent monitoring partners. For further information go to:
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Acknowledgements

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1. INTRODUCTION

In May 2008, the Scottish Government approved a licence for a five-year trial reintroduction of the European beaver to Knapdale, Argyll. Beavers were released in the spring of 2009.

This 'Scottish Beaver Trial' was to include an assessment of the effect of beaver activities on the natural environment. The success of the trial will be judged against criteria that include positive contribution to ecosystem function and absence of significant or unsustainable damage to ecosystems.

The trial prescribed an independent monitoring program to consider the impact of beavers on two species of Odonata:

- The hairy dragonfly, *Brachytron pratense*
- The beautiful demoiselle, *Calopteryx virgo*

Knapdale is an exceptional part of Scotland for dragonflies and damselflies and Knapdale Woods SSSI supports an assemblage of 13 species. *B. pratense* is well represented in the SSSI but also breeds in nearby standing water bodies within the trial area. *C. virgo* does occur within the SSSI, but the main populations breed in adjoining burns. These species were chosen because their restricted distribution and habitat preferences make them more susceptible to beaver impact.

Monitoring of *B. pratense* and *C. virgo* populations for the purposes of the Scottish Beaver Trial started in May 2009. The aim was to detect possible changes in abundance as a consequence of beaver activity. Reference was also to be made to data collected previously for other purposes (e.g. Site Condition Monitoring). Although the SSSI is of key importance, especially for *B. pratense*, sites in the trial area outside the SSSI were included in the study.

The approach taken was based on that used by SNH for Site Condition Monitoring (SCM) of dragonfly features. It is recognised that quantifying population changes for Odonata is difficult because of sampling limitations and variability of factors such as weather, and so the aim of this work was to detect whether any substantial change is taking place.

Eleven lochs were surveyed in the beaver trial area, seven within the SSSI: Loch Barnluasgan, Dubh Loch, Loch Linne, Loch Fidhle, Creagmhor Loch, Un-named loch (North), Loch Coille-Bharr, Lochan Buic, Un-named loch (South), Ford Lochan and Loch Losgunn (Figure 1).

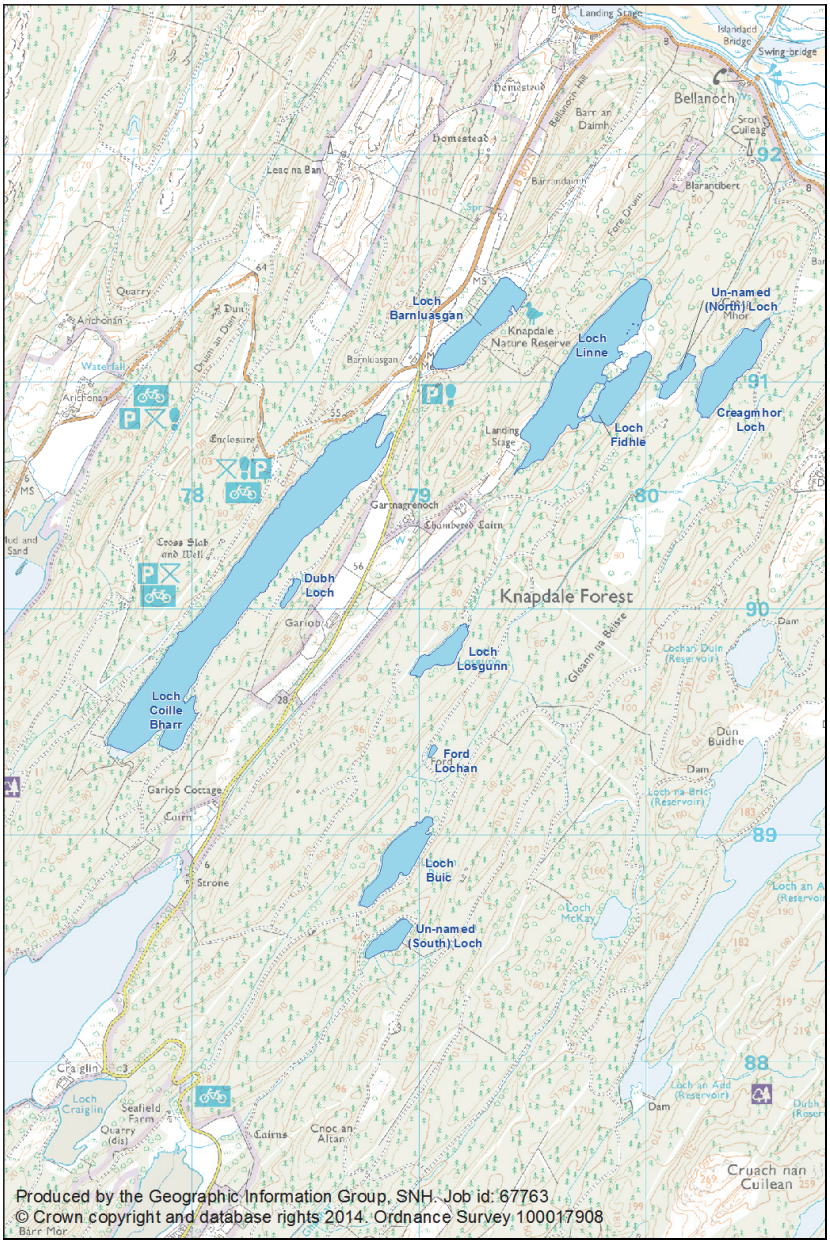

Figure 1. Sampling sites within the beaver trial area. Scale 1:21,000

A total of sixteen beavers in five families or pairs were released during the trial (fifteen in the first year and one in the second). The aim was to establish a minimum of four breeding pairs in the release area by May 2011. Of the released individuals, three deaths (all males) were recorded during the first year of the trial, and five animals went missing (four over the first two years, and one in the fourth year). As of June 2014, eight of the released beavers were known to be alive and present in the release area (three established breeding pairs with young and a single male in four territories). Two lochs sampled for this study were never used by beavers during the trial period (see Harrington *et al.*, 2015, for full details).

Willby *et al.* (2014) used various indices to assess beaver usage, including lodge occupation and duration of usage, especially through the growing season (Table 1). This classification was used to analyse possible impacts of beavers on dragonflies.

Table 1. Classification of beaver usage of lochs

Loch	Beaver usage
Barnluasgan	Low (zero)
Losgunn	Low (zero)
Un-named (South)	Low
Ford Lochan	Medium
Coille-Bharr	Medium
Creagmhor	Medium
Un-named (North)	Medium
Buic	High
Dubh	High
Fidhle	High
Linne	High

The report provides the results of the final year of survey in 2014, and an analysis and review of the data collected over the trial period 2009-2014. Reference is also made to other data collected before this period for other purposes. The implications for the continued presence of beavers at Knapdale in the future, and of a wider Scottish reintroduction, are discussed.

1.1 The hairy dragonfly, *Brachytron pratense*

B. pratense is a small hawker dragonfly found predominantly in southern Britain. In Scotland, it was known from only seven hectads before 1990, but the distribution has increased by 13 in 2012 mainly as a result of increased recording. It occurs in Dumfries & Galloway and Argyll (Cham *et al.,* 2014) and most of the lochans in the Knapdale study area. (Batty, 2003; 2008).

B. pratense is a species with specific habitat requirements; sites need to have a rich complex of submerged and emergent vegetation, and semi-decomposing floating detritus of rushes, sedges and reeds. Females oviposit in the detritus and the fleshy lower leaves of *Cladium mariscus* (Merritt *et al.*, 1996; Batty, 1998; Corbet, 1999; Perrin, 1999). *B. pratense* is usually an indicator of a rich assemblage of dragonfly species. The species is not found in new wetlands or sites with limited vegetation, and clearance of ponds can cause a decline in numbers (Tyrrell, 2011). In Scotland, emergence of *B. pratense* usually takes place from mid- to late May (Batty, 1998), and earlier in England (Tyrrell & Brayshaw, 2004). The flight period is relatively short, from mid-May to end of June (Perrin, 1999).

1.2 The beautiful demoiselle, *Calopteryx virgo*

C. virgo is found in the south and west of England and Ireland and in scattered populations from Skye to Argyll (Merritt *et al.* 1996; Cham *et al.*, 2014). It breeds exclusively in running water, typically fast-flowing streams with a bed of sand or gravel and sections with overhanging trees and abundant bankside vegetation; it makes use of dappled sunlight for courtship displays (Nelson & Thompson, 2004; Corbet & Brooks, 2008).

Prendergast (1988) found that *C. virgo* increases in abundance with decreasing water depth and shade. He linked river depth and current speed to the oxygen requirements of *C. virgo,* and these are the possible reasons why this species is never found in standing water (Brownett, 1994; Corbet & Brooks, 2008).

2. METHODS

Monitoring of *B. pratense* is based on counts of larvae (spring or late summer) or exuviae (late May) along transects, and adults in May-June. For *C. virgo,* larvae and exuviae are difficult to find, and adult monitoring in early summer is the only feasible option.

For *B. pratense,* transects were established mainly in 2009 on lochs within the trial area (Table 1). They were surveyed in 2009, 2010, 2012 and 2014 for both larvae and adults.

For *C. virgo*, transects established in 2009 on three watercourses were surveyed for adults in 2009, 2010, 2012 and 2014 (and reference was also made to data collected for a separate SCM survey carried out in 2008).

For adult monitoring, the 'Pollard walk' approach (Pollard, 1977; northern version with respect to weather) was used: minimum temperature of 13°C with at least 60% open skies or temperature 17°C or above with at least 40% open skies. From personal experience, the best counts are obtained in conditions with temperatures over 17°C and as near to full sunshine. Visits were made in the best conditions possible, and counts were abandoned when cloud cover became extensive because flying adults of both species retreat into the tree canopy.

Details of the methodology are given in each species section below. Notes were made of any relevant changes in vegetation, debris, water level and shade as a consequence of beaver activity that may have a bearing on the target species. All dragonflies seen were recorded. However, as visits were made early in the season, the full range of Odonata species was not seen. In addition, the results from a full survey of dragonfly species for Site Condition Monitoring in 2013 (Batty, 2013) were utilised.

2.1 Hairy dragonfly

At each site, a transect was set up along the loch edge in the area with the best habitat. Each transect was up to 100 m long, but its length depended on the terrain; the edge of a loch or burn was followed as closely as possible but some detours had to be made. A hand-held GPS was used to record all locations, including the start and end points of each transect. Sometimes it was impossible to follow a transect, so records were taken from accessible points in sections of the loch. These sample points are included under 'transects' in this report. At least one visit was made during the main flight time of *B. pratense*. The same area was searched on each visit.

The water was sampled for larvae and the bank vegetation searched for exuviae. Larval surveys were carried out with ten sweeps with a colander in at least ten places along the water edge. A colander was used in preference to a net because water containing mud and detritus is filtered more easily and quicker. All larvae caught were examined with a hand lens, identified and recorded.

At Dubh Loch, the water level was higher from 2010 onwards due to a beaver dam. Therefore new sampling sites had to be established at the new water edge (Figures 2 & 3; the locations' coordinates, timing and weather conditions are shown in the Annex). From these new points, observations of adults were made over as much of the original loch area as possible.

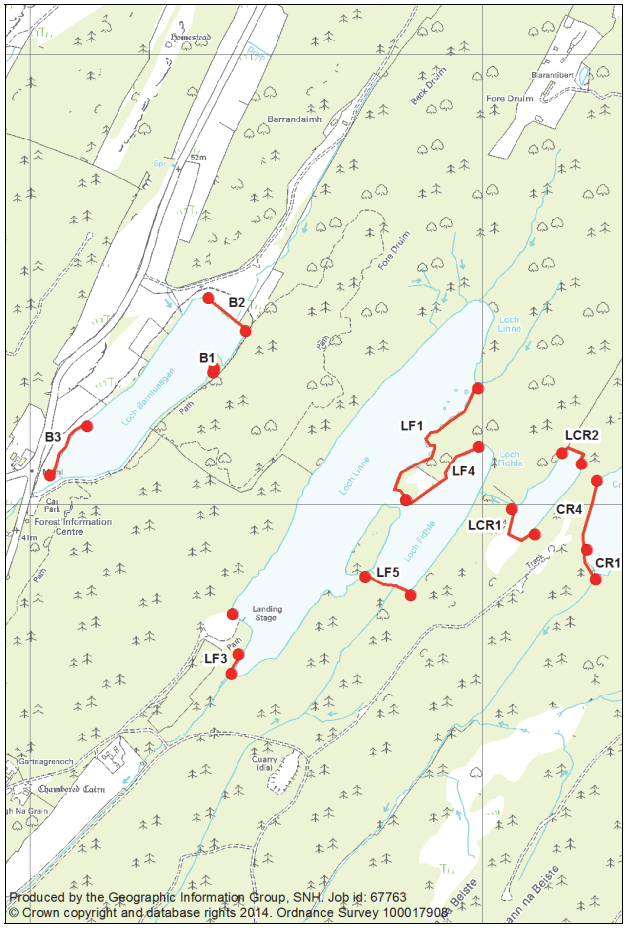

Figure 2. Location of B. pratense *transects and sampling points, North Knapdale Lochs. Scale 1:10,000*

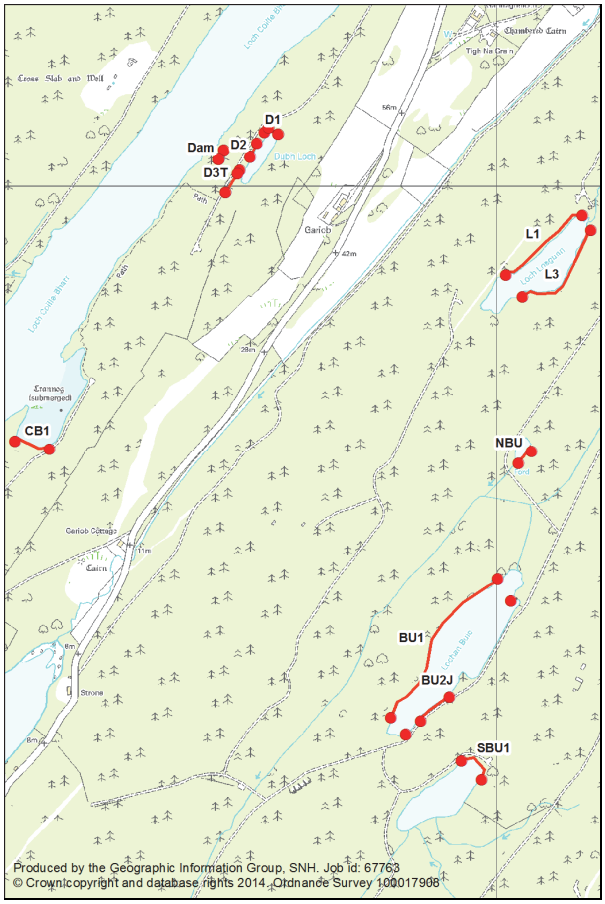

Figure 3. Location of B. pratense *transects and new sampling points, South Knapdale Lochs. Scale 1:10,000*

2.1.1 Emergence survey

As part of a separate, long term survey, two small study sites on Loch Barnluasgan (B1) and Dubh Loch (D1-3) were established in 1991 to evaluate emergence of *B. pratense* (Figures 2 and 3). These sites were visited during the emergence period, early to mid-May, on at least three occasions during the study. The visits happened when the water started to warm up and larvae in their final instar were appearing in the shallows. Each area was searched for larvae and exuviae. All exuviae were collected and counted. Due to increased water levels after 2010 at Dubh Loch, the original survey area was inaccessible. A canoe was used to survey the original transects in 2010, 2012 and 2014.

2.2 Beautiful demoiselle

Three burns have the main population of *C. virgo* in the study area: these form the outflows of Loch Coille-Bharr, Loch Linne/Loch Fidhle and Creagmhor Loch.

The number of adult male and female *C. virgo* in an approximately 5 m wide strip was recorded in each 500 m reach (section), as identified in the River Habitat Survey (RHS) (Gilvear & Casas Mulet, 2010):

1. Creagmhor Loch outflow - including RHS sections 1-4, 2.0 km.
2. Loch Linne outflow (Gariob Burn) - including RHS sections 42-46, length 2.5 km.
3. Loch Coille-Bharr outflow to the sea (Fairy Isles Burn) - including RHS sections 34-37, length 2.0 km

GPS co-ordinates and existing markers were used to identify the beginning and end of each section (Figure 4).

A 1.75 km section of the Kirnan Burn (ca. 8 km north-east of Knapdale, and outwith the Scottish Beaver Trial study area) was also monitored to act as a reference site.

One visit was made during the peak flight time, and an additional visit was made in 2010 because of low numbers on the first visit. A second visit was also made in 2012 to determine whether the peak flight time had been achieved and numbers were similar on both counts. These were also surveyed in late May and June 2014, during the main flight time. Peak count numbers were used for analysis.

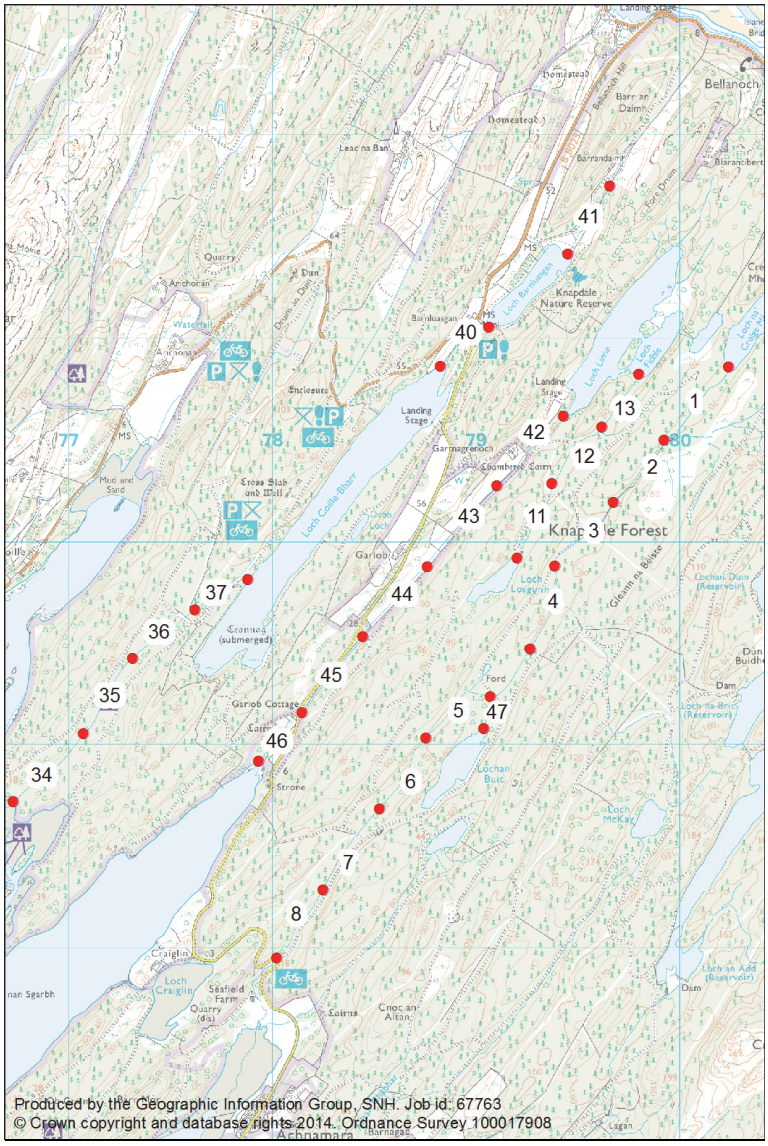

Figure 4. Start and end points of C. virgo *transects. Sections used are Loch Coille-Bharr outflow 34-37, Loch Linne outflow 42-46, Creagmhor Loch outflow 1-4. Scale 1:25,000*

3. RESULTS

3.1 Hairy dragonfly

3.1.1 2014 larvae and exuviae results

Numbers of larvae and exuviae in 2014 represent the highest seen at a site (Table 2). Larvae and exuviae were found at seven of the eleven Knapdale lochs, proof that *B. pratense* was breeding here in 2014. Larvae and exuviae were rarely found at the Ford Lochan and never found at Loch Losgunn. The edges of these lochs are either unstable or difficult to access and search because of the rough heather banks.

Table 2. Summary of B. pratense larvae and exuviae transects May 2014

Site	Section	larvae	exuviae	emerging	Date
Beaver usage: Low					
Barnluasgan	B1	1♂	1♀ 1♂	0	16/5
Barnluasgan	B2	0	2♀	1	23/5
Losgunn	L1,L3	0	0	0	21/5
Un-named (South)	SBU 1	0	2♀ 2♂	0	19/5
Beaver usage: Medium					
Ford Lochan	NBU	0	0	0	19/5
Coille-Bharr	CB1	0	2♀	0	20/5
Creagmhor	CR1,CR4	2	1♂	1	21/5
Creagmhor	CR1,CR4	1	2	0	27/5
Un-named (North)	LCR1&2	0	1	0	21/5
Beaver usage: High					
Buic	BU1	0	5(1♀ 4♂)	0	19/5
Dubh	D1-3	0	3(1♀ 1♂)	0	20/5
Fidhle	LF4,5	0	0	0	21/5
Linne	LF1,3	0	0	0	21/5
Total		**4**	**22**	**2**	

The original edge of the Dubh Loch was searched by canoe, and three exuviae were found in the remaining *C. mariscus* areas. One exuvia was damaged and another was in the water, possibly washed off the vegetation after showers on the previous evening. *B. pratense* continues to breed in the original area. The new edge was also sampled, but no *B. pratense* were found. Lochs Fidhle and Linne are among the sites with high beaver activity since 2009, and no larvae or exuviae were found. Larvae and exuviae have been more difficult to find here since 2010. However, exuviae were found in the north and central area of the west bank of Lochan Buic, four on the bank and another on *Juncus* sp. Some detritus remained in this area.

3.1.2 Comparison of larvae and exuviae transect results 2009-2014

The combined numbers of *B. pratense* larvae and exuviae recorded on the transects for each site from 2009, 2010, 2012 and 2014 are summarised in Table 3. Numbers of larvae represent the maximum found at a site.

Table 3. Comparison of B. pratense *transect results from the 2009-2014 survey*

	2009		2010		2012		2014	
Site	**larvae**	**exuviae**	**larvae**	**exuviae**	**larvae**	**exuviae**	**larvae**	**exuviae**
Beaver usage: Low								
Barnluasgan	4	7	2	4	4	2	0	4
Un-named (South)	1	0	0	2	0	0	0	4
Losgunn	0	0	0	0	0	0	0	0
Beaver usage: Medium								
Ford Lochan	1	0	0	1	0	0	0	0
Coille-Bharr	0	0	0	0	0	0	0	2
Creagmhor	1	0	2	2	4	0	3	3
Un-named (North)	2	0	0	0	0	0	0	1
Beaver usage: High								
Buic	1	6	1	4	1	3	0	5
Dubh	4	2	0	3	0	0	0	3
Fidhle	6	4	2	3	0	1	0	0
Linne	1	0	0	3	1	0	0	0
Total	**21**	**19**	**7**	**22**	**10**	**6**	**3**	**22**

Exuviae indicate that breeding has taken place and give a better measure for comparison than larvae, but they are hard to find: they can be easily dislodged in poor weather. The numbers of exuviae at all sites were similar for all years apart from 2012, probably because of the cool, wet weather during the emergence period.

Exuviae were found in a variety of emergent vegetation, often on *S. lacustris, C. mariscus, Phragmites australis,* sedges and rushes up to 1.5 m away from the bank. They can also be found on *Myrica gale,* willow and on the bank itself.

At Un-named (South) Loch, exuviae were mainly found on *S. lacustris* growing in water 30-50 cm deep, over a metre from the water's edge. At Creagmhor Loch, larvae and exuviae are regularly found at the south of the loch. They were in an area with much floating detritus due to beaver activity (Figure 5). In 2014 exuviae were found at Coille-Bharr for the first time during the survey period.

Figure 5. Creagmhor outflow

3.1.3 Emergence survey

In 2014, it was not possible to start the survey before 16 May, when the first exuviae were found. However this coincided with improved weather conditions and the first emergence is likely to have been just before this date (Table 4).

Table 4. First emergence and number of exuviae at Barnluasgan and Dubh lochs from 1991 to 2014

Year	First emergence date	Number of Exuviae Dubh Loch	Number of Exuviae Loch Barnluasgan
2014	16/05	3	2 + (2 rest of loch)
2013	05/06	0	3
2012	15/05	0	2 + (1 rest of loch
2011	03/05	not accessed	5 + (1 rest of loch)
2010	19/05	3	3
2009	12/05	2	5 + (2 rest of loch)
2008	10/05	12	4
2007	02/05	1	3
2006	19/05	*2-5	1
2005	16/05	1	2-5
2004	10/05	2 to 5	5
2003	22/05	3	1
2002	09/06	1	2-5
2001		Not recorded	
2000	16/05	1	1
1999	07/05	1	2
1998	26/05	2	3
1997	14/05	4	5
1996	21/05	20	5
1995	16/05	5	3
1994	16/05	16	2
1993	08/05	12	17*
1992	25/05	15	5*
1991	26/05	21	10*

* whole loch

3.1.4 2014 adults results

Twenty transects and five sampling points were surveyed (Table 5). The changeable weather in late May and early June limited the number of days with good flight and surveying conditions. Most visits were made in good conditions with completely open skies. Only one main count was possible at most sites during peak flight time. A second visit was made to Loch Barnluasgan and the Dubh Loch, as these sites had been previously been visited later in the day. Adults were recorded during the larval survey at the Dubh and Creagmhor Lochs. Males were seen patrolling territories and females were seen ovipositing at the Ford Lochan and at Lochan Buic.

Table 5. Summary of B. pratense adult transects 2014. Cop: pairs seen in tandem; Ovip: egg-laying female. Double counting was possible for adults

Site	Section	Adult male	Adult female	Cop	Ovip	Date
Beaver usage: Low						
Barnluasgan	B1-3	5	0	0	0	31/5
Barnluasgan	B1-3	6	0	0	0	6/6
Losgunn	L1-3	5	0	0	0	6/6
Un-named (South)	SBU 1	4	0	0	0	31/5
Beaver usage: Medium						
Ford Lochan	NBU	2	1	1	1	31/5
Coille-Bharr	CB1	2	1	0	1	31/5
Creagmhor	CR1,CR4	2	0	0	0	27/5
Creagmhor	CR1,CR4	5	1	0	0	31/5
Un-named (North)	LCR1&2	4	1	0	0	31/5
Beaver usage: High						
Buic	BU1	3	0	0	0	31/5
Buic	BU2 JSN	3	1	0	1	31/5
Dubh	D3T, dam D4b D5b	1	0	0	0	31/5
Dubh	D3T, dam D4bD5b	2	0	0	0	6/6
Fidhle	LF4 LF5	6	0	0	0	31/5
Linne	LF1,3	3	0	0	0	27/5
Linne	LF1,3	7	0	0	0	31/5
Total		**60**	**5**	**1**	**3**	

3.1.5 Comparison of adult results 2009-2014

The combined numbers of *B. pratense* recorded are summarised in Table 6. In 2010 and 2012, repeat adult counts were made on certain lochs, for which only peak counts are included in the table.

Table 6. Comparison of adult B. pratense transects from the survey years 2009-2014

Site	2009	2010	2012	2014
Beaver usage: Low				
Barnluasgan	6	6	11	6
Losgunn	5	15	6	5
Un-named (south)	1	3	4	4
Beaver usage: Medium				
Ford Lochan	1	4	2	3
Coille-Bharr	0	1	3	3
Creagmhor	3	9	2	6
Un-named (north)	0	4	6	5
Beaver usage: High				
Buic	8	20	10	7
Dubh	2	9	5	2
Fidhle	1	4	3	6
Linne	4	11	9	7
Total	**31**	**86**	**61**	**55**

The 2009 results at the Dubh are not directly comparable with the later surveys because the original transects were not accessible. Most adults seen were territorial males. Many lochs had a peak in adult numbers in 2010 (Figure 6).

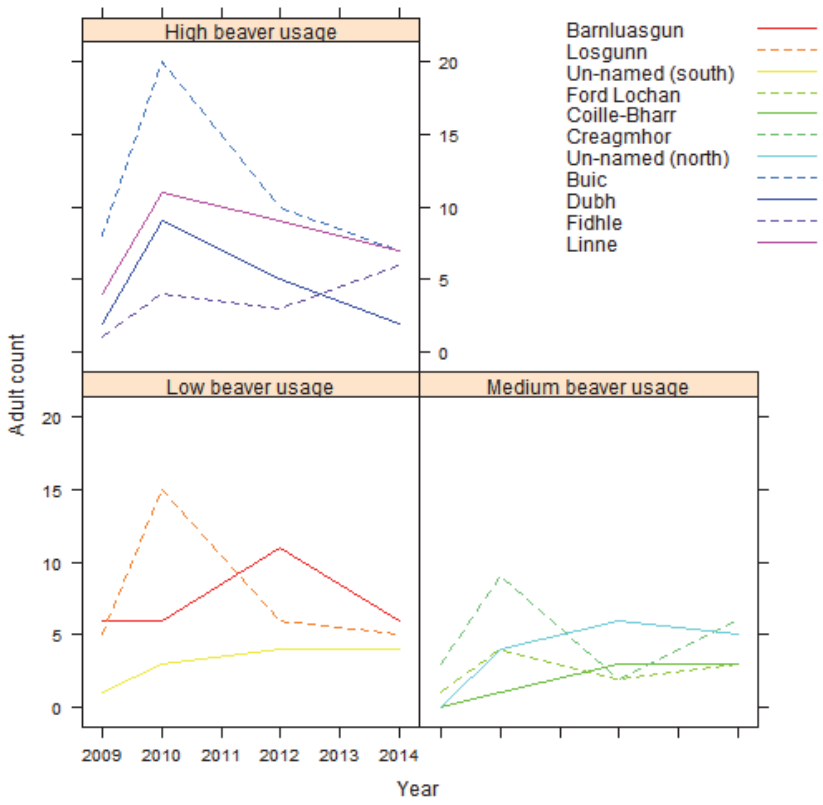

Figure 6. Number of adult B. pratense *at lochs for the 2009-2014 surveys*

3.2 Beautiful demoiselle

3.2.1 2014 results

The numbers of adult *C. virgo* recorded in 2014 on each transect are summarised in Table 7. Weather in late May and early June was warm but changeable, with a limited number of days with good flight and surveying conditions. One main count was undertaken at each site during peak flight time in good conditions, and a second visit was made to Kirnan burn. The date, timing and weather conditions are given in the Annex.

Table 7. Summary of C. virgo *counts for all transects June 2014*

Watercourse	Section	Male adults	Female adults	Total adults	Date
Linne outflow	42	24	3	27	6/6
Linne outflow	43	14	4	18	6/6
Linne outflow	44	48	21	69	6/6
Linne outflow	45	6	1	7	6/6
Linne outflow	46	0	0	0	6/6
Coille-Bharr outflow	37	6	0	6	6/6
Coille-Bharr outflow	36	66	15	81	6/6
Coille-Bharr outflow	35	56	13	69	6/6
Coille-Bharr outflow	34	23	8	31	6/6
Creagmhor Loch outflow	1	5	1	6	8/6
Creagmhor Loch outflow	2	0	0	0	8/6
Creagmhor Loch outflow	3	0	0	0	8/6
Creagmhor Loch outflow	4	4	2	6	8/6
All Knapdale sites Total		**252**	**68**	**320**	
Kirnan Burn	1	5	2	7	8/6
Kirnan Burn	2	15	5	20	8/6
Kirnan Burn	3	1	0	1	8/6
Kirnan Burn	4	3	0	3	8/6
Kirnan Burn	5	0	0	0	8/6
Kirnan Burn Total		**24**	**7**	**31**	8/6

3.2.2 Comparison of the data collected during 2008-2014

The results of the 2008 to 2014 surveys are summarised in Table 8. The full transects were established in 2009, however additional data were added from the 2008 SCM. This pre-dated the establishment of RHS sections by Gilvear & Casas Mulet (2010), but it was possible to translate the results into RHS sections for Linne outflow (Gariob Burn), equivalent to sections 42-44, and the Coille-Bharr Outflow (Fairy Isles Burn). Maximum count figures were used when more than one visit was made.

Table 8. Comparison of C. virgo transect results 2008-2014. Maximum counts are shown for 2010 and 2012

Watercourse	2008	2009	2010	2012	2014	Transect length (km)
Creagmhor outflow	No data	12	3	11	12	2.0
Coille-Bharr outflow	155	64	99	159	187	2.0
Linne outflow	149	121	91	186	121	2.5
All Knapdale sites	**304**	**197**	**194**	**356**	**320**	**6.5**
Kirnan Burn	No data	40	81	34	31	1.75

In Knapdale, adults are not often seen where bank-side trees form a tunnel of shade, but occasional males were seen in tiny patches of sunlight amongst the broadleaves. None were seen in dense conifers. The Coille-Bharr outflow and Linne outflow (sections 45 & part of 44) were clear-felled over nine years ago and *C. virgo* has colonised the area since then. Both these burns had stretches of good habitat where many *C. virgo* adults were seen. In 2013 mature conifers west of Coille-Bharr outflow, sections 34 & 35 (the bridge to the sea section), were felled.

Weather conditions during the flight time in 2014 were changeable and not as good as in 2010 and 2012. It is difficult to predict the exact timing of peak flight time and survey dates are governed by the weather conditions. This should be taken into consideration when examining data.

The Coille-Bharr outflow had the highest number of adults recorded. Particularly high numbers were seen in sections 35 and 36, where there was a balance of sunlight and shade provided by the surrounding tree regeneration. Some sections of the Creagmhor outflow have been canalised and others are shaded by dense conifers thus there was only a small area of suitable habitat.

The reference site, Kirnan Burn, is wider than the Knapdale sites but has sections of comparable habitat. It flows through fields with scattered, regenerating trees and areas without grazing. The Knapdale burns have not been used by beavers to any large extent. No dams have been built apart from one at the Linne outflow in 2009. This dam was removed and was not rebuilt.

Beavers have felled a small number of young trees in section 42 of the Linne outflow, particularly near the loch. Here small open glades were created mostly in 2012. By 2014, these were more shaded due to regrowth, although there were still some open areas. This section had become overgrown and shaded and no adults were seen in 2009 or 2010. Beaver activity continually creates open areas with sunlight and dappled shade, a suitable habitat for *C. virgo*.

3.3 Odonata species assemblage

Figure 7 summarises results from SCM surveys in 2002 and 2008 (Batty, 2003, 2008), before beaver introduction, and 2013.

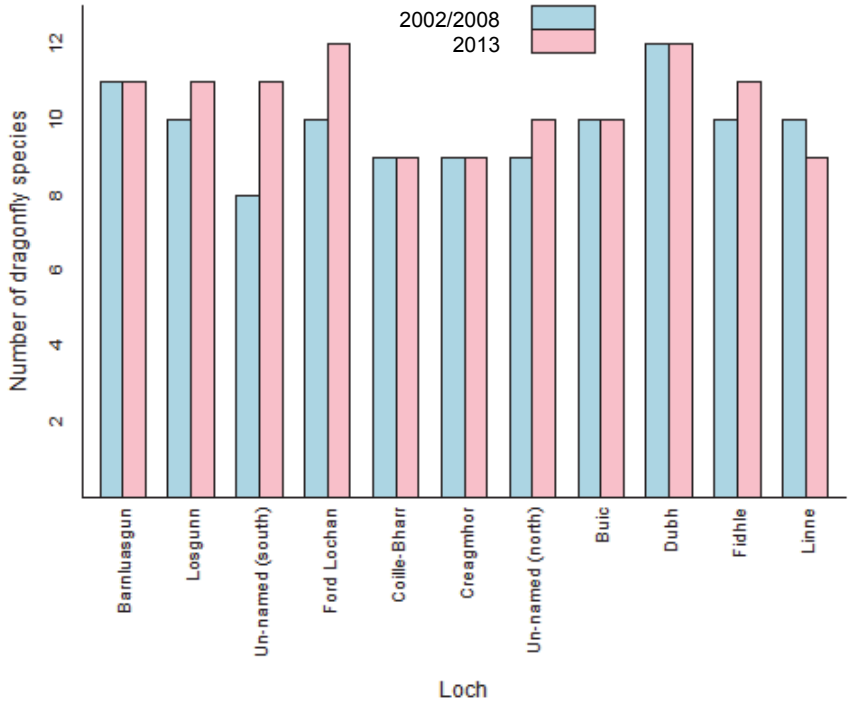

Figure 7. Number of dragonfly species pre and post beaver introduction at Knapdale Lochs

Aeshna cyanea, the southern hawker had colonised the Un-named (North) Loch and Lochan Buic since 2009 (Annex). This species is expanding in Scotland (Cham *et al.*, 2014), most likely as a result of climate change, and is gradually colonising more of the Knapdale lochs. *A. juncea,* the common hawker, was not regularly seen at all lochs (Annex).

Scotland has 23 breeding dragonfly species (Cham *et al.* 2014), of which 15 breed in western Argyll. It is unlikely that any additional species will spread into Knapdale as a result of beaver activity, as all species that breed in such habitat are already present.

4. DISCUSSION

4.1 Beaver grazing

Willby *et al.* (2014) found that beavers have an effect on their two favoured plants in Scottish study sites, *C. mariscus* and *S. lacustris,* which are also associated with *B. pratense* breeding sites (Smith & Smith, 1984; Batty, 1998; Perrin, 1999). This was more evident in lochs with occupied lodges. *C. mariscus* and *S. lacustris* had an overall decline of 83% and 43%, respectively; this is a major change over a short period of time. This effect was most marked in the Loch Linne/Fidhle system, and *C. mariscus* was also drastically reduced in Lochan Buic and in Creagmhor Loch.

Beavers eat the rhizomes of *S. lacustris,* leaving behind cut stems. Normally the stems die off in the autumn, creating a supply of floating material that can be trapped at the water's edge. This floating material does not usually create dense mats and is replenished annually as it decays by the following autumn. As the resource has been depleted by beaver grazing, there has been less detritus in a number of lochs.

Beaver grazing created abundant floating detritus, which was collected in small bays and inlets and in some places was over 30 cm thick. *B. pratense* larvae were not found in areas with a large accumulation, but rather where the material is less dense. Larvae were mainly found in areas with plentiful detritus clinging to the underside of floating stems. Exuviae were found in a variety of situations but always in areas with some floating detritus (Figures 8-10).

Figure *8. Barnluasgan larvae/exuviae area* *Figure 9* - C. mariscus *at Dubh Loch Mid area*

Figure *10. Barnluasgan exuvia on* S. lacustris

By the second season, most of this material had sunk to the bottom. Colonisation by other plants then took place. At Loch Fidhle, *Nymphaea alba* increased as it spread into the *C. mariscus* area (Willby *et al.*, 2014). The grazing of *C. mariscus* is likely to have greater effect on lochs with gently shelving shores, as at Lochan Buic. In places here there was nothing to trap the detritus, so when the water level was high, the detritus had been washed up on the shore (Figure 11) and thus not available to *B. pratense*.

Figure *11. Detritus washed up at Lochan Buic*

Lochs Linne and Fidhle have been the most affected, as *C. mariscus* had declined by 66% in Linne and 83% in Fidhle over the trial period (Figures 12 & 13). At Loch Fidhle, *C. mariscus* was grazed heavily in 2009-2010, with most of decline by May 2011 (Willby *et al.*, 2014).

a b

Figure 12. Habitat changes at the Knapdale lochs as a result of beaver activity. a: Linne Island, 2009; b: Linne Island, 2014

a b

Figure 13. Habitat changes at the Knapdale lochs as a result of beaver activity. a: Fidhle South inlet, 2009; b: Fidhle South inlet, 2014

In 2014 Loch Fidhle had little floating detritus, although some *S. lacustris* remained in the northern area.

With the loss of *S. lacustris,* Loch Linne also had only a small amount of trapped detritus in 2014. The much reduced area of *C. mariscus* was targeted by *B. pratense.* Of the seven males recorded, four were in this area, vying for territories. No larvae or exuviae were recorded in 2014, but as they were present at other lochs on the same day, this may be an indication of reduction in numbers.

Beavers settled on Lochan Buic in 2011, but only started grazing on *C. mariscus in* 2012. It is now heavily depleted (Figure 14) with an 87% reduction in cover by 2013 (Willby *et al.*, 2014). A large amount of floating *C. mariscus* stems was found in 2012. As much of this loch has a gently shelving shallow edge, most of this was washed up by 2013, leaving a tide line. However some remained in the northwest area, trapped by higher banks. Exuviae were mainly found in this area on the bank as there was no emergent vegetation. Males were also patrolling there and the *P. australis* area in the south.

a b

Figure 14. Buic North West. a: 2012; b: 2014

In the south-west of the loch, the grazed *C. mariscus* area is now bare peat. No *B. pratense* adults were seen there in 2013 or 2014, although they were regularly patrolling this area in the past. They had been replaced by the four-spotted chaser (*Libellula quadrimaculata*), which favours the new habitat.

Grazing of emergent plants at lochs with medium beaver usage did not begin until 2011. In 2014, many had abundant detritus that provided good habitat for *B. pratense*. The increased detritus may have helped larval survival.

Some beavers were present at Creagmhor Loch early in the trial, but they disappeared. A new pair introduced in 2011 built a lodge on Un-named (North) Loch which is now occupied by a single beaver. At Creagmhor Loch, the cover of *C. mariscus* was reduced by 96% and *S. lacustris* by 24%. The main stand of *C. mariscus* in the south of the loch was decimated in winter 2013 and there was none remaining by 2014 (Figure 15). In 2014 there was however abundant detritus of both species, and larvae and exuviae were found in this area and at the head of the burn.

a b c

Figure 15. Creagmhor South. a: 2008; b & c: 2013

At Loch Coille-Bharr, *S. lacustris* was untouched and increased by 39% by 2013, but *Nymphaea alba* was reduced (Willby *et al.*, 2014). The beavers had a temporary lodge in the main bay in the winter of 2012/2013. They took up more permanent residence in winter 2013/2014. From the detritus seen, *S. lacustris* is now being grazed.

The Ford Loch has been intermittently used by the Loch Buic beavers, grazing on *N. alba, Potamogeton natans* and *E. fluviatile* (Willby *et al.*, 2014). A fringing ring of *P. australis* provides the main emergent vegetation.

The cover of macrophytes increased at all lochs with low or zero beaver usage. *S. lacustris* increased at Un-named (South) by 88% and at Loch Barnluasgan by 66% (Willby *et al.*, 2014). Loch Losgunn is bordered by heather banks with an area of *Carex paniculata;* neither *S. lacustris* nor *C. mariscus* grow here.

4.1.1 Beaver dams

The Dubh Loch dam was constructed in 2009, and by 2012 this resulted in the surface area of the loch increasing to over four times its original size, with an extended edge and increased water depth to over 1.5 m. The dam was abandoned in 2013, and the beavers moved to Loch Coille-Bharr. In 2014 water levels started to gradually drop. The water level rise had a marked effect on the aquatic vegetation, much of which was lost through submersion or grazing (Willby *et al.*, 2014). The loch was originally lush with abundant vegetation (Figures 16 & 17).

a b

Figure *16. Dubh Loch North. a: 2008; b 2012*

a b

Figure *17. Dubh Loch Mid area. a: 2008; b: 2014*

In 2009/2010 the flooded edge was bare and shaded by standing trees and unsuitable for dragonflies. Between 2011and 2013, it was rapidly colonised by aquatic vegetation (Figure 18).

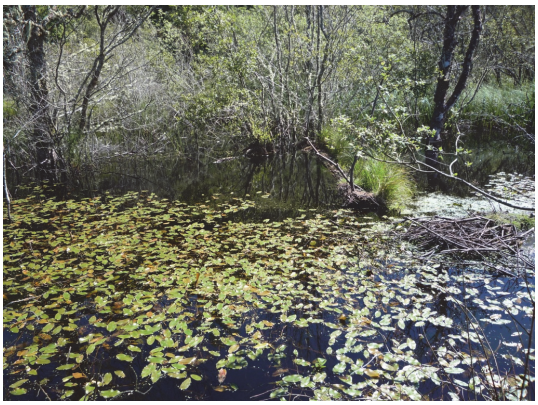

Figure 18. Dubh Loch new edge 2014

Six species of dragonflies were breeding at the new edge in 2012 and an additional four species were found in 2013. However, the newly colonised habitat is unsuitable for *B. pratense* and no larvae or exuviae were found here. The flooded southern end of the loch where *C paniculata* is dominant still provides some suitable conditions (Figure 19) but is difficult to access.

Figure 19. Dubh Loch South area 2014

The habitat has become more heterogeneous, with macrophytes patchily distributed. Before these changes, *B. pratense* was found mainly along the edge of the fringing *C. mariscus* and *C. paniculata.* Water level rise and grazing has caused a loss of 58% cover (Willby *et al.*, 2014). However, water depth is not critical, as larvae of *B. pratense* survive in water deeper than several metres (Perrin, 1999; Batty, 2010; Tyrrell, 2011).

Dubh Loch used to be the main site for *B. pratense* in Knapdale (Batty, 1998). From experience of visiting the loch since 1991, the impression is that numbers have been reduced, even though it was not possible to access deeper water to view the whole site.

Beavers constructed a dam on Un-named (North) Loch in 2011 which resulted in a small water level rise. The water is now just level with the banks, which continue to retain detritus.

This could be washed up on the banks if the water level increases. The cover of *N. alba* has been reduced, but the vegetation change up to 2013 was minor, and *Sphagnum* cover has increased at the edges (Willby *et al.*, 2014). This, combined with creation of pools and channels by beavers, could increase the bog habitat for other dragonflies.

4.2 Potential effects on the hairy dragonfly

Weather conditions are likely to be the main factor in the difference in adult numbers between years. In 2010 and 2012, there was a settled period of warm weather and sun during the main flight time. 2010 was exceptionally warm, and greater numbers of *B. pratense* were seen at Knapdale and other sites as well. Prolonged period of good weather can extend the flight time and create more opportunities for breeding.

The weather in the previous season can affect oviposition and larvae survival as well. The weather in late May and early June was particularly wet in 2011, and this could affect numbers as far as in 2014 because larvae take at least two years to develop (Perrin, 1999; Corbet & Brooks, 2008; Tyrrell, 2011), but from the size of the larvae found in Knapdale, some will take three years. Weather can also affect the chance of finding larvae and exuviae; when water is cool, larvae retreat to deeper waters.

B. pratense is a Type 1 or 'Spring' species (Corbet & Brooks, 2008). The larvae are able to suspend their development and spend the last winter before emergence in the final larval stage. They are able to respond promptly to rising water temperature in the spring; about half emerge in the first four to eight days (Batty, 1998).

In 2014, exuviae were found in five of the eight Knapdale lochs that are used by beavers, proving that *B. pratense* continues to breed in these lochs. Given the difficulty of finding either larvae or exuviae, their absence does not necessarily mean that breeding has not taken place. A female was observed ovipositing at a sixth loch, Un-named (North) in 2014 and 2013, another indication of breeding. There was breeding on the other two lochs, Linne and Fidhle in 2013 because three and two small larvae, respectively, were found in those sites. Also, there were seven territorial males at Loch Linne, an indication of possible breeding.

The reduction of cover of macrophytes, particularly of *C. mariscus* and *S. lacustris,* had not had a major impact on *B. pratense* by 2014. However, there are some indications at the lochs with high beaver usage that it may happen in the future. Floating macrophyte detritus is a key requirement for *B. pratense.* Additional detritus has been created by grazing, but it will eventually decay. There will be a time lag of five to six years after the decrease in plant cover before any effects show because of the rate of decay and larval development. Thus the study period was too short to show the effects of beaver grazing on *B. pratense.*

Beavers also feed on the riparian woodland, which produces woody detritus at the loch edge (Willby *et al.*, 2014). This is much paler in colour than the plant detritus and will not provide as good a camouflage for *B. pratense* larvae. No larvae have been found amongst this detritus.

As the food resources are depleted, beavers may abandon the lochs they are using at present and move to others. The macrophyte vegetation could then recover. This may take decades for *C. mariscus,* as there is little evidence of a seed bank, and 5-10 years for *S. lacustris* and *N. alba* if residual populations remain (Willby *et al.*, 2014). The Dubh Loch was abandoned by beavers in late 2013 and by 2014 the water levels were gradually dropping as the unmaintained dam was leaking. There are good remaining stands of *C. mariscus*.

Glades have been created in the willow and birch scrub around many of the beaver lochs, creating sheltered feeding areas for dragonflies. *B. pratense* males have been seen using these.

Dam building has a long-term effect on vegetation cover, which could last for several decades even after beavers leave the site (Willby *et al.*, 2014). Other species of dragonflies found at the Knapdale lochs are likely to colonise the pools created behind the beaver dams as they did at the new edge at the Dubh Loch. However it is likely to take a long time for *B. pratense* to colonise, if at all, because of its habitat requirements.

The numbers of *B. pratense* depend on the nature of the loch, the rate of colonisation of tall emergent species and the recovery of *C. mariscus.* Over the next few years, *C. mariscus*, *S. lacustris* and other targeted species may no longer be present (Willby *et al.*, 2014). Eventually there will be less suitable habitat and *B. pratense* will have fewer territories, which could lead to a reduction in numbers and possibly local loss. The species is on the edge of its range in Scotland, and populations at many sites are small and vulnerable.

To summarise, in the future, the potential beaver effects are:

Negative: the loss of cover of key emergent vegetation through grazing or water level rise has resulted in a loss of trapped floating macrophyte detritus habitat and loss of breeding habitat.

Positive: *B. pratense* may adapt to using woody detritus, which is likely to increase (Willby *et al.*, 2014), though to date no evidence has been seen for this. However oviposition has been witnessed on other dead wood in Knapdale. The creation of clearings in the riparian woodland provides additional areas for adult dragonfly activity.

4.3 Potential effects on the beautiful demoiselle

To date the beavers have had a limited effect on the Knapdale burns (Perfect & Gilvear, 2011) and any changes seen in *C. virgo* numbers have been mainly influenced by other factors. These include weather conditions, forestry operations and natural regeneration.

It is possible that beavers will start to use the burns in Knapdale, building dams and creating new ponds and wetlands. Dams change the habitat from flowing water to still or slow moving water behind the dam (MacDowell & Naiman, 1986; Redin & Sjöberg, 2012). This may bring changes in stream sediments (Rosell *et al.*, 2005), the chemical composition of the water, cause retention of organic matter and water warming (Rolauffs *et al.*, 2001). Surveys upstream of a dam have detected changes in species composition and a reduction in invertebrate species richness (Wright *et al.*, 2002), favouring predators such as Odonata (Rolauffs *et al.*, 2001; Redin & Sjöberg, 2012). The Odonata assemblage composition changes from species adapted to flowing water to still water species (Arndt & Domdei, 2011).

From experiences elsewhere, flowing water species such as *C. virgo* and *Cordulegaster boltonii* will continue to breed in the unaffected sections of water courses (Arndt & Domdei, 2011; Schloemer *et al.,* 2012). Conditions at the beaver dam itself are similar to those in running water (Rolauffs *et al.,* 2001) and the dam structure increases habitat diversity (Arndt & Domdei, 2011). A few larvae of *C. virgo* have been found in beaver ponds, although they could have arrived by drift (Arndt & Domdei, 2011).

C. virgo has the capacity to adapt to major changes caused by woodland management. The species moved into sections of river when densely shading conifers were clear-felled. Since conifer removal, there has been regeneration of native broad-leaved trees, forming areas of

scrub along sections of the burns. This is providing ideal habitat for *C. virgo*. In comparison, the changes caused by beaver activity are more local. Eventually the burns will become overgrown and shaded, making these sections unsuitable. Beaver grazing is likely to open up scrub allowing more sunlit areas (Schloemer *et al.*, 2012). Thus the negative effect of reducing the area of flowing water could be offset by the creation of sunlit sections.

For *C. virgo,* the limited use of the burns by the beavers during the trial restricted the conclusion from the survey. Nonetheless potential effects can be summarised:

Positive: creation of clearings through the felling of willow and birch.

Negative: damming sections of burns and reducing the amount of flowing water.

4.4 Studies on the effects of beavers on Odonata in Europe and North America

From the literature, beavers are generally considered beneficial for dragonflies by creating a variety of wetlands. On river systems, beavers can increase the biodiversity through damming and increase the number species present. Studies that have looked at beavers and Odonata have compared beaver-created ponds and the free flowing sections of river systems, and there have been no other comparable studies where baseline data were available before beavers were released.

In Germany, *B. pratense* individuals were found at beaver ponds in reeds and reed fragments in slow flowing water and also in beaver back waters (Günther, 2005). In a river system in Germany where beavers had been established since 1981, 29 species of dragonflies were associated with beaver ponds and the surrounding wetland. In comparison, only four species were found in the streams and seven species at abandoned beaver pools (Schloemer *et al.*, 2012). These differences are not surprising, as the number of dragonfly species that breed in flowing water is far fewer than those breeding in still waters.

Harthun (1999) found significant numbers of dragonflies and damselflies in beaver home ranges in comparison to brooks without beavers in Germany. In Bavaria, dammed waters showed a significant increase in the number of species; 38 dragonflies were present at monitored sites, 26 of which directly benefitted from beaver activity, including 11 important species (Messlinger, 2012). Beavers were continually creating and changing habitats, providing areas with bare ground that favours pioneering species and areas with more vegetation for species typical of the later stages of succession (Messlinger, 2012).

The surrounding wetlands also contained runnels and small beaver canals that attracted different species (Schloemer, pers. comm.). By digging channels, beavers can extend wetland by up to 200 m and create aquatic habitats that favour predatory macro-invertebrates (Hood *et al.*, 2012).

In North America, dragonflies have long been associated with beaver ponds. In Virginia, 43 dragonflies and 23 damselflies were found in the Laurel Fork recreation area, which consists of a series of rivers systems with beaver ponds. A third of the species were on the state rare species list. The majority of species were in beaver ponds and four were only known from beaver ponds or their vicinity. The number of species of dragonflies in one area fell from 61 to four when beavers disappeared from the area (Roble *et al.*, 2009). However several species that inhabit wetlands with more emergent vegetation were not present in the Virginia beaver ponds (Roble *et al*., 2009)

4.5 Implications for wider beaver reintroduction in Scotland

Many parts of Scotland do not have the diversity of dragonfly habitat present in Knapdale and have a restricted number of ponds suitable for dragonflies. This is particularly so in the east in the lowland areas of Fife and Angus and parts of the Tay catchment area. Here the creation of new habitat could increase dragonfly numbers and diversity. However, beavers may affect species that breed in pools with abundant emergent vegetation. *B. pratense* is the most likely species to be affected, and possibly the variable damselfly (*Coenagrion pulchellum*). The rare northern damselfly (*Coenagrion hastulatum*) breeds in water bodies with fringing emergent vegetation. However, this species is common in beaver ponds in Norway (Rossell, pers. comm.) and may not be affected.

Other Scottish species are associated with mires and bog pools. They would only be at risk if a particular mire was inundated. Many sites for these species are in upland areas and are much less likely to be affected by beavers.

5. CONCLUSIONS

At this stage there do not appear to be clear differences between lochs with and without beavers. Weather is likely to be the main factor influencing differences in *B. pratense* numbers.

Dubh Loch suffered substantial changes in size and habitat due to dam building. All *B. pratense* exuviae were found amongst the remaining *C. mariscus* in the inundated area with none at the new edge. There are some indications that the population of *B. pratense* is falling at this site.

A longer study is needed to determine the effects of beavers on *B. pratense.* At present they are neutral to potentially negative.

Beavers have made little use of the outflowing burns and therefore there are no data from this study on the impact of beavers on *C. virgo.* However both *B. pratense* and *C. virgo* have been using the clearings created by beaver activity.

The trial period of five years has been too short to show the effects of beaver reintroduction on *C. virgo* and particularly *B. pratense,* as its larvae can take up to three years to develop.

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ANNEX - SUPPLEMENTARY DATA

Location details for transects established to monitor B. pratense. *Sampling points are marked with an asterisk. Only transects used throughout the trial period are included apart from at the Dubh loch where equivalent transect were established at the new water's edge. Transects D1-3 on the Dubh Loch only accessible by canoe from 2010.*

		Start grid reference			End grid reference		
Loch	**Transect/ Point No.**	**100km square**	**easting**	**northing**	**100km square**	**easting**	**northing**
Loch Barnluasgan	B1	NR	79403	91295	NR	79406	91304
Loch Barnluasgan	B2	NR	79476	91387	NR	79393	91460
Loch Barnluasgan	B3	NR	79125	91176	NR	79030	91065
Dubh Loch	D1	NR	78444	90127	NR	88470	90120
Dubh Loch	D2	NR	78446	90106	NR	78410	90070
Dubh Loch	*D3	NR	78380	90030			
Dubh Loch	*D4b	NR	78454	90139			
Dubh Loch	*D5b	NR	78477	90124			
Dubh Loch	D3T	NR	78385	90038	NR	78351	89985
Dubh Loch	Dam	NR	78347	90085	NR	78335	90064
Loch Linne	LF1	NR	79989	91260	NR	79830	91010
Loch Linne	LF2	NR	79446	90758			
Loch Linne	LF3	NR	79456	90681	NR	79444	90625
Loch Fidhle	LF4	NR	79830	91010	NR	79990	91130
Loch Fidhle	LF5	NR	79840	90800	NR	79740	90840
Creagmhor Loch	CR1	NR	80230	90900	NR	80240	90820
Creagmhor Loch	*CR4	NR	80286	91055			
Un-named (North)	LCR1	NR	80100	90920	NR	80050	90990
Un-named (North)	LCR2	NR	80218	91091	NR	80180	91100
Loch Coille-Bharr	CB1	NR	77939	89384	NR	77850	89390
Ford Lochan	NBU	NR	79064	89345	NR	79081	89366
Loch Buic	BU1	NR	79002	89048	NR	78746	88729
Loch Buic	*BU2S	NR	78782	88689			
Loch Buic	BU2J	NR	78817	88721	NR	78869	88768
Loch Buic	*BU2N	NR	78770	88450			
Un-named(South)	SBU1	NR	78913	88612	NR	78950	88567
Loch Losgunn	L1	NR	79219	89913	NR	79020	89787
Loch Losgunn	L3	NR	79060	89736	NR	79222	89895
22 Transects and 6 sampling points							

Details of weather conditions and transect times for adult surveys 2014

Site	Date	Start time	End time	Temp°C	Wind	Sun
***Calopteryx virgo* transects**						
Linne outflow	06/06/2014	11:30	13:05	air 19	light breeze	100%
Coille-Bharr outflow	06/06/2014	13:40	15:05	air 20	light breeze	100%
Creagmhor outflow	08/06/2014	10:20	12:00	air 19	breeze	100%
Kirnan Burn	08/06/2014	14:00	15:05	air 21	strong breeze	100%
***Brachytron pratense* larvae and exuviae transects**						
Barnluasgan	16/05/2014	15:00	15:45	water 19 air 17	light breeze	none cloud
Barnluasgan	23/05/2014	12:30	13:30	water 17 air 15	light breeze	none cloud
Losgunn	21/05/2014	16:05	16:55	water 21 air 17	light breeze	100% sun
Un-named (south)	19/05/2014	14:45	15:30	water 17 air 21	light breeze	none cloud
Ford Lochan	19/05/2014	17:00	17:15	water 18 air 19	light breeze	50% sun
Coille-Bharr	20/05/2014	14:00	14:20	water18 air 17	light breeze	none cloud
Creagmhor	21/05/2014	11:15	12:30	water 18 air 16	light breeze	none cloud
Creagmhor	27/05/2014	12:30	13:10	water 20 air 19	none	100%
Buic	19/05/2014	15:45	16:55	water 17 air 19	light breeze	none cloud
Dubh	20/05/2014	11:00	13:00	water 17 air 19	light breeze	10% sun
Fidhle LF4	21/05/2014	10:05	10:35	water 19 air 17	light breeze	100%sun
Fidhle LF5	21/05/2014	14:00	14:15	water 19 air 17	light breeze	100%sun
Linne LF1	21/05/2014	14:15	14:45	water 19 air 17	light breeze	100%sun
Linne LF2-3	21/05/2014	15:25	15:40	water 19 air 17	light breeze	100%sun
***Brachytron pratense* adult transects**						
Barnluasgan	31/05/2014	17:05	17:35	air 21	light breeze	90% hazy
Barnluasgan	06/06/2014	15:55	16:30	air 21	light breeze	100%
Losgunn	06/06/2014	10:10	11:10	air 17	light breeze	100%
Un-named (south)	31/05/2014	13:25	13:40	air 21	light breeze	100%
Ford Lochan	31/05/2014	14:35	14:55	air 21	light breeze	90%
Coille-Bharr	31/05/2014	16:25	16:30	air 23	light breeze	100%
Creagmhor	27/05/2014	12:30	13:10	air 19	none	100%

Creagmhor	31/05/2014	09:30	10:05	air 17	none	100%
Un-named (north)	31/05/2014	10:10	10:40	air 20	none	100%
Buic BU1	31/05/2014	14:00	14:20	air 22	light breeze	100%
Buic BU2N,J,S	31/05/2014	13:45	14:00	air 22	light breeze	100%
Dubh	31/05/2014	15:35	16:15	air 24	light breeze	100%
Dubh	06/06/2014	16:45	17:05	air 22	light breeze	hazy 100%
Fidhle LF4	31/05/2014	10:45	11:00	air 21	light breeze	100%
Fidhle LF5	31/05/2014	12:25	12:40	air 21	light breeze	100%
Linne LF1-3	27/05/2014	10:30	11:00	air 17	light breeze	100%
Linne LF1	31/05/2014	10:45	11:00	air 20	light breeze	100%
Linne LF2-3	31/05/2014	11:50	12:10	air 20	light breeze	100%

Grid coordinates of River Habitat Survey sections used for C. virgo *transects and for Kirnan Burn Transects*

Water course name	RHS section	Start/End	X coord	Y coord
Creagmhor Loch outflow	1	Start	180237	690828
	1	End	179968	690515
Creagmhor Loch outflow	2	Start	179968	690515
	2	End	179692	690196
Creagmhor Loch outflow	3	Start	179692	690196
	3	End	179400	689865
Creagmhor Loch outflow	4	Start	179400	689865
	4	End	179273	689473
Fairy Isles Burn	34	Start	177047	689035
	34	End	176745	688718
Fairy Isles Burn	35	Start	177318	689423
	35	End	177049	689037
Fairy Isles Burn	36	Start	177628	689682
	36	End	177313	689425
Fairy Isles Burn	37	Start	177902	689862
	37	End	177636	689673
Gariob Burn	42	Start	179425	690590
	42	End	179103	690269
Gariob Burn	43	Start	179103	690266
	43	End	178774	689886
Gariob Burn	44	Start	178771	689892
	44	End	178427	689498
Gariob Burn	45	Start	178428	689498
	45	End	178162	689172
Gariob Burn	46	Start	178164	689163
	46	End	177979	688934
Kirnan Burn Sections (not part of RHS study)				
Kirnan Burn	S1	Start	186590	695007
	S1	End	186759	695180
Kirnan Burn	S2	Start	186759	695180
	S2	End	186994	695404
Kirnan Burn	S3	Start	186994	695404
	S3	End	181782	695583
Kirnan Burn	S4	Start	181782	695583
	S4	End	187566	695890
Kirnan Burn	S5	Start	187566	695890
	S5	End	187781	696322

Odonata species pre-2009 and 2013

Sites Beaver usage = Low/Zero; p = present; b = breeding

Species	Loch Barnluasgan		Loch Losgunn		Un-named (South)		Linne outflow	
	Pre-2009	2013	Pre-2009	2013	Pre-2009	2013	Pre-2009	2013
Calopteryx virgo							b	p
Lestes sponsa	b	b	b	b	b	b		
Pyrrhosoma nymphula	b	b	b	b	b	p	p	p
Ischnura elegans	b	b	b	b	b	p		
Enallagma cyathigerum	b	b	b	b	b	p	p	p
Ceonagrion puella	b	b		b		p		p
Brachytron pratense	b	b	b		p	b		
Aeshna juncea	p	p		p		p		
Aeshna cyanea	b		b	p		p		
Cordulegaster boltonii	b	b	p	b			p	b
Libellula quadrimaculata	b	b	b	b	b	b		
Sympetrum striolatum	b	b	b	b	p	b		
Sympetrum danae	b	b	b	b	p	p		
Total species	**12**	**11**	**10**	**11**	**8**	**11**	**4**	**5**

Sites Beaver usage = Medium; p = present; b = breeding

	Ford Lochan		Loch Coille-Bharr		Creagmhor Loch		Un-named (North)	
	Pre-2009	2013	Pre-2009	2013	Pre-2009	2013	Pre-2009	2013
Calopteryx virgo								
Lestes sponsa	b	p	p	p	b	b	b	b
Pyrrhosoma nymphula	b	p	p	b	b	b	b	b
Ischnura elegans	b	p	p	p	b	p	b	b
Enallagma cyathigerum	p	p	b	b	b	p	b	p
Ceonagrion puella	b	b	b	p	b	p	b	p
Brachytron pratense	b	b	b	p	b	b	b	
Aeshna juncea	p	p		p	b			p
Aeshna cyanea	b	p						b
Cordulegaster boltonii		p	p		b			
Libellula quadrimaculata	b	p	p	p	b	b	b	b
Sympetrum striolatum	b	p	b	p	b	b	b	b
Sympetrum danae	b	p	b		b	p	b	b
Total species	**11**	**12**	**10**	**9**	**9**	**9**	**9**	**10**

Sites Beaver usage = High; p = present; b = breeding

	Lochan Buic		Dubh		Fidhle		Linne	
	Pre-2009	2013	Pre-2009	2013	Pre-2009	2013	Pre-2009	2013
Calopteryx virgo						p	b	
Lestes sponsa	b	b	b	b	b	b	b	b
Pyrrhosoma nymphula	b	b	b	b	b	b	b	b
Ischnura elegans	b	p	b	b	b	b	b	b
Enallagma cyathigerum	b	p	b	b	b	b	b	b
Ceonagrion puella	b	p	b	b	b	b	b	b
Brachytron pratense	b	b	b	p	b	b	b	b
Aeshna juncea	p		b	b		p		
Aeshna cyanea		b	b	b				
Cordulegaster boltonii			p	p				
Libellula quadrimaculata	b	b	b	b	b	b	b	b
Sympetrum striolatum	p	b	p	b	b	b	b	b
Sympetrum danae	p	p	p	b	b	b	b	b
Total species	**10**	**10**	**12**	**12**	**9**	**11**	**10**	**9**

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