Limekiln Wind Farm:
Baseline fish survey

Commissioned Report to Nevis Environmental

December 2020

Waterside Ecology
Druimindarroch
Arisaig
Inverness-shire
PH39 4NR
T: 01687 450298
M: 07788717605
jon@watersideecology.co.uk

www.watersideecology.co.uk

Table of Contents **Page**

List of Tables **Page**

Limekiln Wind Farm, baseline fish survey 2020

Commissioned Report to: Nevis Environmental

Contractor: Waterside Ecology

Report authors: Isabel Isherwood & Jon Watt

SUMMARY

Background

This report provides a fish population monitoring baseline for the Limekiln Wind Farm, a consented development of 21 turbines south of the village of Reay in Caithness. The main watercourses on the site are Achvarasdal Burn along the eastern margin, Reay Burn which flows through the middle of the site, and Sandside Burn just outside the western margin of the site. Habitat surveys of Achvarasdal Burn and Reay Burn have been previously conducted by Waterside Ecology (Waterside Ecology 2012). Sandside Burn was surveyed for the first time as part of this study.

This report presents the results from the Sandside Burn habitat survey and from electric fishing surveys of all the three watercourses, carried out in August 2020

Methods

Fish populations in Achvarasdal Burn, Reay Burn and Sandside Burn were surveyed by electric fishing. Fish habitat in Sandside Burn was surveyed using a quantitative walkover method. Surveys were carried out by certified and experienced fieldworkers.

Main findings

- Electric fishing was carried out at five sites on Achvarasdal Burn (three impact, two control), three sites on Reay Burn (all impact) and three sites on Sandside Burn (two impact, one control).
- Trout fry and parr were caught at all sites (impact and control). Small numbers of salmon were caught on Achvarasdal Burn and Sandside Burn but not on Reay Burn.
- Trout fry and parr densities on Achvarasdal Burn were excellent by regional standards at all but the most upstream site, where parr densities were excellent but fry densities were poor.
- Trout parr densities on Reay burn were excellent by regional standards. Trout fry densities ranged from fair to excellent.
- Trout fry and parr densities on Sandside Burn varied considerably between sites, ranging from very poor to excellent.
- A single salmon fry was caught on Achvarasdal Burn, indicating successful spawning somewhere on the burn but perhaps at some distance from any of the electric fishing sites surveyed. No salmon parr were caught.
- Salmon fry and 2+ parr were caught on Sandside Burn. No 1+ parr were caught. Fry densities ranged from very poor to fair by regional standards. The lack of 1+ parr may suggest that successful spawning in Sandside Burn may not be an annual event.
- Eels were caught at all survey sites with the exception of AB4 on Achvarasdal Burn
- Sandside Burn offers good juvenile salmonid habitats and plentiful spawning opportunities.
- Comparison with data collected in 2012 suggests that there is considerable inter-annual variation in juvenile trout densities.

The findings are discussed in more detail below.

1 INTRODUCTION

1.1. Proposed development

This report provides a fish population monitoring baseline for the Limekiln Wind Farm, a consented development of 21 turbines south of the village of Reay in Caithness, in an area largely used for commercial forestry. The forested areas are densely planted and there is little development of a field layer except at the perimeter. The land has been ploughed for planting and the trees are planted on ridges; the habitat remnants in the firebreaks indicate that much of the original habitat prior to afforestation would have been blanket bog. The main watercourses on the site are the Achvarasdal Burn along the eastern margin, the Reay Burn which flows through the middle of the site, and the Sandside Burn just outside the western margin of the site. All three watercourses flow due north, meeting the sea in the vicinity of the village of Reay.

1.2. Fish populations

Waterside Ecology (2012) carried out fish habitat and population surveys in Achvarasdal Burn and Reay Burn, as part of the Environmental Impact Assessment process. Species present were brown trout *Salmo trutta*, Atlantic salmon *Salmo salar* and European eel *Anguilla anguilla*. Targeted surveys were carried out for lamprey larvae, but none were found. No other fish species were recorded.

Sandside Burn was not included in the 2012 surveys, and no historical data on fish populations are available. There are no reported barriers and the watercourse is thus considered to be accessible to migratory fish.

1.3. Rationale for survey

Marine Scotland Science (MSS) requested that a fully quantitative electric fishing survey of sites within and downstream of the development area should be carried out prior to construction. This was to include: i) establishment of fish population monitoring sites within the potentially impacted reaches of water courses on and downstream of the site and ii) establishment of control sites. Baseline fish monitoring sites were selected to harmonise with invertebrate monitoring sites (see Appendix 1).

2 AIMS AND OBJECTIVES

The aim of the current survey was to provide a monitoring baseline for fish populations in relation to the Limekiln Wind Farm. Specific objectives were to:

(i) Carry out a fish habitat survey in Sandside Burn, which was not included in the 2012 habitat surveys carried out for the Environmental Impact Assessment.

(ii) Identify suitable survey sites in Achvarasdal Burn, Reay Burn and Sandside Burn for baseline and future monitoring.

(iii) Identify suitable control sites on Achvarasdal Burn and Sandside Burn upstream of any possible impact from the proposed works (the headwaters of Reay Burn upstream of the development are too small to be suitable for control sites for fish, so none were proposed)

(iv) Carry out fully quantitative fish population surveys at identified sites.

3 METHODS

3.1. Site selection

A map showing the location of the 11 fish population monitoring sites is provided in Appendix 1. Sites were harmonised with invertebrate monitoring sites and are referred to on the map as ‘BM’ (Biological Monitoring sites) followed by the site codes used throughout this report.

Fish population data (Waterside Ecology 2012) were previously collected from Achvarasdal Burn and Reay Burn. Where possible these sites were retained for the baseline fish population survey. If the site was not repeatable, e.g. due to scouring and increased depth, a new site was established as close as possible to the original site. On Sandside Burn, sites were selected in suitable habitat based on the fish habitat data gathered as part of this survey. The full suite of baseline fish monitoring sites is set out in Table 1 below. Sites which repeat, or were re-established in close proximity to, 2012 sites are shown alongside the 2012 site code and grid reference.

Table 1 Baseline fish monitoring sites 2020, with corresponding 2012 sites.

Code	Stream	NGR	2012 code	2012 NGR
Impact sites				
AB3	Achvarasdal Burn	NC 99455 60607	A3	NC 9947 6061
AB4	Achvarasdal Burn	NC 98922 61907	A2	NC 9896 6201
AB5	Achvarasdal Burn	NC 98923 62683		
RB1	Reay Burn	NC 97435 60492	R3	NC 9749 6052
RB2	Reay Burn	NC 97331 61267	R2	NC 9729 6131
RB3	Reay Burn	NC 97116 62917	R1	NC 9711 6292
SB2	Sandside Burn	NC 96263 62422		
SB3	Sandside Burn	NC 96384 63250		
Control sites				
AB1	Achvarasdal Burn	NC 99604 57893		
AB2	Achvarasdal Burn	NC 99407 59093		
SB1	Sandside Burn	NC 96546 61552		

3.2. Electric fishing survey

The electric fishing survey took place on 22nd 23rd, 24th and 27th August 2020 under Scottish Government License CSM-20-098. Sites were surveyed using the fully quantitative (multi-run) method described by the SFCC (2014) protocol. Survey sites covered the full stream width and incorporated a representative range of suitable habitat types for salmonid fish. Water levels at the time of survey were low. All sites were surveyed using smooth DC from backpack electric fishing equipment. Further details of electric fishing sites and events are provided as Appendix 7.6. Sites were isolated with stop nets to prevent fish leaving or entering the site during the survey. Each site was fished through three times, allowing an estimate of total fish density to be calculated along with lower and upper 95% confidence limits.

Fish were captured in hand-held dip nets (30 cm and 60 cm diameter) and placed in clean water where they were held until ready for processing. Salmonid fork length was measured to the nearest 1 mm and eel total length was measured to the nearest 0.5 cm. Scales were collected from salmon and trout to assist with age determination. All fish were allowed to recover fully in clean water before being released back into the survey reach. Habitat descriptions at electric fishing survey sites were collected according to the SFCC protocol (SFCC 2014).

3.3. Habitat survey, Sandside Burn

The habitat survey of Sandside Burn was carried out on 26th August 2020. Survey conditions were good with low flows and good light. The survey was carried out using a quantitative walkover method, based on protocols described by Hendry and Cragg-Hine (1997), Summers *et al*. (1996) and SEPA (2010). These characterise in-stream habitats according to depth, substrate, flow and thus suitability for different age classes of salmonid fish (Table 2). Note that throughout this report the term ‘fry’ is used for salmonid fish in their first year of life (i.e. fish aged 0+ years). The term ‘parr’ is used for juvenile salmonid fish aged 1 year or older. Substrates are described using the Wentworth scale.

Table 2 Habitat categories used for walkover survey

Habitat category	Description
Fry habitat	For salmon, shallow fast flowing habitat with substrate of pebble and cobble. For trout, shallow slow flowing habitats with substrate of pebble and cobble.
Mixed juvenile habitat	Habitats with mixed depth and coarse substrates including cobble, boulder and pebble that provide cover for salmonid fry and parr. Depth typically 10 to 50 cm.
Productive glide	Low gradient channel with glide flow. Fish cover provided by some coarse substrates (pebble, cobble, boulder) and instream macrophytes.
Unproductive glide	Low gradient channel with glide flow and small substrates. Lacking cover for fish.
Pool	Slow or eddying current. Suitable for adult salmonids if cover is present. If >1 m deep cover may be less important, as depth can provide refuge.
Spawning	Ideally well oxygenated, stable & not compacted. Typically comprising gravel and pebble (also cobble for salmon). Sand & fine gravel (<2 mm) less than 20%. Not silted.

The survey was based on contiguous sections of varying length, generally between 200 m and 300 m. Within each section, data were collected on substrate composition, flow types and depths. Areas of each habitat category were marked on 1:10,000 maps of the watercourses in the field, using colour codes.

Areas of suitable spawning substrate were recorded using the SFCC protocol (SFCC 2007). The location of individual patches was recorded with GPS and marked on the field maps. Other variables recorded in each survey section were: (i) up and downstream grid reference, (ii) wet width, (iii), stability of substrate and compaction of substrate. The availability of cover for fish alongside banks was recorded as this can be an important factor in determining trout density, particularly in habitats where cover on the streambed is sparse. In addition, surveyors made subjective assessments of typical habitat quality for juvenile salmon and trout in each section, based on published habitat requirements and many years’ experience of electric fishing in streams throughout Scotland.

There are no recognised UK protocols for assessing habitat suitability for European eels. Eels have a very broad habitat niche and their main requirement other than a food source is cover. This may take the form of stones, roots or vegetation but eels also have the ability to bury themselves in soft streambeds. Target notes were maintained on likely habitat suitability for eels.

3.4. Analyses and data presentation

All fish densities are expressed as fish per 100 square metres of wetted stream area (fish.100m^{-2}). Salmonid densities are presented separately for fish aged 0+ years old, i.e. young of the year, and for fish aged 1 year or older. Throughout the report 0+ salmonids are referred to as fry and older juveniles as parr. Zippin densities were calculated using the programme Population Estimation by Removal Sampling (Pisces Ltd., version 2.2.2.22).

The classification provided by Godfrey (2006) is used to describe fish abundance in a national context. The classification is based on large data sets held by Scottish Fisheries Co-ordination Centre (SFCC). The quintile ranges of salmon and trout densities (Appendix 7.7) allow for comparison of fishery performance against nationally based reference points. The classification system is based on semi-quantitative fishing i.e. density based on number of fish captured during a single electric fishing run through an undisturbed site. Different classifications are provided for stream of various widths. The classification for stream of less than 6 m wet width was used throughout the current survey.

4 RESULTS

4.1. Sandside Burn fish habitat survey

Sandside Burn rises in moorland and blanket bog at around 200 m altitude, and flows roughly due north close to the western margin of the wind farm site to meet the sea at Sandside Bay near Reay. In its lower reaches the river passes through a conifer plantation badly affected by wind-throw, making access to this section extremely challenging and potentially unsafe.

Fish habitat in the Sandside Burn was surveyed from the upstream edge of the conifer plantation at NC 96259 62442 to NC 96622 61000, upstream of any potential impact from the wind farm development. Habitat within the conifer plantation was not surveyed fully due to the difficulty of accessing the watercourse, but spot-checks were made at points where access was feasible.

Although glide is typically considered to be a relatively unproductive habitat for juvenile fish, the glide flow types in the surveyed reach of the Sandside Burn offer excellent cover and would appear to provide good habitat for juvenile salmonids. For the purposes of this report, the habitat classifications ‘productive glide’ and ‘unproductive glide’ are used for glide with good cover from substrate and vegetation, and glide with poor cover, respectively.

The habitat in the surveyed reaches of the Sandside Burn is described below, and is shown in the map on Figure 1. Full details of the extent, distribution and quality of habitat types are provided in Appendices 7.2, 7.3 and 7.4. Photographs illustrating habitats typical of the surveyed reach are in Appendix 7.13.

The surveyed reach is characterised by short sections of shallow riffle and run (fry habitat) alternating with longer sections of productive shallow glide with a substrate of pebble, cobble and boulder, abundant macrophytes, and some extensive areas of emergent vegetation. There are frequent small pools to 0.5 m deep, and a single longer and somewhat deeper pool which will be a useful holding pool for adult fish.

In the upper to middle part of the surveyed reach, the river meanders strongly. On the outsides of these large bends, high eroding banks of fluvial or morainic sediments topped with a thick layer of peat deliver substantial amounts of clean small substrate to the watercourse, creating particularly good quality and sometimes quite extensive spawning areas. At the time of the survey peat fragments from the eroding banks did not appear to be deposited in these reaches and spawning habitat appeared of good quality.

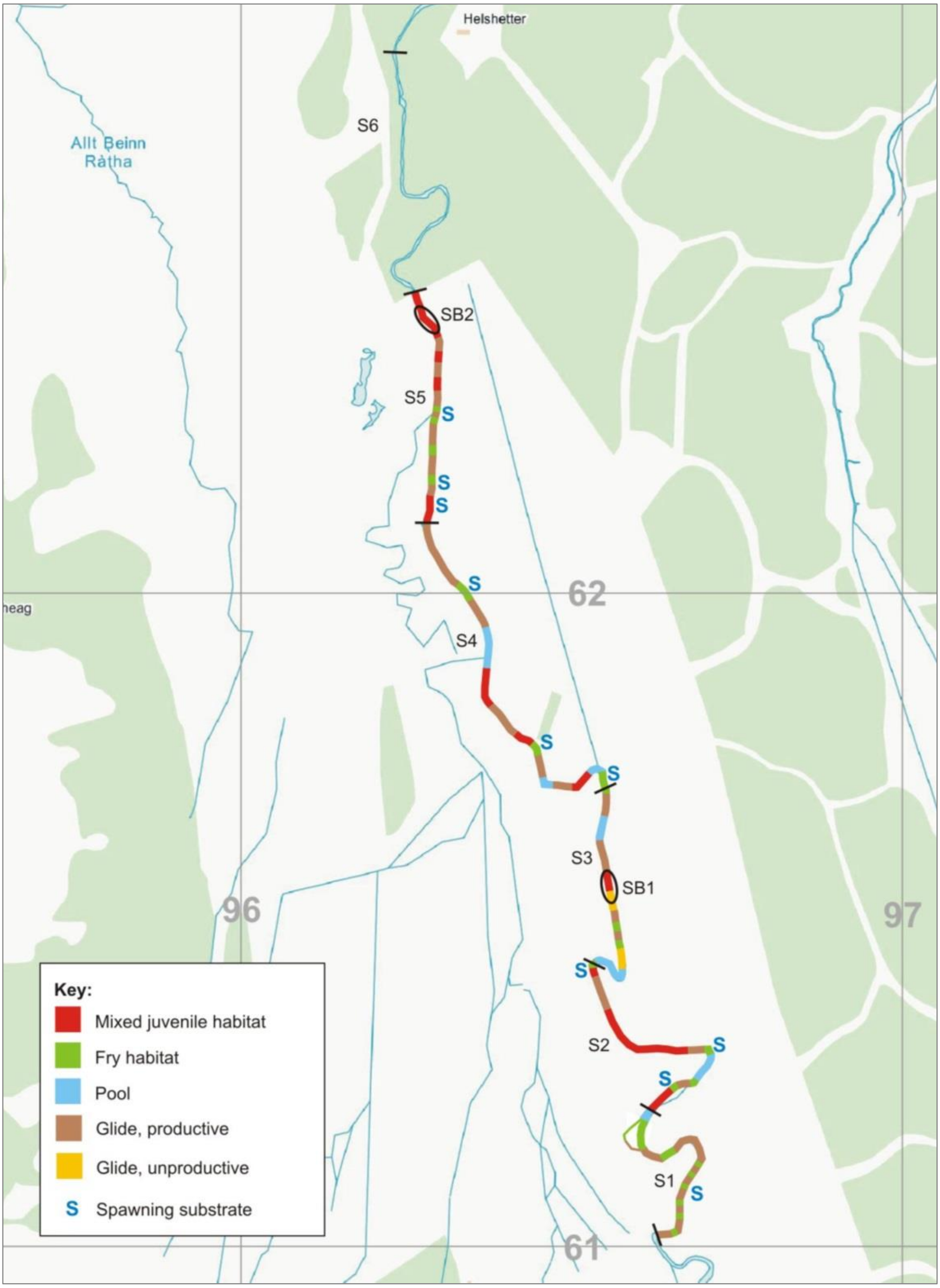
In the lower part of the surveyed reach, especially in the long straight section upstream of the conifer plantation, glide sections become deeper and cover from substrate and macrophytes becomes poorer (though these sections still offer relatively good cover and are classed as productive glide). There are only short sections of fry and mixed juvenile habitat between longer sections of glide. Flow is rather slow, and peat eroded from banks higher upstream is deposited here.

Spawning habitat is available throughout the surveyed reach where it flows through open ground. Full details of spawning areas recorded during the survey can be found in Appendix 7.5.

Table 3 Summary of habitat availability, Sandside Burn survey reaches

Length (m)	**Total area** (m^2)	**Estimated area of habitat type** (m^2)					**Spawning** (m^2)
		Fry	Mixed juvenile	Productive glide	Unproductive glide	Pool	
1820	6916	1445	1855	3115	315	915	147

Figure 1   Sandside Burn habitat survey sections and habitat distribution, showing the locations of electric fishing sites SB1 and SB2



Within the conifer plantation, access to the river is largely impossible due to extensive areas of windthrow. The first 100 m downstream of the watergate at NC 96622 61000 was surveyable, as was a section of about 30 m around NC 96223 62810 and approximately 40 m around the electric fishing site SB3 at NC 96384 63250. Habitat within the surveyed reaches is stable boulder-dominated mixed juvenile habitat, with good cover, run flow 10 to 30 cm deep, with a substrate of mixed boulder, cobble, pebble and gravel. At the electric fishing site the substrate included more bedrock and deeper pools as well as mixed juvenile habitat. No spawning habitat was noted at any of the accessible points. Conifers have been planted right up to the banks, and fallen trees have the potential to create obstacles if debris builds up against them to form dams.

4.2. Electric fishing survey: Potentially impacted sites

4.2.1. Achvarasdal Burn

Three impact sites were surveyed on Achvarasdal Burn. Trout fry and parr were present at all three sites (Table 4). A single salmon fry was caught at site AB4, indicating that salmon must have spawned successfully somewhere in the reach, but no other salmon fry or parr were caught.

Trout fry density exceeded parr density at all sites, and both fry and parr densities were classified excellent by regional standards. Parr density classifications were also excellent, although the density of 9.2 parr per 100 square metres recorded at site AB4 is towards the lower end of the excellent category.

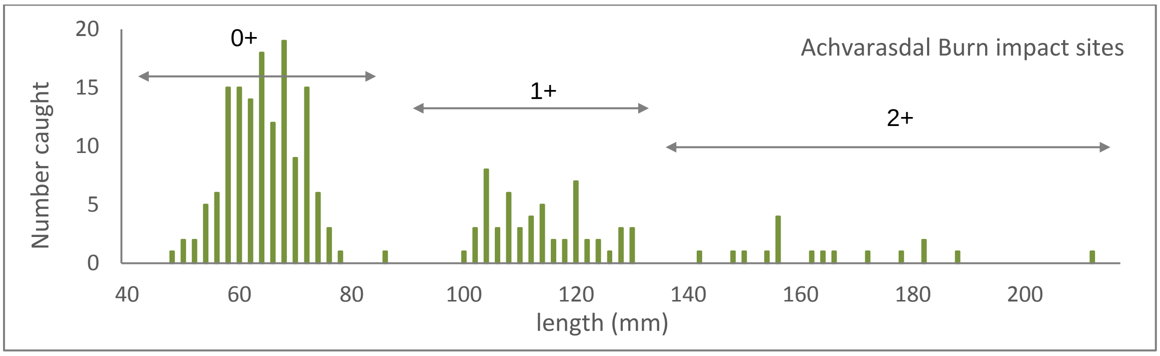
Table 4 Achvarasdal Burn, trout densities, impact sites

Site	**Fry density** (fish.100m^{-2})		**Parr density** (fish.100m^{-2})		**Classification**	
	Single run	Zippin*	Single run	Zippin*	Fry	Parr
AB3	32.7	48.3	20.8	23.8	Excellent	Excellent
AB4	30.7	48.5	9.2	16.7	Excellent	Excellent
AB5	28.4	38.0	16.7	28.5	Excellent	Excellent

*see Appendix 7.9 for confidence linits around Zippin densities

The fry (0+) year class was well defined, ranging in length from to 51 mm to 86 mm, and showed no overlap with the 1+ year class (Figure 2). The 1+ year class ranged from 100 mm to 130 mm. Insufficient scales were taken from larger fish to identify how many older year classes were present; the largest trout caught was 211 mm in length and is likely to have been aged at least 3+.

Figure 2 Length distribution of trout, Achvarasdal Burn, impact sites



Two eels were caught at site AB3 and one at site AB5 (Appendix 7.12). No other fish species were recorded.

4.2.2. Reay Burn

Three sites were surveyed on Reay Burn, all of which have the potential to be impacted by the wind farm development. Trout were present at all three sites (Table 5), but salmon were not recorded. Trout parr densities were classified as excellent throughout. Fry densities ranged from fair to excellent. Fry density exceeded parr density at site RB2 (fry and parr both classed as excellent), but parr density exceeded that of fry at sites RB1 and RB3. Cover for parr was good throughout, with plentiful overhead shelter alongside the banks from undercuts and draped vegetation (see Appendix 7.10).

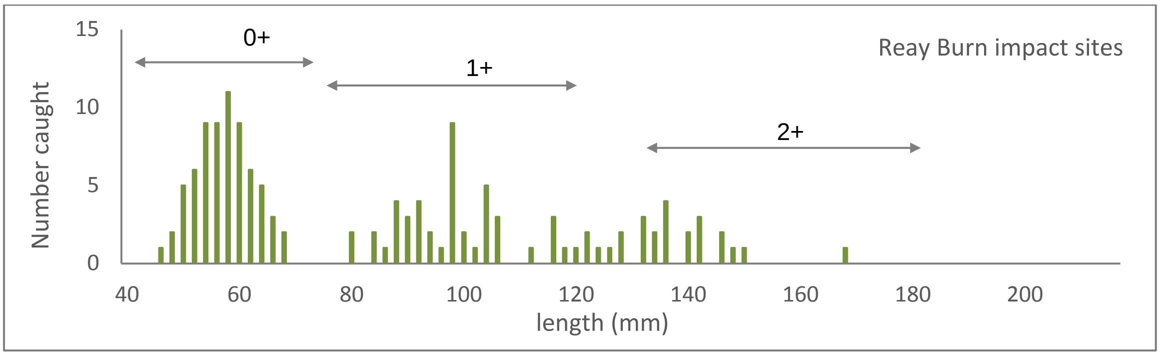
Table 5 Trout densities, Reay Burn catchment, impact sites

Site	**Fry density** (fish.100m^{-2})		**Parr density** (fish.100m^{-2})		**Classification**	
	Single run	Zippin	Single run	Zippin	Fry	Parr
RB1	8.0	13.07	21.6	26.2	Fair	Excellent
RB2	28.8	51.83	19.2	35.7	Excellent	Excellent
RB3	9.8	13.26	16.3	21.1*	Good	Excellent

*Model rejected, depletion not consistent

Trout fry in Reay Burn were rather smaller than those in the neighbouring Achvarasdal Burn, ranging in length from 46 m to 68 mm (Figure 3). Slow growth made scales challenging to read, but the 1+ parr year class appeared to range from 80 mm to the mid-120s, with larger parr likely to represent 2+ and possibly also 3+ year classes. There was a clear break between fry and parr lengths.

Figure 3 Length distribution of trout, Reay Burn, impact sites



Eels were caught at all sites but were more numerous downstream, with two at site RB1, four at RB2 and nine at RB3 (Appendix 12).

4.2.3. Sandside Burn

Two sites with the potential to be impacted by the wind farm development were surveyed on Sandside Burn. Salmon, trout and eels were caught at all three sites.

4.2.3.1. Salmon

Salmon fry were caught at both sites SB2 and SB3, with densities classified as very poor and fair respectively. A single parr was caught at SB3, giving a classification of very poor; no parr were caught at SB2.

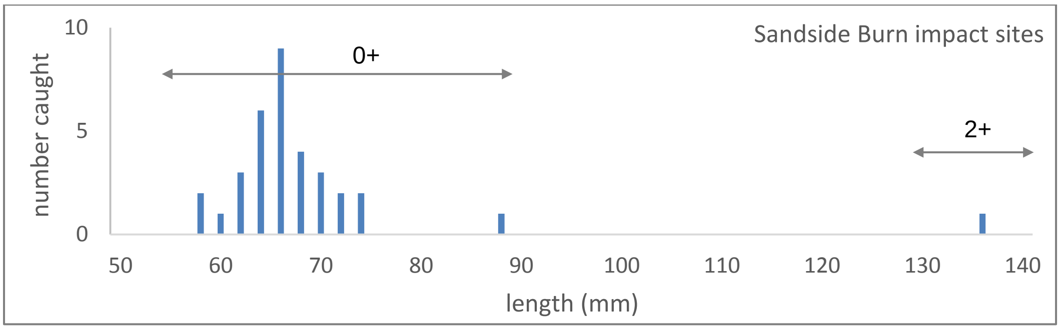
Table 6 Salmon densities, Sandside Burn, impact sites

Site	**Fry density** (fish.100m^{-2})		**Parr density** (fish.100m^{-2})		**Classification**	
	Single run	Zippin	Single run	Zippin	Fry	Parr
SB2	3.8	9.10	0.0	0.0	Very Poor	Absent
SB3	12.0	16.6*	0.7	0.7	Fair	Very Poor

*Model rejected, depletion not consistent

Salmon fry ranged in length from 57 mm to 88 mm in length. The single parr caught was 135 mm in length, and scale reading confirmed that this was a 2+ individual (Figure 4). No 1+ salmon were caught, suggesting that perhaps salmon do not spawn successfully in or around the surveyed reach of Sandside Burn every year.

Figure 4 Length distribution of salmon, Sandside Burn, impact sites



4.2.3.2. Trout

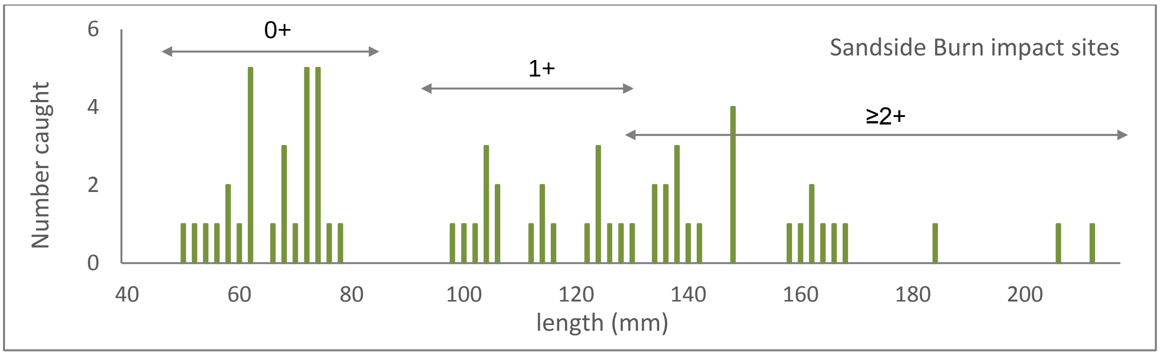
Trout fry density exceeded parr density at SB2, where fry and parr densities were classified as excellent and good respectively. However parr density was substantially greater than fry density at SB3, where parr density was classified as excellent but fry as very poor (Table 7). The high parr density at SB3 probably reflects the presence of deep pool habitat and plentiful cover amongst roots and woody debris at this location (Appendix 7.10). The low fry density may be a consequence of a relative lack of good spawning habitat in the reaches immediately up and downstream of the site, but due to the impenetrability of the wind-thrown conifers this is uncertain. Spawning habitat was plentiful further upstream around SB2 and control site SB1.

Table 7 Trout densities, Sandside Burn, impact sites

Site	**Fry density** (fish.100m^{-2})		**Parr density** (fish.100m^{-2})		**Classification**	
	Single run	Zippin	Single run	Zippin	Fry	Parr
SB2	13.3	18.6	7.6	8.5	Excellent	Good
SB3	2.0	6.7	14.7	21.1	Very Poor	Excellent

Trout fry in Sandside Burn ranged in length from 49 m to 78 mm (Figure 5). There was no overlap with the 1+ parr age class, which ranged from the high 90s to the mid-120s. All scales read from parr over 130 mm referred to individuals at least two years old, however insufficient scales were taken to allow further age classes to be identified. It is likely that the two fish over 200 mm that were caught are at least 3+.

Figure 5 Length distribution of trout, Sandside Burn, impact sites



4.2.3.3. Other fish species

Six eels were caught at site SB2 and two at SB3. No other fish species were recorded during the survey. Spot checks for lampreys in suitable habitat at SB3 found none.

4.3. Electric fishing survey: Control sites

4.3.1. Achvarasdal Burn

Two control sites were surveyed, coded AB1 and AB2. Fry and parr densities were both classified as excellent at site AB2, with fry densities greater than parr densities. Site AB1 had very high parr densities and was also classified as excellent, but fry were quite scarce here and the density was classified as poor. AB1 is the most upstream site of the five surveyed on the Achvarasdal Burn; it is just downstream of a higher gradient reach, and there is some substantial bank erosion in the area; it is possible that winter spates might have a greater impact in this reach than at sites further down the watercourse where the gradient is slight and the watercourse very stable, with implications for redd stability and habitat for young fry.

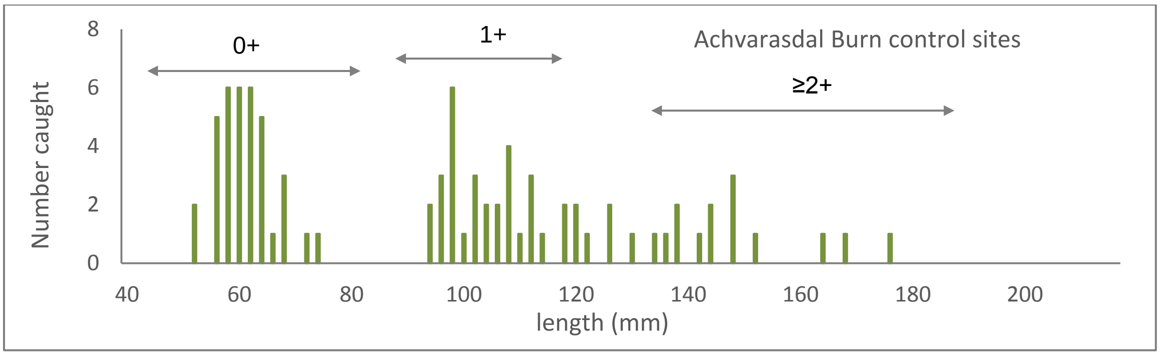
Table 8 Trout densities, Achvarasdal Burn control sites

Site	**Fry density** (fish.100m^{-2})		**Parr density** (fish.100m^{-2})		**Classification**	
	Single run	Zippin	Single run	Zippin	Fry	Parr
AB1	4.4	12.4*	16.7	23.17	Poor	Excellent
AB2	19.2	26.8	16.3	30.48	Excellent	Excellent

*Model rejected, depletion not consistent

Trout fry in the Achvarasdal Burn control sites were slightly smaller than those further downstream in the potentially impacted reaches, ranging from 51 mm to 73 mm (Figure 6). Fry and parr were clearly differentiated, with the 1+ parr age class beginning at 94 mm. Insufficient readable scales were collected to allow the break between 1+ and 2+ to be clearly identified, but an individual at 138 mm was identified as a 2+ parr.

Figure 6 Length distribution of trout, Achvarasdal Burn control sites



Eels were recorded at both of the two control sites, one at AB1 and two at AB2 (Appendix 12).

4.3.2. Sandside Burn

4.3.2.1. Salmon

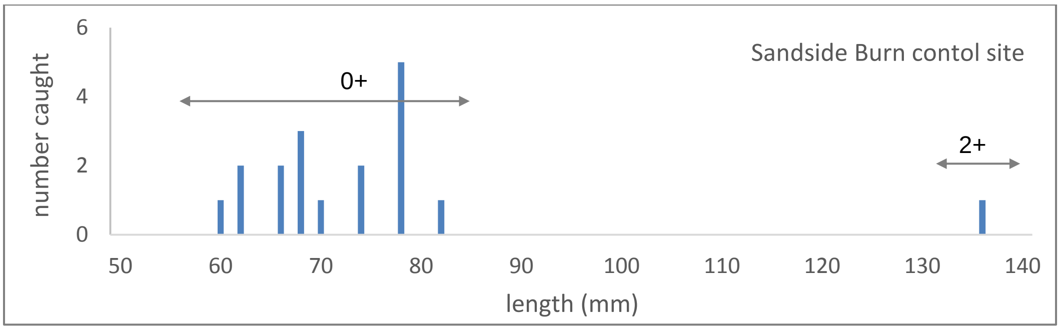
Salmon fry were caught in moderate numbers at the control site on Sandside Burn, but only a single parr was captured. Fry densities were classified as fair, and parr as very poor.

Table 9 Salmon densities, Sandside Burn control site

Site	**Fry density** (fish.100m^{-2})		**Parr density** (fish.100m^{-2})		**Classification**	
	Single run	Zippin	Single run	Zippin	Fry	Parr
SB1	11.6	17.15	0	0	Fair	Very poor

As at impact site SB3, the single parr captured was rather large (135 mm) and scale reading confirmed that it was a 2+ individual. Thus at both control and impact sites the 2+ year class appears to be missing, indicating that salmon probably do not spawn successfully in Sandside Burn every year.

Figure 7 Length distribution of salmon, Sandside Burn control sites



4.3.2.2. Trout

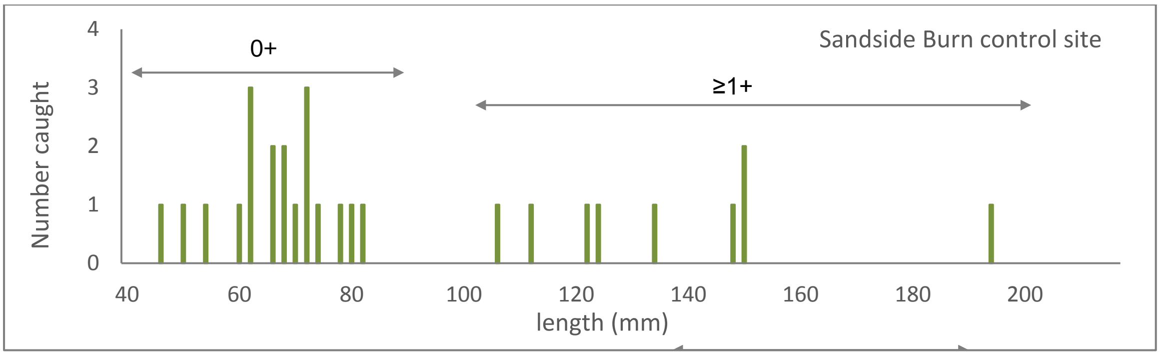
Trout fry and parr were both caught in moderate numbers at control site SB1. Fry density was higher than parr density, and fry were classified as good while parr came out as fair.

Table 10 Trout densities, Sandside Burn control site

Site	**Fry density** (fish.100m^{-2})		**Parr density** (fish.100m^{-2})		**Classification**	
	Single run	Zippin	Single run	Zippin	Fry	Parr
SB1	11.6	15.9	5.8	7.6	Good	Fair

Fry and 1+ parr were clearly differentiated (Figure 8), however insufficient scales were taken to allow a break between 1+ and 2+ parr to be identified. A single large parr (194 mm) was likely to be aged at least a 2+.

Figure 8 Length distribution of trout, Sandside Burn control site



4.3.2.3. Other fish species

Four eels were caught at site SB1 (Appendix 12). No other fish species were recorded during the survey. Spot checks for lampreys found none.

5 DISCUSSION

5.1. Data quality

Water levels were low and conditions were good for both the habitat survey and the electric fishing survey. The depletions attained (Appendix 7.8) suggest that electric fishing was effective and that efficiency was mainly high. Reasonably consistent depletions were attained for most species and age classes at most sites, permitting calculation of confidence limits for density estimates (Appendix 7.9).

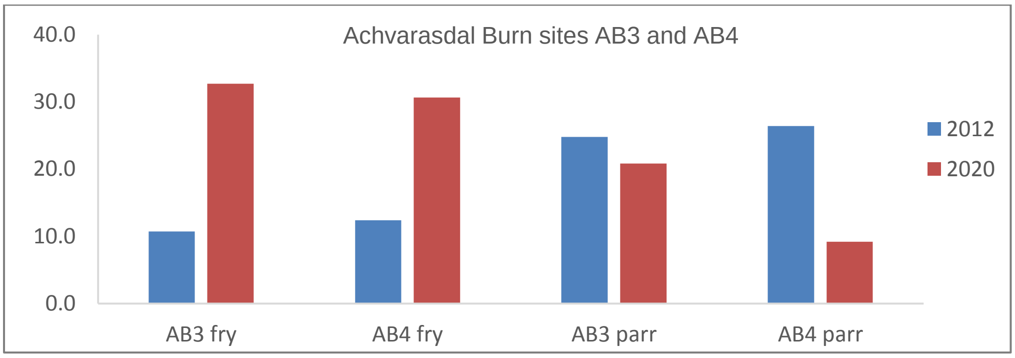
5.2. Comparison with previous surveys

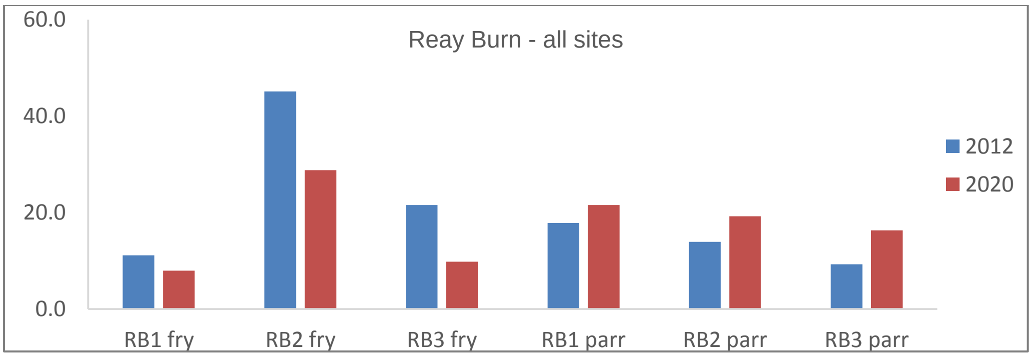
Waterside Ecology surveyed a number of sites on Achvarasdal Burn and Reay Burn in 2012 (see Table 1). Two sites on Achvarasdal Burn (AB3 and AB4) were fully or partially re-surveyed in 2020. No sites on Reay Burn were resurveyed, but all three sites surveyed in 2020 were within 100 m of sites surveyed in 2012. The 2012 survey mainly used semi-quantitative (single run) methods (see Appendix 7.11 for single run data). Single run densities for trout from the five repeat-surveyed sites and reaches in 2012 and 2020 are reproduced in Figure 9 below. Although only two datasets from widely-separated years are available, it is nevertheless clear that there is considerable annual variation in both burns, and that a good year for one burn may be a poor year for the other, and vice versa. On Achvarasdal Burn fry were at substantially higher densities in 2020 than in 2012, while parr were at lower density in 2020 than in 2012. This observed pattern was true of both repeat sites.

On Reay Burn the reverse pattern was observed, with fry densities in 2020 being lower at all three reaches than they were in 2012, while parr densities were consistently higher.

Changes in density may simply be a reflection of normal inter-annual variation or may be due e.g. to changes in the distribution of spawning effort or changes in the numbers of sea trout versus resident trout spawning in each burn in any given year. It is not possible to distinguish between these possibilities based on current data. Nevertheless, the data strongly suggest that trout numbers cannot be expected to be stable over time. This has implications for the interpretation of future monitoring data.

Figure 9 Past and current single run densities at repeat reaches on Achvarasdal and Reay Burns





5.3. Detecting future change

Repeat surveys in monitored streams show that changes in fish abundance may occur without perturbation from construction activity. Monitoring and the ability to detect impact are enhanced by the inclusion of three control sites in the current monitoring programme. While fish populations at these control sites show many similarities with impact monitoring sites, the impact and control streams may be individually affected by variables unrelated to wind farm construction or operation. Thus any future change in fish numbers may not, of itself, provide compelling evidence of wind farm impacts without corroborating evidence from control sites, hydrochemical monitoring or direct observations of incidents e.g. by an Ecological Clerks of Works.

6 REFERENCES

Godfrey, J. D. 2006. Site condition monitoring of Atlantic salmon cSACs. Commissioned report to Scottish Natural Heritage, December 2006. Scottish Fisheries Co-ordination Centre, Pitlochry.

Marine Scotland Science. 2018. Generic Monitoring Programme for Monitoring Watercourses in relation to Onshore Wind Farm Developments. August 2018.

SEPA. 2010. Guidance for applicants on supporting information requirements for hydropower applications. Scottish Environment Protection Agency.

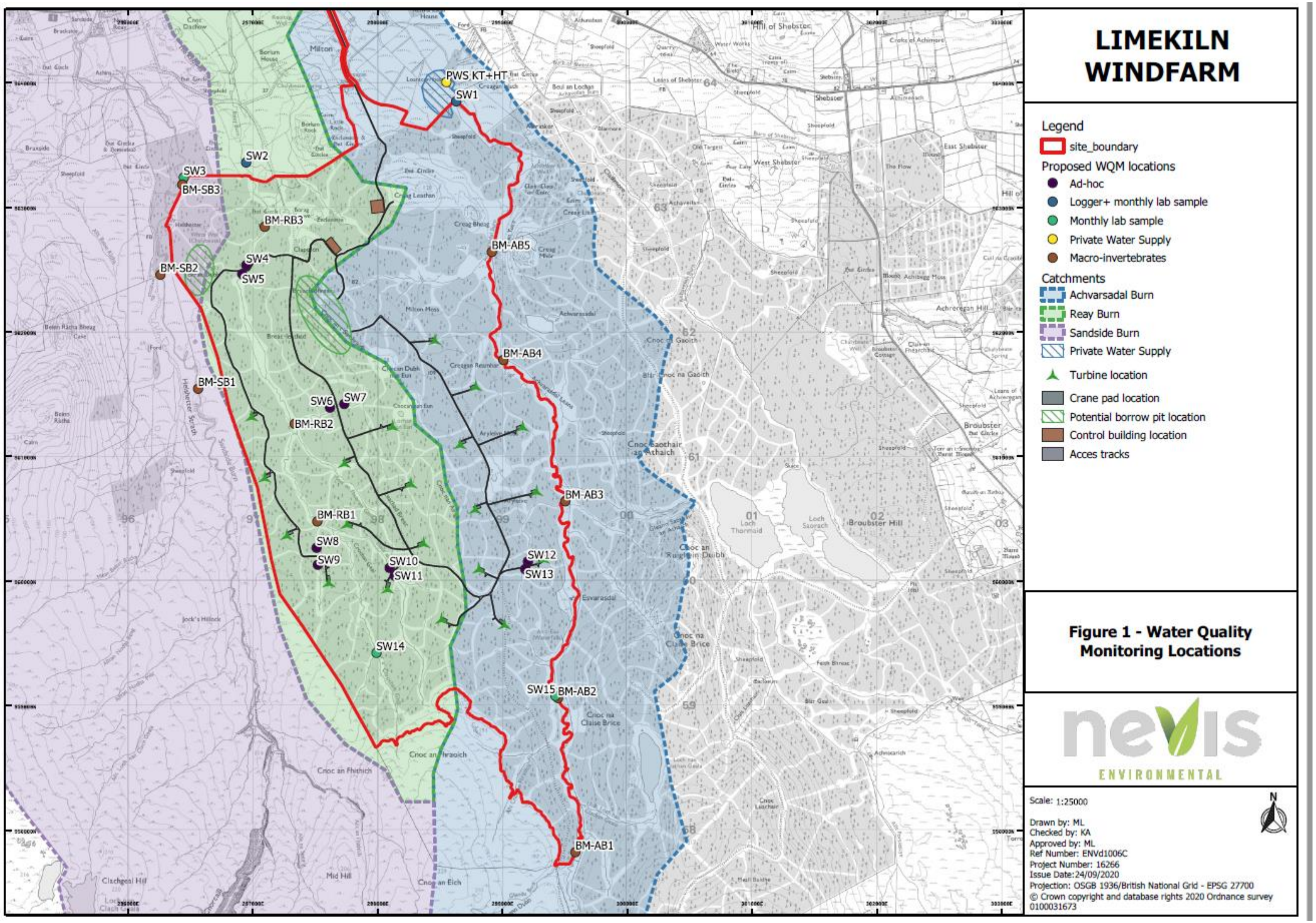
SFCC. 2007. Scottish Fisheries Co-ordination Centre Habitat Surveys Training Course Manual.

SFCC. 2014. Team Leader Electrofishing: manage electrofishing operations. Inverness & Barony Colleges. April 2014.

Waterside Ecology. 2012. Limekiln Wind Farm: Survey of fish and fish habitats. Commissioned report to Infinergy Ltd., August 2012.

7 APPENDICES

7.1. Limekiln Wind Farm, proposed layout and monitoring sites



7.2. Stream survey sections and habitat descriptions

Watercourse	Section code	NGR		Instream habitats	Banks
		Downstream	Upstream		
Sandside Burn	S1	NC 96628 61207	NC 96622 61000	Alternating short (5-10 m) sections of shallow riffle/run and productive shallow glide over pebble and cobble. Small deeper pools. Abundant macrophytes in glides. Exposed mossy cobble and boulders in runs. Lots of filamentous algae. Plenty of cover, fish abundant. Depths 5-20 cm in runs, to 50 cm in pools. Pocket spawning.	Some cover from undercuts and draped vegetation but also erosion on outsides of bends and some side and point bars inside bends.
Sandside Burn	S2	NC 96529 61420	NC 96628 61207	Shallow run and glide over cobble and pebble, more boulder in the mix at the top of the section, more gravel towards the lower end. Downstream 40 m is very unusual mix of shallow run and glide through dense emergent and instream vegetation and macrophytes. Good spawning at eroding bends. Depths generally less than 20 cm deep, excluding in pools.	Erosion and deposition on bends, straight sections more stable. High banks at bends have 1.5 m of peat over glacial/river deposits. Latter produces good spawning substrates, former adds peat fragments to the watercourse.
Sandside Burn	S3	NC 96558 61696	NC 96529 61420	As previous section, except some of the glides offer poorer cover and are not likely to be very productive	As previous section
Sandside Burn	S4	NC 96274 62080	NC 96558 61696	Long glide sections with some moderate cover from cobble and pebbles plus macrophytes and filamentous algae. Not as productive as shallower glides upstream. Parr seen. Depth in glides is up to 30 cm.	Banks mainly stable, low and grassy, some undercuts
Sandside Burn	S5	NC 96259 62442	NC 96274 62080	This reach holds long stretches of productive glide (moderate not good) 30-40 cm deep. Boulder and cobble substrate, silted (or peat fragments from eroding banks upstream). Short MJ riffles between glides. Spawning at riffles. Bouldery MJ here is uncharacteristic of the rest of the section.	Banks mainly stable, low and grassy, some undercuts
Sandside Burn	S6	NC 96223 62810	NC 96259 62442	This reach flows through conifer plantation with much windthrow, large sections inaccessible to survey. Accessible reaches are boulder-dominated mixed juvenile habitat, excellent juvenile salmon habitat stable with good cover 10-30 cm deep, substrate of mixed boulder, cobble, pebble and gravel.	Conifers planted right up to banks, fallen trees have potential to create obstacles if debris builds to form dams

7.3. Stream survey data and habitat quality assessments

Section code	% visible streambed	Length (m)	Width (m)		Substrate		Instream cover	Bankside cover (% of bank length)		Quality for salmon		Quality for trout	
			Wet	Bank	Stability	Compaction		left	right	Fry	Parr	Fry	Parr
S1	100	320	3	3.5	Stable	Uncompacted	good	10-25	10-25	good	moderate	good	good
S2	100	350	3.5	4	Stable	Uncompacted	good	10-25	10-25	good	moderate	good	good
S3	100	360	4.5	5	Stable	Uncompacted	moderate	10-25	10-25	good	moderate	good	good
S4	100	580	4	4.2	Stable	Uncompacted	moderate	10-25	10-25	good	moderate	good	good
S5	100	380	4	4.2	Stable	Uncompacted	moderate	10-25	10-25	moderate	moderate	good	good
S6	100		5.5	6	Stable	Uncompacted	good	<10	<10	good	good	good	good

7.4. Wetted area of each habitat category in survey sections

Section	Wetted area (m^2)					
	Fry	Mixed juvenile	Productive glide	Unproductive glide	Pool	Spawning
S1	420	0	480	0	60	0
S2	140	595	385	0	105	38
S3	405	180	450	315	270	35
S4	280	520	1040	0	480	29
S5	200	560	760	0	0	45
S6	Not fully surveyed					

7.5. Spawning habitats identified during survey

Watercourse	Section	NGR	Area (m^2)	Washout*	Suitability		Notes
					Salmon	Trout	
Sandside Burn	S2	NC 96679 61235	8	no	yes	yes	Good clean pebble riffle, shallow flow, stable.
Sandside Burn	S2	NC 96714 61290	30	no	mod	good	Eroding banks provide clean pebble and gravel, excellent spawning for both salmon and trout (better for trout due to small grainsize)
Sandside Burn	S3	NC 96566 61413	35	no	good	good	Excellent clean pebble, gravel and cobble. Some patches better suited to salmon, others to trout. In braided reach at eroding bend.
Sandside Burn	S4	NC 96558 61696	10	no	good	good	As previous. Apex of eroding bend, provides clean material for spawning
Sandside Burn	S4	NC 96434 61759	4	no	yes	yes	
Sandside Burn	S4	NC 96338 62007	15	no	yes	yes	
Sandside Burn	S5	NC 96287 62114	15	no	yes	yes	In run at top of glide, cobble and pebble, moderate quality
Sandside Burn	S5	NC 96286 62148	10	no	yes	yes	
Sandside Burn	S5	various	20	no	yes	yes	
Sandside Burn	S6	various					Likely to hold spawning but largely un-surveyable due to wind-thrown trees.

7.6. Electric fishing site and event details

IMPACT MONITORING SITES

Code	Stream	NGR	Date surveyed	Location	Length (m)	Width (m)	Volts	Conductivity (µS.cm^{-1})	Temp (°C)	Level	Colour
AB3	Achvarasdal Burn	NC 99455 60607	23/08/2020	Start at inflow to deep corner pool on right-hand bend	35	2.9	140	263	17.0	low	slightly coloured
AB4	Achvarasdal Burn	NC 98922 61907	23/08/2020	Downstream end is shallow riffle at the top of a broad glide	45	2.9	140	282	14	low	slightly coloured
AB5	Achvarasdal Burn	NC 98923 62683	23/08/2020	Bottom of site is 7 m upstream of watergate	40	2.6	160	288	16.0	low	slightly coloured
SB2	Sandside Burn	NC 96263 62422	24/08/2020	Start at triangular boulder by left bank approximately 20 m upstream of water gate. Top is top of riffle, small right bank boulder.	24	4.4	240	163	16.0	low	clear
SB3	Sandside Burn	NC 96384 63250	24/08/2020	Start at narrow 'neck' of pool downstream of bedrock step. Stop at line (right angles to bank) through riffle, under BR leaning multi-stem birch.	35	4.3	180	167	12	low	clear
RB1	Reay Burn	NC 97435 60492	22/08/2020	Top of site is small left bank tributary	69	1.3	120	252	14	low	coloured
RB2	Reay Burn	NC 97331 61267	22/08/2020	Start at constriction at upstream end of broad glide (at bottom of ride). Top is on left bend 15 m downstream from big corner pool, NC 97348 61195	75	1.1	140	249	13	low	coloured
RB3	Reay Burn	NC 97116 62917	27/08/2020	Top of site is runout of big pool. Downstream is immediately upstream of wee path crossing and red post	51	1.8	190	262	12.5	low	coloured

CONTROL SITES

Code	Stream	NGR	Date surveyed	Location	Length (m)	Width (m)	Volts	Conductivity (µS.cm^{-1})	Temp (°C)	Level	Colour
AB1	Achvarasdal Burn	NC 99604 57893	23/08/2020	Start at top of small island above sharp right-hand bend. Top is shallow riffle at top of eroded bend.	53	2.2	140	204	14	low	slightly coloured
AB2	Achvarasdal Burn	NC 99407 59093	23/08/2020	Start at top of riffle downstream of top pool on Z bend	50	2.1	130	226	14.0	low	slightly coloured
SB1	Sandside Burn	NC 96546 61552	24/08/2020	Start at bottom of short section of riffle/glide with exposed boulder, 2m up from bottom of exposed eroded heather-topped bank-face set 1 m back from left bank. Top is very small riffle in glide section upstream.	26	4.7	240	163	16.0	low	clear

7.7. Salmonid density classification system for watercourses of <6 m wet width in North Region (Godfrey 2006).

	Density (fish.100m^{-2})			
	Salmon 0+	Salmon 1++	Trout 0+	Trout 1++
Min	1.0	1.2	1.0	1.2
20th percentile	7.1	1.7	4.4	3.0
40th percentile	9.3	4.6	5.2	4.4
60th percentile	12.7	8.5	8.5	7.1
80th percentile	20.1	13.0	12.6	8.6
Max	48.9	21.3	98.5	14.7

Density in regional classification	**Descriptive category used in text**
Min to 20th percentile	Very poor
20th to 40th percentile	Poor
40th to 60th percentile	Moderate
60th to 80th percentile	Good
80th to 100th percentile	Excellent

The classification is based on large data sets held by SFCC. The quintile densities allow for comparison of fishery performance against regionally based reference points. Classifications are based on single run minimum densities.

7.8. Numbers of fish caught during consecutive electric fishing runs

Site	Salmon fry			Salmon parr			Trout fry			Trout parr			Total (all fish)		
	run 1	run 2	run 3	run 1	run 2	run 3	run 1	run 2	run 3	run 1	run 2	run 3	run 1	run 2	run 3
AB1	0	0	0	0	0	0	5	1	3	19	3	1	24	4	4
AB2	0	0	0	0	0	0	20	4	3	17	5	5	37	9	8
AB3	0	0	0	0	0	0	33	10	4	21	3	0	54	13	4
AB4	1	0	0	0	0	0	40	14	6	12	6	2	53	20	8
AB5	0	0	0	0	0	0	29	6	3	17	7	3	46	13	6
SB1	14	2	1	0	1	0	14	5	0	7	1	1	35	9	2
SB2	4	3	1	0	0	0	14	3	2	8	1	0	26	7	3
SB3	18	3	3	1	0	0	3	3	4	22	8	1	44	14	8
RB1	0	0	0	0	0	0	7	4	1	19	4	0	26	8	1
RB2	0	0	0	0	0	0	24	11	8	16	8	3	40	19	11
RB3	0	0	0	0	0	0	9	4	0	15	2	2	24	6	2

7.9. Lower and upper 95% confidence limits for fish densities

Site	**Salmon fry** (fish.100 m^{-2})		**Salmon parr** (fish.100 m^{-2})		**Trout fry** (fish.100 m^{-2})		**Trout parr** (fish.100 m^{-2})	
	Lower 95%	Upper 95%	Lower 95%	Upper 95%	Lower 95%	Upper 95%	Lower 95%	Upper 95%
AB1					7.9*	30.3*	20.2	21.1
AB2					25.9	29.3	25.9	36.2
AB3					46.6	52.0	23.8	24.2
AB4					46.0	52.8	15.3	20.2
AB5					37.3	40.3	26.5	33.3
SB1	14.0	14.9	0.0	0.0	15.7	16.8	7.4	8.6
SB2	7.6	14.8	0.0	0.0	18.0	20.6	8.5	8.7
SB3	16.0*	18.3*	0.0	0.7	14.5*		20.7	22.6
RB1					13.6	18.9	26.1	27.0
RB2					51.7	79.4	32.4	42.8
RB3					14.2	15.8	20.7*	22.9*

*The model was rejected for these age classes/species on these runs due to inconsistent depletions, hence confidence limits cannot be calculated reliably

7.10. Instream habitats at electric fishing sites

SITE	DEPTH						SUBSTRATE								FLOW TYPES								
	<10	*11-20*	*21-30*	*31-40*	*41-50*	*>50*	*HO*	*SI*	*SA*	*GR*	*PE*	*CO*	*BO*	*BE*	*OB*	*SM*	*DP*	*SP*	*DG*	*SG*	*RU*	*RI*	*TO*
AB1	25	65	10	0	0	0	0	0	5	15	20	20	30	5	0	5	0	0	0	45	45	5	0
AB2	10	20	30	25	10	5	0	0	5	20	35	40	5	0	0	3	5	5	10	55	20	2	0
AB3	5	35	40	15	5	0	0	0	5	10	15	20	50	0	0	2	20	15	0	10	45	8	0
AB4	5	10	50	30	5	0	0	0	5	5	20	45	25	0	0	0	0	0	0	5	90	5	0
AB5	10	30	40	15	5	0	0	0	5	10	10	20	40	15	0	5	0	0	10	40	40	5	0
SB1	30	55	15	0	0	0	0	0	10	25	35	15	15	0	0	10	0	0	0	45	45	0	0
SB2	30	45	20	5	0	0	0	0	10	20	25	30	15	0	0	10	0	0	0	35	53	2	0
SB3	12	20	35	20	10	3	0	0	5	15	25	35	20	5	0	10	30	25	0	10	20	5	0
RB1	10	35	40	10	5	0	0	0	5	25	20	30	20	0	0	3	15	25	0	30	35	2	0
RB2	5	40	50	5	0	0	0	0	15	15	30	30	10	0	0	5	5	10	0	35	40	5	0
RB3	10	45	20	20	5	0	0	0	8	2	5	45	40	0	0	5	25	25	0	0	45	5	0

Substrates: HO = high organic (peat); SI = silt; SA = sand; GR = gravel; PE = pebble; CO = cobble; BO = boulder; BE = bedrock; OB = obscured.
Flow types: SM = shallow marginal; DP = deep pool; SP = shallow pool; DG = deep glide; SG = shallow glide; RU = run; RI = riffle; TO = torrent.

SITE	Left Bank				Right Bank			
	UC	DR	BA	MA	UC	DR	BA	MA
AB1	15	0	80	5	30	0	65	5
AB2	50	10	40	0	50	0	50	0
AB3	80	0	20	0	80	0	20	0
AB4	70	50	30	0	70	50	30	0
AB5	70	5	25	0	0	5	25	0
SB1	50	0	50	0	10	0	90	0
SB2	20	0	80	0	10	0	90	0
SB3	0	20	60	20	0	0	100	0
RB1	70	0	30	0	70	0	30	0
RB2	95	80	5	0	95	80	5	0
RB3	20	0	80	0	25	0	75	0

Bankside fish cover: UC = undercut bank; DR = draped vegetation; BA = bare (no cover); MA = marginal vegetation (incl. tree toots).

7.11. 2012 electric fishing sites and single-run densities for trout

2012 site code	NGR	Watercourse	2012 density (fish.100m^{-2})		Notes	2020 site code
			fry	parr		
A3	NC 9947 6061	Achvarasdal Burn	10.7	24.8	Within 100m	AB3
A2	NC 9896 6201	Achvarasdal Burn	12.4	26.4	Within 100m	AB4
R3	NC 9749 6052	Reay Burn	11.2	17.9	Within 100m	RB1
R2	NC 9729 6131	Reay Burn	45.1	14.0	Within 100m	RB2
R1	NC 9711 6292	Reay Burn	21.6	9.3	Repeat site	RB3

7.12. Eel numbers and sizes at electric fishing sites

Length of individual eels (mm)										
AB1	AB2	AB3	AB4	AB5	SB1	SB2	SB3	RB1	RB2	RB3
(1 not caught)	(2 not caught)	360	no eels	320	190	160	220	200	290	205
		213			195	170	340	210	(3 not caught)	225
					340	125				310
					(1 not caught)	155				(6 not caught)
						160				
						180				

7.13. Sandside Burn habitat survey photographs

	Section SB1 NC 9662 6100 The habitat is mainly productive glide broken by short sections of fry or habitat with shallow run flow
	Section SB2 NC 9662 6121 Productive glide habitat with abundant macrophytes
	Section SB2 NC 9654 6137 Productive glide habitat with emergent vegetation

	Section SB2 NC 9672 6189 Fry habitat and spawning habitat at the tail of a pool. Erosion at bends adds both clean substrate and peat fragments to the watercourse
	Section SB3 NC 9625 6208 Alternating shallow riffles and glides.
	Section SB3 NC 9657 6141 Fry habitat and spawning

	Section SB4 NC 9627 6208 Mixed juvenile habitat
	Section SB5 NC 9629 6239 Long glides broken by short sections of mixed juvenile habitat
	Section SB6 NC 9623 6278 Mixed juvenile habitat with plenty of cover in the conifer plantation

	Section SB6 NC 9622 6281 Windthrown trees prevent access to much of the watercourse within the conifer plantation

7.14. Electric fishing site photographs

	AB1 NC 99604 57893 (downstream stop net had been where marked by dip net)
	AB2 NC 99407 59093 (downstream stop net had been where marked by dip net)
	AB3 NC 99455 60607

	AB4 NC 98922 61907
	AB5 NC 98923 62683
	RB1 NC 97435 60492

	RB2 NC 97331 61267
	RB3 NC 97116 62917
	SB1 NC 96546 61552

	SB2 NC 96263 62422
	SB3 NC 96384 63250

Appendix 11.J
Survey of Fish and Fish Habitats Report

Limekiln Wind Farm:

Survey of fish and fish habitats

Report to Infinergy Ltd

August 2012

Waterside Ecology
Druimindarroch
Arisaig
Inverness-shire
PH39 4NR
T: 01687 450298
M: 07788 717605
jon@watersideecology.co.uk

www.watersideecology.co.uk

Table of Contents **Page**

List of Figures **Page**

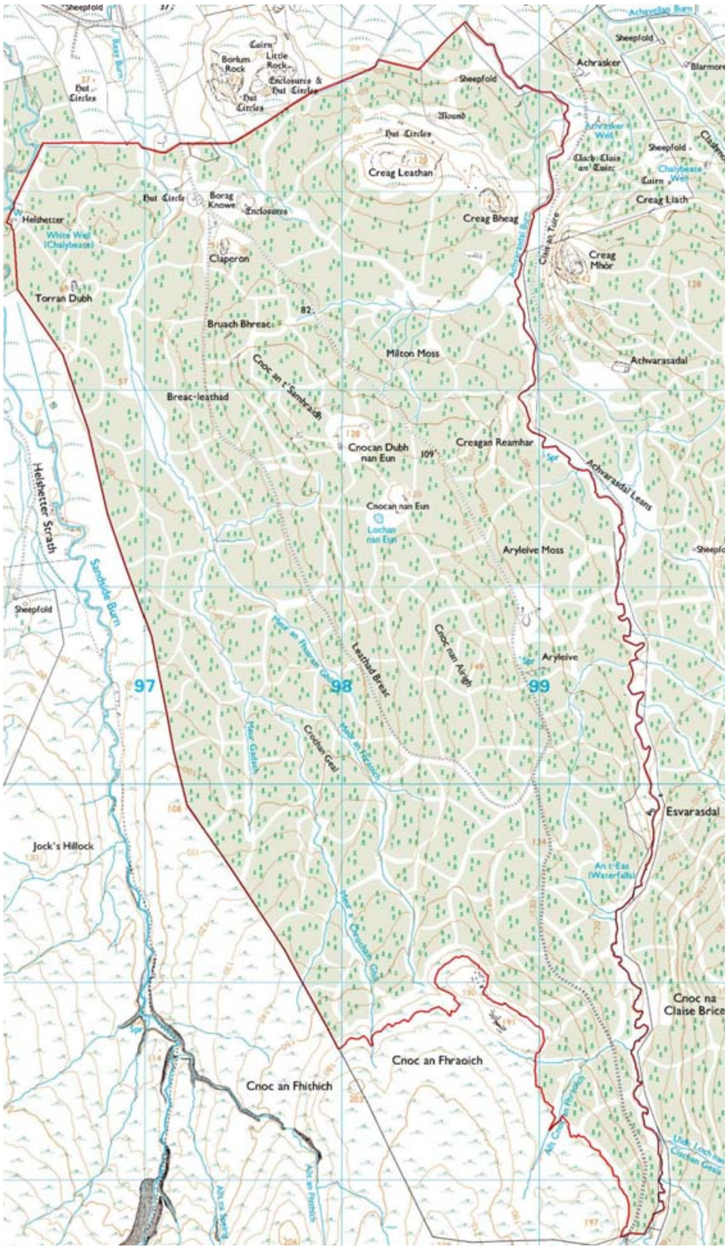
List of Tables **Page**

1 Introduction

1.1 Proposed scheme

This survey of freshwater fish and fish habitats was commissioned to inform the Environmental Impact Assessment for the proposed Limekiln Wind Farm. The proposed development is anticipated to have 30 to 50 turbines and would be constructed to the south of the village of Reay, in Caithness. The development site extends to approximately 11 km^2 and is currently used mainly for commercial forestry (Figure 1).

Figure 1 Proposed Limekiln Wind Farm site



Two main watercourses, the Achvarasdal Burn and Reay Burn, drain the site both running south to north. The Achvarasdal Burn runs along the eastern site boundary and the Reay Burn runs close to its western edge. Both of these streams are fed by a number of small tributaries that drain the site. The proposed development has potential to impact on fish through changes in water quality or direct disturbance to streambed habitats e.g. at stream crossings.

1.2 Freshwater fish species potentially present

Few data on freshwater fish populations in the Reay Burn or Achvarasdal Burn have been identified. Searches of data held by the National Biodiversity Network (NBN) show that salmon *Salmo salar*, trout *S. trutta* and European eels *Anguilla anguilla* have been recorded in the lower reaches of the Reay and Achvarasdal Burns. All three of these fishes are listed as priority species on the UK Biodiversity Action Plan. In addition, salmon are listed under Annex II of the Habitats and Species Directive and the Bern Convention. European eels are of increasing conservation interest and are protected by European legislation (EC No 1100/2007), requiring member states to implement eel stock recovery plans. The Freshwater Fish Conservation (Prohibition on Fishing for Eels) (Scotland) Regulations 2008 prohibits targeted fishing for eels without a license from Scottish Ministers.

Other fish species potentially present include brook lampreys *Lampetra planeri*, which have been recorded in nearby catchments including the River Halladale, River Strathy and Wick River (Watt & Ravenscroft 2005; Watt *et al*. 2011). Brook lampreys are listed on Annex IIa of the Habitats Directive and Appendix III of the Bern Convention. Three-spined sticklebacks *Gasterosteus aculeatus* have been recorded in grid square NC95, which includes parts of the Achvarasdal Burn, but no site name is provided (NBN data download April 2012). Three-spined sticklebacks are not threatened in the UK, Europe or globally (Davies *et al*. 2004).

1.3 Biology and habitat requirements

1.3.1 Salmon and trout

The physical habitat requirements of juvenile salmonids have been subject to a considerable amount of detailed study (for reviews see e.g. Crisp 1993; Hendry & Cragg-Hine 2003; Klemetsen *et al.* 2003; Summers *et al*. 1996; Youngson & Hay 1996). Trout and salmon spawn in late autumn and early winter, depositing their eggs in redds which they excavate in gravel and pebble substrates. Spawning depth can range from 5 cm to 90 cm (review by Neary 2006), but it is likely that habitat is selected on the basis of suitable substrate and flow rather than depth per se. Eggs are often deposited in areas of accelerating flow, such as the tails of pools and glides, upstream from riffles. However, in upland streams eggs may be deposited in any areas of gravel that can be physically moved. A good supply of oxygen is essential for eggs to develop and this is facilitated by a flow of water through the gravel. Clogging with fine sediment such as silt and fine sand reduces water flow resulting in egg mortality due to lack of oxygen. Egg survival is also affected by redd 'washouts' during winter spates – the direct, physical, scouring out of eggs from the gravel. Substrate stability, the dynamics of water flow and the weather all determine the extent of siltation and washouts.

After hatching the young fry remain in the gravel, absorbing nutrient from the remaining yolk sac. On emergence, usually between March and early May, the fry disperse and set up territories which they defend aggressively. Salmon fry prefer fast flows (>30 cm/s) and favour areas with surface turbulence (riffle habitat). They require a rough bed of pebble, cobble and gravel. Trout fry prefer areas of relatively low velocity water near the streambed and often inhabit slower flows than salmon fry. Cover from stones, plants or debris is required and good cover is essential for maintaining high fry densities.

Salmon that have survived their first winter (parr) prefer deeper water than fry (typically 15-40 cm) and a coarser substrate often consisting of cobbles and boulders. Trout parr generally favour areas of relatively low current speed where cover is available. Juvenile trout are often to be found in cover alongside the banks, in undercuts, among tree roots or in marginal vegetation. Cover remains important for adult trout and salmon particularly in smaller streams. In larger rivers and lochs this may be less important, as deep water provides refuge.

1.3.2 Eels

Eel habitat requirements have received less attention than those of salmonid fish. Tesch (2003) suggests that so long as temperature and oxygen requirements are met, there are few stretches of water that are not suitable for eels. The main requirement for eels is cover, as they are averse to light and require suitable refuges during daylight hours. Eels of different size show different substrate preferences. Larger eels require large hollows, crevices or weed beds whereas small eels are sometimes abundant in cobble substrates, where they can burrow between the stones. Tree stumps, roots and other large structures provide ideal cover for eels. Eel diet is diverse, but the majority consists of benthic species (Moriarty 1978; Kottelat & Freyhof 2007).

1.3.3 Lampreys

Three lamprey species occur in the UK: brook lamprey, river lamprey *Lampetra fluviatilis* and sea lamprey *Petromyzon marinus*. Adult lampreys aggregate to spawn and extrude their eggs into 'nests' excavated in the riverbed. After hatching the young lamprey larvae, known as ammocoetes, drift downstream with the current. They settle in nursery habitat consisting of fine, soft substrate in well oxygenated, slow flowing water. The ammocoetes are blind and feed on fine particulate matter such as diatoms, algae and bacteria. Ammocoetes spend several years in this muddy nursery habitat before metamorphosing (or transforming) from larval to adult form. Upstream migrating lampreys may be prevented from reaching spawning grounds by both natural and man-made barriers. They are weak jumpers, so can be prevented from moving upstream by relatively low vertical barriers.

2 Objectives

The objectives of the survey were to:

(i) Describe stream habitats in the watercourses draining the site of the proposed wind farm. In particular, to describe their suitability for the various fish species that are potentially present.

(ii) Identify the main obstacles to migration in the above streams, in particular the likely upstream limits for the distribution of salmon, sea trout or lampreys.

(iii) Determine the fish species present and their distribution in streams at the Limekiln site.

(iv) Determine fish abundance.

3 Survey areas and methods

3.1 Survey area, dates and conditions

The survey covered all waterbodies potentially suitable for fish production within the proposed boundary of the wind farm (Figure 1). Jon Watt of Waterside Ecology, an experienced fish biologist with Scottish Fisheries Co-ordination Centre (SFCC) habitat survey qualifications, conducted the habitat survey on 16th to 18th August 2011 and led the electric fishing survey between 26th and 28th of July 2012. Survey conditions were good with low water levels and good light.

3.2 Salmonid habitats

The survey extended over all the main watercourses within the wind farm boundary (Figure 1). Methods were based on protocols described by Hendry and Cragg-Hine (1997) and Summers *et al*. (1996). These characterise in-stream habitats according to depth, substrate, flow and thus suitability for different age classes of salmonid. The habitat categories used during the survey and in this report are set out in Table 1.

Table 1 Salmonid habitat categories used for walkover survey.

Habitat category	Description
Juvenile habitat	Habitats with mixed depth including areas ≥20 cm. Cobble and/or boulder substrate.
Pool	Over 60 cm deep. Slow or eddying current. Suitable for adult salmonids if cover is present. If >1 m deep cover may be less important, as depth can provide refuge.
Glide	Moderate to slow flow. Small substrates provide little cover. May be productive if bankside cover or macrophytes present.
Spawning	Ideally well oxygenated, stable & not compacted. Typically comprising gravel and pebble. Fines (sand & fine gravel <2 mm) less than 20%. Not silted.
Bedrock	Sheet bedrock covering majority of streambed. No cover. Unproductive habitat.
Incised peat	Small channels incised through peat. No bed transport. Hard substrates if present are set in peat matrix and do not provide cover. Poor or unproductive.

Surveys were based on contiguous sections of approximately 250 m in length. Within each survey section areas of productive juvenile habitats (see also SEPA 2010), glides, pools and bedrock were marked on maps. The broad suitability for juvenile and adult salmonids of each section was noted. Habitats were categorised as productive if they provided areas of suitable cover as described by Hendry and Cragg-Hine (1997) and Summers *et al*. (1996). Sheet bedrock or incised peat channels lacking hard substrate were categorised as unproductive. Areas of smooth shallow glide with small substrates and no cover are also likely to be unproductive for juvenile or adult salmonids, unless bank cover or macrophytes are present.

The survey also identified barriers to migration that may, in part, determine the distribution of fish species. The likely permeability of obstacles for adult salmonids, eels and lampreys was assessed. Other variables recorded in each survey section were:

- Up and downstream grid reference.
- Wet width.
- Stability (of substrate).
- Compaction (of substrate).
- Availability of cover for fish alongside banks.

3.3 Lamprey habitats

The walkover survey identified areas of suitable larval lamprey habitat, consisting of areas of soft, stable, well-oxygenated fine sand and silt. Where larval habitat was found, the location of each habitat unit was determined using hand-held GPS. The area of individual habitat units was estimated and the habitat was defined as optimal or sub-optimal based on standard classifications (Harvey & Cowx 2003). Optimal habitat was defined as stable, fine sediment (silt/sand) to a depth of 15 cm or more, in slow flowing well oxygenated water, often with a fine layer of organic detritus. Sub-optimal habitat was defined as a patchy or shallow (<15 cm) covering of fine sediment among larger substrates. The presence of woody debris, generally consisting of well-established piles of small twigs trapped in eddies or by larger debris, was noted. Woody debris provides a source of organic matter and can trap fine sediment creating or enhancing larval habitat. The surveyor assessed the likely longevity of units of larval habitat. Habitats were classified as:

Permanent:	likely to persist for more than 10 years
Semi-permanent:	likely to persist for 1-10 years
Ephemeral:	likely to change substantially or be lost in less than 1 year due e.g. to spates.

In making these assessments the main factor considered was whether the physical feature causing silt/sand deposition was likely to persist. Thus an eddy behind projecting bedrock would be classified as permanent while silt trapped in unstable debris would be classified as ephemeral.

Notes were kept on the presence of suitable spawning sites, based on published descriptions (e.g. Hardisty 2006; Maitland 2003) and the surveyor's own experience. Sea lamprey spawning requirements are broadly similar to those for trout and salmon, with stones of up to 10 cm and a high proportion of smaller materials. The smaller lamprey species require finer material, mainly gravel and coarse sand.

3.4 Fish populations

Suitable survey sites, representative of available habitats, were identified during the habitat inspection. Fish populations were surveyed by electric fishing, a non-lethal sampling technique. All surveys were carried out to SFCC 2007 protocols and included both fully quantitative and semi-quantitative assessments (Table 2, Appendix 1). Fully quantitative surveys provide data on absolute fish abundance within known error margins. The inclusion of semi-quantitative surveys allows a greater number of sites to be assessed than if all sites were surveyed fully quantitatively.

Where practical, fully quantitative sites were isolated using stop nets, to prevent fish from moving in or out of the site during surveys. Each fully quantitative site was fished through three times. The catch from each run through the site was held and processed separately. This multiple pass fishing allows absolute fish densities to be calculated, based on the decline in catch during successive runs. No stop nets were used at semi-quantitative sites and a single electric fishing run will be made through each.

Some qualitative (presence versus absence) survey was carried out to identify the upstream limits of fish distribution. These qualitative survey sites were in small streams in the upper Reay Burn catchment. Due to their small size and the fact that stream channels were deeply incised in peat, only short reaches were sufficiently open enough to insert the electric fishing anode. At such sites, surveyors fished through a series of short, accessible reaches in order to determine fish presence.

Fish were held in covered bins prior to processing and were identified and scored separately for each run. Salmonid fork length was measured to the nearest 1 mm. Scales were collected from trout and salmon to assist with age determination. Fish were allowed to recover fully in clean water before being released back into the survey reach. All fish density data are presented as number of fish per 100 square metres of wetted survey area (fish.100m^{-2}). The density classifications provided by Godfrey (2006) are used to describe the abundance of salmon and trout within a regional context (Appendix 10). Habitat descriptions at electric fishing survey sites were collected according to the SFCC protocol (SFCC 2007).

Table 2 Electric fishing survey sites

Site	Catchment	Stream	NGR	Survey type
R1	Reay	Reay Burn	NC 9711 6292	Semi-quantitative
R2	Reay	Reay Burn	NC 9711 6292	Fully quantitative
R3	Reay	Reay Burn	NC 9749 6052	Semi-quantitative
MF1	Reay	Meur an Fhraoich	NC 9801 6022	Qualitative
MCG1	Reay	Meur a' Chrochain Ghill	NC 9776 6028	Semi-quantitative
MCG2	Reay	Meur a' Chrochain Ghill	NC 9779 6005	Qualitative
MCG3	Reay	Meur a' Chrochain Ghill	NC 9783 5998	Qualitative
A1	Achvarasdal	Achvarasdal Burn	NC 9912 6324	Semi-quantitative
A2	Achvarasdal	Achvarasdal Burn	NC 9896 6201	Semi-quantitative
A3	Achvarasdal	Achvarasdal Burn	NC 9947 6061	Fully quantitative
A4	Achvarasdal	Achvarasdal Burn	NC 9950 5869	Semi-quantitative

4 Results

4.1 Reay Burn catchment

4.1.1 Obstacles

No significant obstacles to fish migration were recorded in the Reay Burn or in the lower reaches of its tributaries. A waterfall with a 1 m vertical drop was recorded in the Meur an Fhraoich, in survey section MF4 at NC 9820 5991. This is probably upstream from the natural limit of fish distribution, as the stream here is a small, incised peat channel (Figure 3, Appendix 1).

4.1.2 Salmonid habitats

The lower reaches of the Reay Burn in survey sections RB1 to RB3 (see Figure 2) provide habitat that is suitable for juvenile salmonids. Substrates comprise stable boulder surrounded by coarse sand and small gravel. Flows are mixed and gradient is moderate. No significant areas of spawning habitat were identified in these reaches but it is probable that smaller trout could spawn in gritty material surrounding the larger substrates. There is no bank erosion is these reaches, which are generally very stable. Wet width varies from 1 to 2 m (average 1.4 m) and typical depths are in the range 10 to 30 cm. Individual survey sections are described in Appendices 1 and 2.

Sections RB4 to RB7 appear to have been straightened at some time in the past. Gradient in these reaches is low and streambed substrate is primarily sand and gravel overlying peat. Some of this appears superficially suitable for spawning fish, but in fact the surface layer of gravel is mainly very thin (~ 2 cm) overlying peat. Flow is sluggish in places with growth of *Potamogeton* species ('pond weeds'). Cover for fish alongside the banks is abundant, but the small substrate provides little or no cover on the streambed. These sections are generally poor salmonid habitat. Some spawning habitat was recorded in section 6, but this was of poor quality due to a high silt content (Appendix 3).

Figure 2 Reay Burn salmonid habitats and electric fishing sites, north.

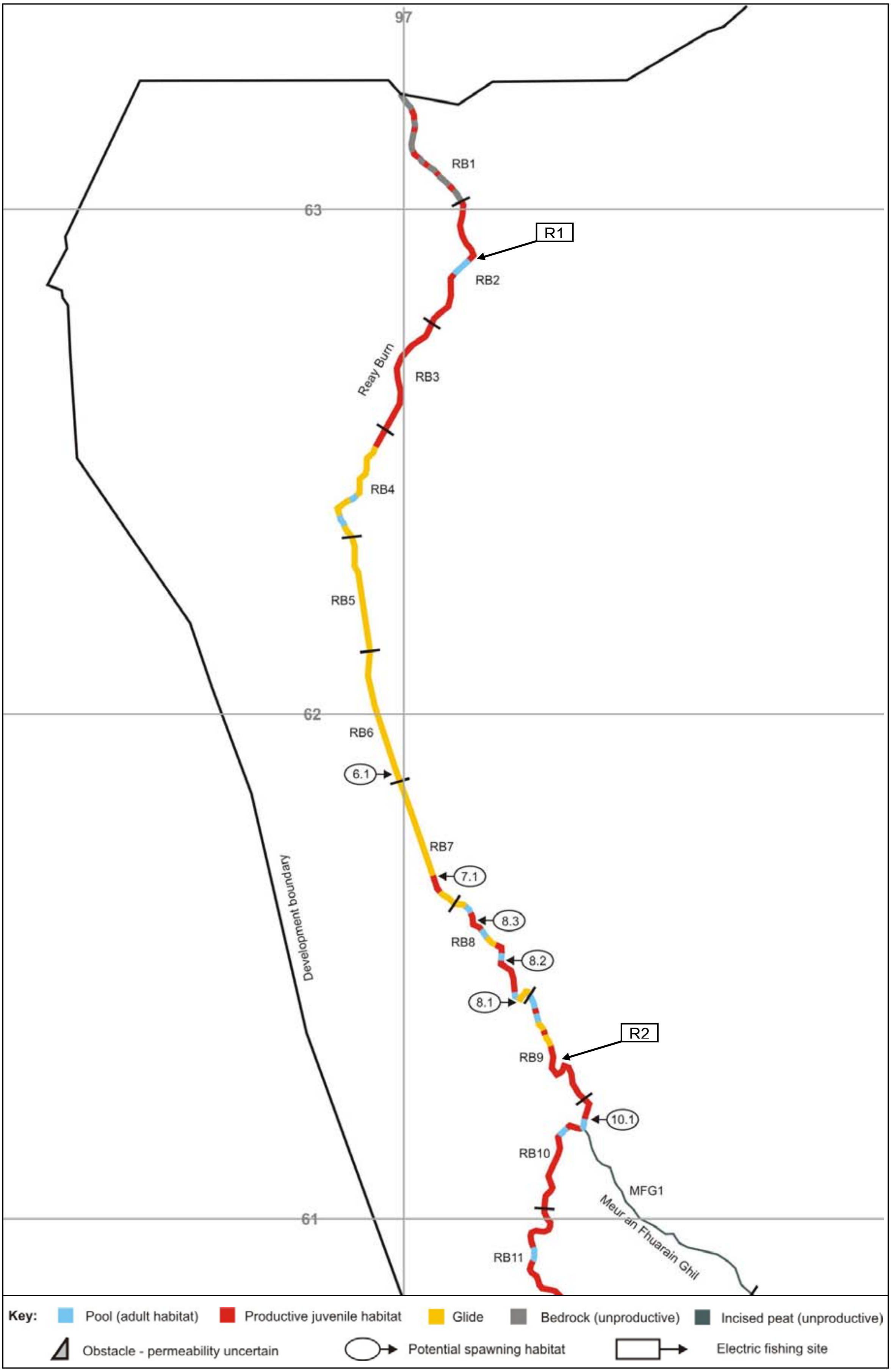
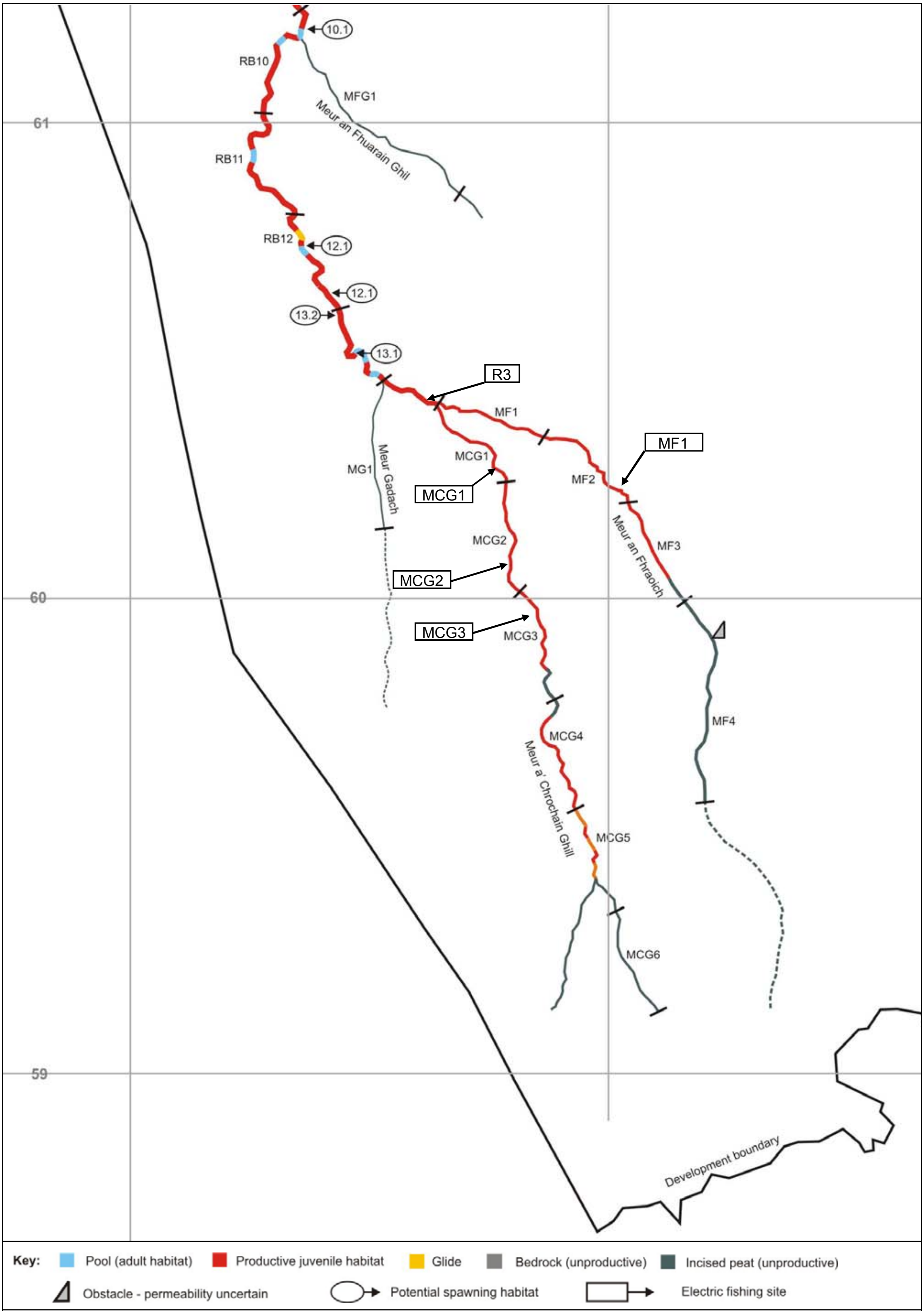


Figure 3 Reay Burn salmonid habitats and electric fishing sites, south



The remainder of the Reay Burn, upstream to the confluence of the Meur Fhraoich and Meur a' Chrochain Ghill, provides good quality habitat for juvenile salmonids. Current speed is moderate, the channel is meandering and there are numerous riffle, run and glide sequences providing varied instream habitats. Substrate is predominantly cobble, pebble and coarse sand. There are numerous patches of gravel and pebble that provide good spawning opportunities (Appendix 3) and salmonid fry and parr were abundant in some survey reaches. The streambed is mainly stable and washout of ova seems unlikely at most potential spawning locations.

The Meur an Fhraoich and Meur a' Chrochain Ghill converge to form the Reay Burn at the top of section RB14 (Figure 3). At their confluence, both these tributary streams are approximately 0.3 m wet width.

Meur an Fhraoich is incised through peat but the streambed substrates in the lower 0.75 km are predominantly cobbles, coarse sand and small gravel. Much of the cobble is firmly embedded in a hard, peaty matrix and there is minimal bed transport. There appear to be few inputs of pebble or cobble as any areas of bank erosion provide only peat. As a result, there is little spawning habitat although some of the small patches of gravel around larger embedded cobbles may permit spawning by smaller trout. Salmonid fry were observed as far upstream as section MF2 and potentially suitable habitat extends upstream into MF3 (see Figure 3). Further upstream the channel is very narrow, lacking hard substrates and unsuitable for fish production.

Meur a' Chrochain Ghill is very similar to Meur an Fhraoich, comprising a channel incised through peat with substrates of embedded cobbles and grit. It is shallow, mainly 5 – 10 cm, but with a few small pools that might support trout parr. Several little patches of gravel were noted in the lower reaches that might permit spawning. No fish were seen but as the stream is very narrow and overgrown it was difficult to see into the channel without disturbing any fish that may have been present. The lower reaches would be expected to support trout. By section MCG3 the stream is very small, overgrown in rushes and habitat quality from here upstream is very poor. By section MF4 stream habitats were judged incapable of supporting fish.

Two other tributaries, the Meur an Fhuarain Ghil and Meur Gadach were inspected. Both are narrow, peat-based channels that provide no suitable habitat for salmonid fish.

4.1.3 Lamprey and other non-salmonid habitats

No discrete patches of larval lamprey habitat were recorded in the Reay Burn. However, some parts of survey sections RB4 and RB5 where there is a predominance of sand and silt substrates potentially provide suitable habitat. Elsewhere, most of the small patches of sand appeared too unstable to be suitable for ammocoete larvae. Potential spawning habitat for brook lampreys is widespread in the gritty material that surrounds cobbles in many of the survey reaches.

As noted above, eel habitat requirements are very broad and it is likely that the species is present. The low gradient reaches of the stream in RB4 and RB5 also provide suitable habitat for three-spined sticklebacks, although none were seen.

4.1.4 Fish populations

Trout were present at six of seven survey sites in the Reay Burn catchment and eels at two (Table 3). No other fish species was caught or seen.

Trout fry and parr were present at all three survey sites in the Reay Burn and also at site MF1 in the Meur Fraioich. Due to its small size and the fact that much of it flows below ground it was not possible to survey further upstream in the Meur Fraioich. Nevertheless, based on habitat availability, it seems likely that the upstream limit of trout distribution is somewhere around site MF1.

Trout fry were absent from all sites the in Meur a' Chrochain Ghill, but parr were present as far upstream as site MCG2 (NC 9779 6005), some 400 m upstream from the Reay Burn. Site MCG3 was fishless and it seems likely that MCG2 represents the approximate upstream limit of trout distribution. The absence of fry from all sites in the Meur a' Chrochain Ghill suggests either that trout swim up into this watercourse from Reay Burn or that successful spawning in it is not an annual event.

Average single run minimum densities were 19.5 and 11.6 fish.100.m^{-2} for trout fry and parr respectively. This density of fry would be classified as good by regional standards (Godfrey 2006 – see Appendix 10) while parr density would be considered excellent.

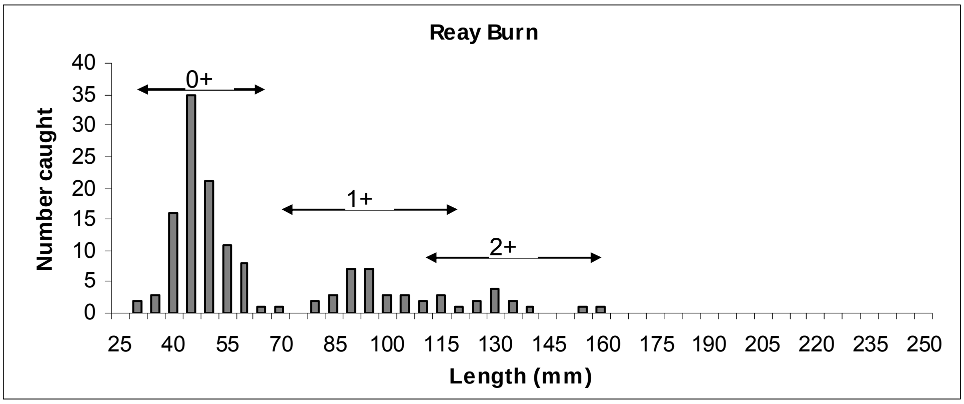
Table 3 Electric fishing results, Reay Burn

Site	Area (m^2)	**Trout** (n)		**Trout.100 m^{-2}**		**Salmon** (n)		**Eel** (n)
		Fry	*Parr*	*Fry*	*Parr*	*Fry*	*Parr*	
R1	97.2	21	9	21.6	9.3	0	0	14
R2	93.1	42	13	77.3 (7.4)	19.3 (3.1)	0	0	3
R3	89.6	10	16	11.2	17.9	0	0	0
MF1	NA	present	present	present	present	absent	absent	0
MCG1	55.0	0	3	0.0	5.5	0	0	0
MCG2	NA	absent	present	absent	present	absent	absent	0
MCG3	NA	absent	absent	absent	absent	absent	absent	0

NB. Data are single run minimum densities except at site R2 (Zippin denity and 95% c.l.)

The fry year class (aged 0+) ranged in length from 31 mm to 68 mm (Figure 4) with a mean of 47.5 mm (±6.9 s.d.). There was no overlap with the 1+ year class, which ranged in length from 79 mm to approximately 115 mm. Overlap in size was evident between the 1+ and 2+ year classes.

Figure 4 Trout length frequency distribution, Reay Burn catchment



Eels ranged in length from 11 cm to 36 cm. Spot checks for lamprey larvae were carried out where suitable patches of sand and/or silt were encountered. No lampreys were present.

4.2 Achvarasdal Burn catchment

4.2.1 Obstacles

A low rock shelf in survey section AB10 may be difficult for upstream migrating salmonids at low water level (Table 4). At a moderate or high flow it will be easily passable. Further rock shelves likely to create low flow obstacles are present in section AB21, but these too would be expected to be passable on higher flows. The An t-Eas waterfalls in section AB22 presents more significant obstacles to upstream migrants. Obstacle AB22.1 at NC 9956 5963 is a bedrock ledge with a vertical drop of approximately 1.5 m over a 10 m length. It is shallow but the flow is somewhat concentrated to the left bank and it seems likely to be passable at medium flows (see Appendix 8). Obstacle 22.2 is the most difficult in the survey reach and is probably impassable to upstream migrating salmon or trout due its height and the shallow, flat sill below it. Obstacle 22.3 a short distance further upstream is also difficult but, as it has a pool below it, salmon or larger trout may be able to jump up on higher flows should a suitable standing wave form downstream.

Upstream migrating juvenile eels seem likely to be able to ascend all of the above obstacles with little difficulty due to the presence of mossy climbing substrate. The An t-Eas waterfalls may however be difficult for lampreys to ascend, should they be present.

Table 4 Obstacles to fish passage identified on Achvarasdal Burn.

Code	Location	Permeability (salmonids)	Type	Notes
AB10.1	NC 9897 6213	Yes S/F	Bedrock ledges	Low flow obstacle passable in spates.
AB21.1	NC 9958 5973	Yes S/F	Shallow bedrock chute	60 cm high ledge part way up a shallow, sloping bedrock chute. The total drop is about 1.5 m over a 10 m reach.
AB21.2	NC 9958 5982	Yes	50 cm ledge	Low flow obstacle easily passable in spates.
AB22.1	NC 9956 5963	Unknown	Waterfall	Vertical drop of 1.5 m. Pool immediately downstream.
AB22.2	NC 9955 5960	Impassable?	Waterfall	Two tier waterfall with 2.3 m high vertical upper tier. This is probably impassable as very shallow at base.
AB22.3	NC 9953 5954	Yes S/F	Waterfall	Vertical drop of about 1 m. Deep pool below. Passable.

4.2.2 Salmonid habitats

The Achvarasdal Burn provides long reaches of stream habitat that are very well suited to production of juvenile salmonids with plentiful instream and bankside cover and good spawning opportunities. A section-by-section assessment is provided in Appendices 4 and 5 and selected, representative photographs are provided in Appendix 9. Juvenile salmonids were seen throughout the study reaches during the survey.

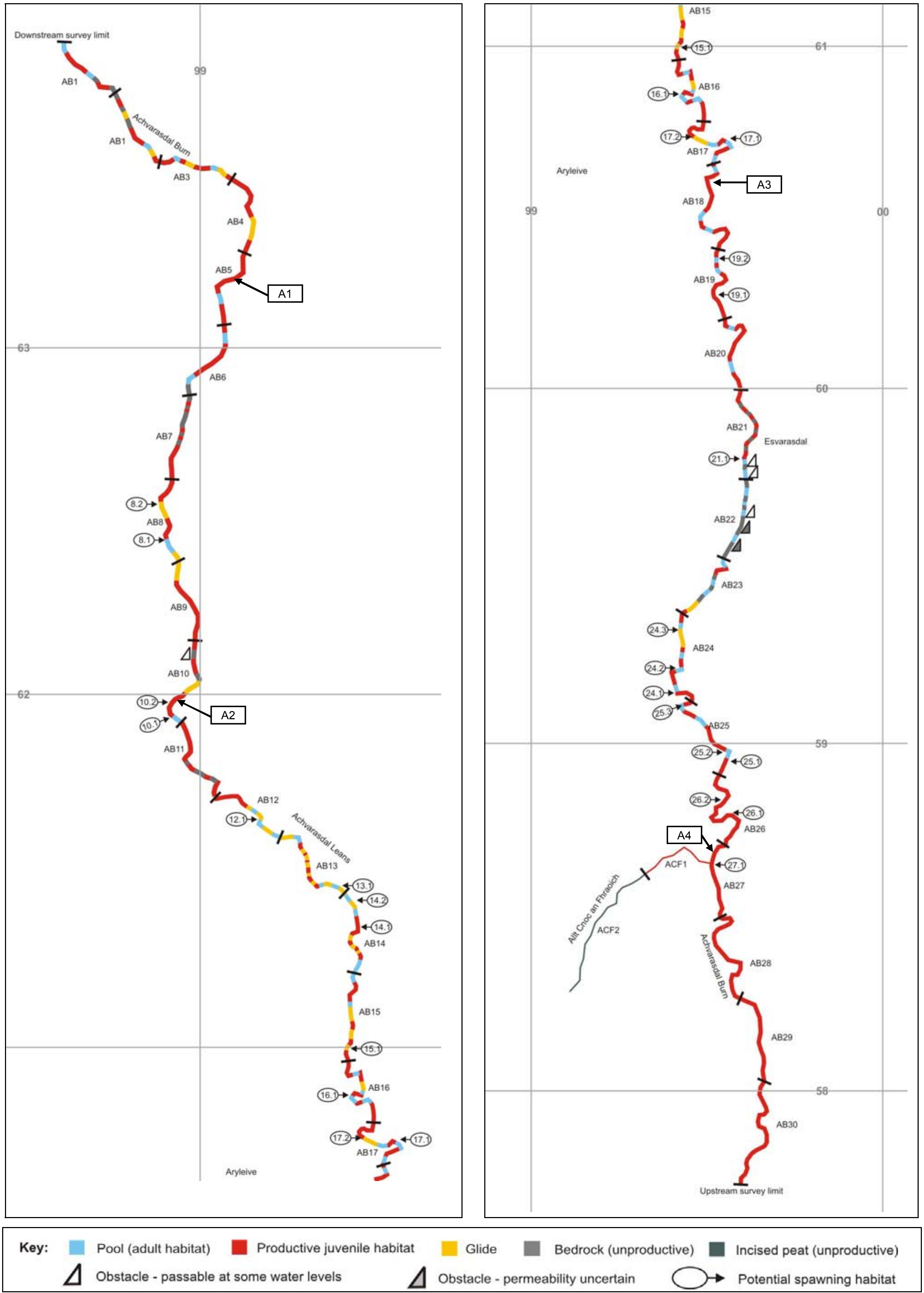
Stream habitats in the lower 3 km of the survey reach (sections AB1 to AB12) are almost entirely suitable for juvenile salmonids (Figure 4). Substrates are dominated by cobble, providing some instream cover and in most reaches the habitat is stable. Additional bankside cover below undercut banks or among roots is plentiful in most survey sections. Pools are present and, especially in sections AB1 to AB6, some of these may be deep and large enough to hold salmon prior to spawning. These lower reaches vary in wet width from about 2 m to 5 m. Spawning opportunities are rather limited, mainly consisting of small patches of gravel and pebble among larger material, but larger patches of potential spawning habitat extending to 5 m^2 were recorded in section AB8 to AB12. Gradient is moderate throughout and flows are mixed.

Sections AB13 to AB17 running through the Achvarasdal Leans are meandering with a low gradient. Pool and glide habitat are plentiful, interspersed with short sections of faster flow. Substrates are mainly very stable with mossy cobble and boulder surrounded by coarse sand. However, some good quality spawning habitat is also present, especially in accelerating flows at the downstream ends of some pools and glides.

Gradient increases in section AB18 and the next three sections comprise mixed flows over stable, mossy boulders surrounded by cobble and pebble. Instream fish cover is generally good and some patches of vegetation suggest long term stability. Juvenile habitat quality is good throughout and some deeper glides and pools provide habitat for larger fish.

Gradient increases at Esvarasdal and sections AB21, AB22 and AB23 are somewhat gorge-like with long reaches of bedrock and a number of waterfalls and short rapids of various heights (see 4.2.1 above). The remaining sections between Esvarasdal and the upstream survey limit at NC 996 577 comprise typical mixed juvenile salmonid habitat with varied flows over substrates of cobble and boulder. Typical wet width is 1.5 m to 2 m with depths of 10 cm to 30 cm. Some good patches of spawning habitat are present, especially in sections AB24 to AB27 (Appendix 6). Some bank erosion is evident in the upper reaches, but this is not rapid and habitat quality is generally good.

Figure 5 Achvarasdal Burn salmonid habitats and electric fishing sites



Substrates in the lower reaches of the Allt Cnoc an Fhraoich are mainly cobble embedded in a peat matrix. There are some patches of gravel & pebble but the stream is very shallow and generally unsuited to fish. The upper section (ACF2) is a simple peat-based channel or an ill-defined seep through soft rush. It is entirely unsuitable for fish production.

4.2.3 Lamprey and other non-salmonid habitats

The Achvarasdal Burn contains a number of patches of habitat that appear well suited to juvenile lampreys (Table 5, Appendix 7). These are mainly small and scattered through the meandering lower gradient reaches. Further tiny pockets of potentially suitable habitat were observed in these reaches but these were not plentiful and were too small to be quantified. Overall, juvenile lamprey habitat was not abundant. The gritty material surrounding stable boulders in many of the survey reaches provides suitable spawning substrate for brook lampreys, the only species likely to be present. Most patches of habitat were judged to be permanent, usually forming on the insides of bends in eddying flows (Appendix 7).

Table 5 Patches of larval lamprey habitat recorded in Achvarasdal Burn.

Survey section	**Patches (n)**	**Area (m^2)**	
		Optimal	Sub-optimal
AB3	1	0	2
AB5	1	0	0.5
AB6	1	2	0
AB12	1	3	0
AB13	3	0	7
AB14	4	3	8
AB16	4	5	2.5
AB17	1	2	0

Eels were seen during the survey and the low gradient reaches of the stream also provide suitable habitat for three-spined sticklebacks, although none were seen.

4.2.4 Fish populations

Trout were present at all four survey sites in the Achvarasdal Burn (Table 6). Average single run minimum densities were 10.4 and 20.9 fish.100.m^{-2} for trout fry and parr respectively. These densities would be classified as good and excellent for fry and parr and respectively, based on national classifications (Godfrey 2006). Trout parr density exceeded fry density at all survey sites, perhaps suggesting a relatively weak 2012 year class.

Growth rates in the Achvarasdal Burn were higher than in the Reay Burn and mean length of fry was 57 mm ± 5.9 mm s.d. (Figure 6). Age 1+ parr ranged in length from 79 mm to 132 mm and lengths overlapped with those of the 2+ year class (Figure 6).

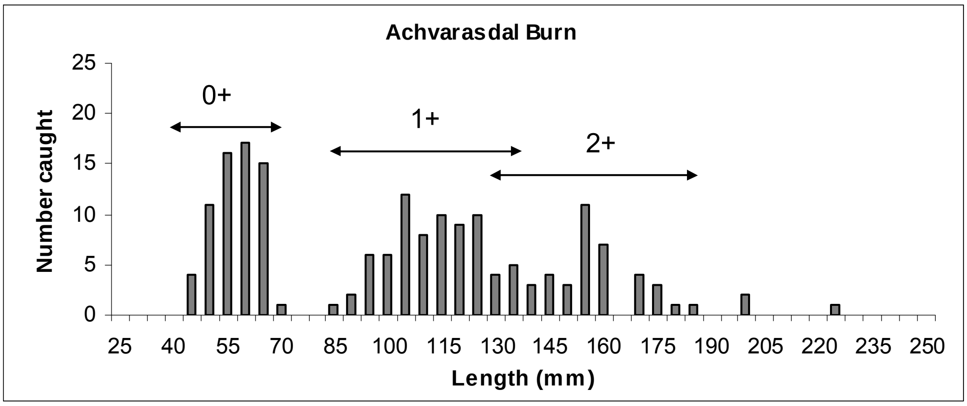
Three salmon parr were captured at site A3 along with one fish that appeared to be a salmon/trout hybrid. All of the salmon were aged 2+ and their lengths were 122 mm, 123 mm and 139 mm. The probable hybrid was 160 mm long and also aged 2+.

Table 6 Electric fishing results, Achvarasdal Burn

Site	**Area** (m^2)	**Trout** (n)		**Trout.100 m^{-2}**		**Salmon** (n)		**Eel** (n)
		Fry	*Parr*	*Fry*	*Parr*	*Fry*	*Parr*	
A1	140.0	14	22	10.0	15.7	0	0	1
A2	121.2	15	32	12.4	26.4	0	0	2
A3	149.4	16	37	18.1 (1.7)	30.8 (2.0)	0	3	8
A4	82.8	7	14	8.5	16.9	0	0	1

NB. Data are single run minimum densities except at site R2 (Zippin denity and 95% c.l.)

Figure 6 Trout length frequency distribution, Achvarasdal Burn



Eels were present at all survey sites, including A4 which is located upstream from the An t-Eas waterfalls. Eel length ranged from 16 to 37 cm.

Targeted surveys of lampreys were carried out at three sites where optimal habitat was present (Table 7). Larvae were absent from all sites. Further spot checks of small patches of suitable habitat were conducted during the salmonid surveys, but no larvae were seen or caught.

Table 7 Lamprey survey results, Achvarasdal Burn

NGR	Area	Habitat quality	Time fished (mins)	Larvae caught (n)
NC9915 6162	3	optimal	6	0
NC9928 6147	4	sub-optimal	5	0
NC9928 6149	4	sub-optimal	10	0

5 Discussion

5.1 Fish and fish habitats at Limekiln

5.1.1 Reay Burn

The Reay Burn provides habitats that are well suited to trout production and trout densities in the stream were good to excellent by regional standards. The smaller tributaries in the headwaters provide small areas of habitat that may support juvenile trout, but only in their lower reaches. Electric fishing confirmed that trout were restricted to the lower reaches of the Meur a Chrochain Ghill and, on the basis of habitat suitability, it seems certain that trout distribution in the Meur Fhraoich will be similarly restricted. Clearly the majority of productive trout habitat is in the mainstem of the Reay Burn i.e. downstream from the confluence of the Meur Fhraoich and Meur a’ Chrochain Ghill. These reaches contain 87% of productive juvenile habitat in the survey reaches (Appendix 2) as well as all of the quantifiable areas of spawning habitat that were identified during the survey (Appendix 3).

The only other fish species present were eels, which were most abundant in the lower reaches of the stream. It is probable that the small substrates that characterise the upper reaches of the Reay Burn do not provide sufficient cover for eels, which seek refuge in crevices or similar cover during daylight hours.

Salmon were absent from all survey sites and it is probable that the stream is too small to sustain a salmon population.

5.1.2 Achvarasdal Burn

Stream habitats in the Achvarasdal Burn include extensive areas that are very well suited to the production of salmonid fish. Habitats suitable for all life stages are present and these include pools that were judged sufficiently deep and large to hold salmon in the run up to spawning. Electric fishing confirmed the presence of salmon, but these were scarce and present at only one of the survey sites. The three salmon parr that were caught were all aged 2+ i.e. they would have hatched in spring 2010. The size of these fish and the absence of other salmon suggest that the majority of this cohort are likely to have gone to sea as 2+ smolts in spring 2012. The absence of fry and 1+ parr suggests that salmon have not spawned regularly in the survey reaches in recent years.

Trout parr densities in the Achvarasdal Bun were excellent. It is not known what proportion of these fish will migrate from the stream as sea trout, but the presence of salmon is a clear indication that the site is accessible to migratory salmonids. The waterfalls at Esvarasdal seem likely to be impassable to both sea trout and salmon and it is probable that trout upstream from these obstacles are resident brown trout.

Habitat suitable for larval lampreys was present but electric fishing found that larvae were absent at all sites that were surveyed. Watt & Ravenscroft (2005) found that in streams where lampreys were present, larvae were found at the great majority of survey sites. Thus while it is difficult to prove absence, it is very unlikely that lampreys are present in the survey reaches.

5.1.3 Areas not surveyed

A number of small drainage ditches running beneath thicket conifer were omitted from the survey. Limited observations indicated that substrate in the ditches was mainly peat and that water flow was minimal. It was clear that they were entirely unsuitable for salmonid fish. It is possible that occasional eels may enter these drains, but most appeared too unproductive to support sustainable fish populations.

5.2 Potential impacts

5.2.1 Freshwater habitats

Typical issues relating to wind farm developments and fish relate to the exposure of large quantities of soil and the consequent potential for siltation. Inputs of silt and other fine material including peat can cause damage to fish habitats and direct mortality to fish and ova. Similar or greater impacts would be expected in the event of any peat slips resulting from the proposed development. Should the scheme proceed, silt management will be one of the most significant issues relating to watercourses.

The combination of extensive tree felling and exposure of mineral soils to mildly acidic water during construction could potentially result in increased aluminium levels during the first four years following felling (Neal *et al*. 1992). Some forms of aluminium are toxic to aquatic life, including fish. Aquaterra Ecology (2012) found that the pH of the Reay Burn was lower than that of the Achvarasdal Burn (i.e. it was more acidic) and this stream may be the more sensitive of the two to potential changes in water quality.

Good quality salmonid habitats are present in the mainstem of the Reay Burn and Achvarasdal Burn. Ideally, any stream crossings should be located where they would have minimal impact on these habitats. Spawning habitats were not particularly abundant and these, in particular, should be avoided during construction of crossings. Trout and lampreys (if present) both undergo local spawning migrations and any stream crossings should be constructed in a manner that will allow fish passage, unless they are located in fishless headwater streams. Advice on stream crossings for fish is available from the Scottish Government and from Scottish Environment Protection Agency.

5.3 Recommendations

Detailed pollution prevention plans and construction method statements, including silt reduction measures, should be developed in order to protect stream habitats. The EIA may also have to consider any potential for changes to water quality resulting from tree felling.

6 References

Aquaterra Ecology. 2012. Limekiln Wind Farm: freshwater invertebrate survey. Report to Infinergy, March 2012.

Crisp, D.T. 1993. The environmental requirements of salmon and trout in fresh water. Freshwater Forum, 3(3), 176-201.

Davies, C., Shelley, J., Harding, P., McLean, I., Gardiner, R. & Peirson, G. 2004. Freshwater Fishes in Britain: the species and their distribution. Harley Books.

Godfrey, J. D. 2006. Site condition monitoring of Atlantic salmon cSACs. Commissioned report to Scottish Natural Heritage, December 2006. Scottish Fisheries Co-ordination Centre, Pitlochry.

Hardisty, M.W. 2006. Lampreys, Life Without Jaws. Forest Text, Cardigan.

Harvey, J & Cowx, I. 2003. Monitoring the River, Brook and Sea Lamprey, *Lampetra fluviatilis*, *L. planeri* and *Petromyzon marinus*. Conserving Natura 2000 Rivers Monitoring Series No. 5, English Nature, Peterborough.

Hendry, K. & Cragg-Hine, D. 1997. Restoration of Riverine salmon habitats. Fisheries Technical Manual 4, Environment Agency, Bristol.

Hendry, K & Cragg-Hine, D. 2003. Ecology of the Atlantic Salmon. Conserving Natura 2000 Rivers Ecology Series No. 7, English Nature, Peterborough.

Klemetsen, A., Amundsen, P-A, Dempson, J.B., Jonsson, B., Jonsson, N., O'Connell, M.F. & Mortensen, E. 2003. Atlantic salmon *Salmo salar* L., brown trout *Salmo trutta* L. and Arctic charr *Salvelinus alpinus* (L.): a review of aspects of their life histories. Ecology of Freshwater Fish, 12, 1-19.

Kottelat, M. & Freyhof, J. 2007. Handbook of European Freshwater Fishes. Cornol, Switzerland.

Maitland, P.S. 2003. Ecology of the River, Brook and Sea Lamprey. *Conserving Natura 2000 Rivers Ecology Series No. 5*. English Nature, Peterborough.

Moriarty, C.M. 1978. Eels: A Natural and Unnatural History. David & Charles, Newton Abbot. 192 pp.

Neary, J.P. 2006. Use of Physical Habitat Structure to Assess Stream Suitability for Brown Trout: A Case Study of Three Upland Scottish Streams. Ph.D. Thesis, University of Stirling, October 2006.

Neal, C., Fisher, R., Smith, C.J., Hill, S., Neal, M., Conway, T., Ryland, G.P. & Jeffrey, H.A. 1992. Effects of tree harvesting on stream-water quality at an acidic and acid-sensitive spruce forested area: Plynlimon, mid-Wales. Journal of Hydrology, 135, 305–319.

SFCC. 2007. Scottish Fisheries Co-ordination Centre Electrofishing Team Leader Training manual. Inverness College. June 2007.

SEPA. 2010. Guidance for applicants on supporting information requirements for hydropower applications.

Summers, D., Giles, N. & Willis, D.J. 1996. Restoration of Riverine Trout Habitats: A Guidance Manual. Fisheries Technical Manual 1, R&D Technical Report W118, Environment Agency, Bristol.

Tesch, F. W. 2003. The Eel. 3rd Edition. Blackwell Science, Oxford.

Watt, J. & Ravenscroft, N.O.M. 2005. The distribution of lampreys in Scotland: National lamprey survey 2003-2004. Commissioned Report to Scottish Natural Heritage.

Watt, J., Brown, L.J. & Seed, M. 2011. Strathy North wind farm: fish monitoring program 2010. Commissioned report to SSE Renewables, March 2011.

Youngson, A & Hay, D. 1996 The Lives of Atlantic Salmon. An illustrated account of the life-history of Atlantic salmon. Swan Hill Press, Shrewsbury.

Appendix 1. Stream survey sections and habitat descriptions: Reay Burn catchment.

Watercourse	Section Code	NGR		Habitat description
		Downstream	Upstream	
Reay Burn	RB1	NC 9700 6327	NC 9711 6293	Steep and fast flowing with boulders and grit on top of bedrock. No significant obstacles. Pockets of unstable spawning habitat.
Reay Burn	RB2	NC 9711 6293	NC 9706 6276	Stable mossy cobbles and boulders surrounded by grit. Depth typically 10 to 30 cm.
Reay Burn	RB3	NC 9706 6276	NC 9696 6258	Stable mossy cobbles and boulders surrounded by grit.
Reay Burn	RB4	NC 9696 6258	NC 9687 6236	Sluggish and weedy. Substrate mainly sand. Very poor salmonid habitat. Lower 25% of section is embedded cobble and boulder surrounded by grit.
Reay Burn	RB5	NC 9687 6236	NC 96936211	Substrate mainly sand. Flow is sluggish. Poor habitat.
Reay Burn	RB6	NC 96936211	NC 97006185	Sand, gravel and pebble substrates in glide and runs. Straightened channel cut through peat. Little cover and poor fish habitat. Potential spawning areas are silted and poor. Many patches that superficially look like spawning habitat comprise a thin layer of gravel over peat. Depth 15 - 20 cm.
Reay Burn	RB7	NC 97006185	NC 9710 6160	Sand, gravel and pebble substrates in glides and runs. Straightened channel incised through peat. Little cover and poor fish habitat. Potential spawning areas are silted and poor. Many patches that superficially look like spawning habitat comprise a thin layer of gravel over peat. Depth 15 - 20 cm.
Reay Burn	RB8	NC 9710 6160	NC 9723 6143	Low gradient with long, 20-40 cm deep glides interspersed with shallow (5-10 cm deep) pebble/cobble runs. Some siltation. Poor instream cover. Deep pools present - depth 60 – 150 cm. Good cover alongside banks.
Reay Burn	RB9	NC 9723 6143	NC 9735 6125	Low gradient. Mainly glide with some shallow runs. Potential spawning habitat is silted and full of peat particles.
Reay Burn	RB10	NC 9735 6125	NC 9727 6103	Moderate gradient. Mainly narrow run and glide. Hard substrates in many places are a thin layer on top of peat.
Reay Burn	RB11	NC 9727 6103	NC 9729 6083	Cobble and pebble substrate. Narrow runs with broader pools. Scattered patches of spawning habitat throughout.
Reay Burn	RB12	NC 9729 6083	NC 9741 6061	Good trout fry and parr habitats. Mixed flows and depths. Cobble, pebble and grit.
Reay Burn	RB13	NC 9741 6061	NC 9752 6044	Riffle & glide sequences. Cobble, pebble and grit. Glides and pools. Depth 15 – 40 cm. Decent trout habitat. Some compacted/embedded cobble. Patchy spawning.
Reay Burn	RB14	NC 9752 6044	NC 9763 6040	Largely as RB13. Overall, this section is good trout habitat.
Meur Chrochain Ghill	MCG1	NC 9763 6040	NC 9778 6024	Low gradient. Narrow channel incised though peat. Some below ground. Substrates of cobble, pebble and grit.
Meur Chrochain Ghill	MCG2	NC 9778 6024	NC 9779 6002	Varied habitats. Mixed substrates including patches of potential spawning. Depth 5-10 cm with a few deeper pools.
Meur Chrochain Ghill	MCG3	NC 9779 6002	NC 9788 5979	Top of section is narrow incised channel, overgrown in rushes. Little visible streambed. No fish seen. Depth 2 – 10 cm.
Meur Chrochain Ghill	MCG4	NC 9788 5979	NC 9793 5956	Mainly hard substrates of cobble and grit. Tiny, narrow stream. A few open pools but mainly very narrow channel incised through peat.
Meur Chrochain Ghill	MCG5	NC 9793 5956	NC 9800 5937	Narrow incised channel with a few open pools. Embedded cobble and grit on peat. Depth 2 to 10 cm.
Meur Chrochain Ghill	MCG6	NC 9800 5937	NC 9811 5912	Narrow peat channel through rushes. Totally unsuitable for fish.
Meur an Fhraoich	MF1	NC 9763 6040	NC 9785 6033	Very poor. Coarse sand and gravel around embedded mossy cobbles. Some parts run below ground. Depth mainly <5 cm. Too narrow to electric fish.

Appendix 1. contd.

Watercourse	Section Code	NGR		Habitat description
		Downstream	Upstream	
Meur an Fhraoich	MF2	NC 9785 6033	NC 9806 6015	Broader and more open than MF1 but very shallow. Trout fry seen. Flows below ground near top of section. Depth 2 to 10 cm. Some grit and gravel in little pools may permit spawning by small trout.
Meur an Fhraoich	MF3	NC 9806 6015	NC 9820 5999	Very small, shallow stream. Below ground in places. Substrates as MF2.
Meur an Fhraoich	MF4	NC 9820 5999	NC 9820 5958	Peat channel and wet flush. Unsuitable for fish.
Meur an Fhuarain Ghill	MFG1	NC 9735 6116	NC 9765 6092	Small, incised peat channel lacking hard substrates. Unsuitable for fish.
Meur Gadach	MG1	NC 9752 6044	NC 9790 5914	Lacks hard substrates. Much underground peat tunnel and wet flush without defined channel. Unsuitable for fish.

Appendix 2. Stream survey data, Reay Burn catchment.

Section Code	Length (m)	Width (m)		Bankside cover		Substrate		Habitats (area in m^2)					Bankside notes
		Wet	*Bank*	*Left*	*Right*	*Stability*	*Compaction*	*Juvenile*	*Pool*	*Glide*	*Bedrock*	*Incised peat*	
RB1	250	1.4	2	poor	poor	stable	compacted	175	0	0	175	0	Densely overgrown with gorse. Could not be fully surveyed.
RB2	280	1.4	1.5	moderate	moderate	stable	compacted	364	28	0	0	0	
RB3	250	1.4	1.5	moderate	moderate	stable	compacted	350	0	0	0	0	
RB4	260	1.5	1.6	good	good	stable	partly	45	45	300	0	0	Cover from draped heather and undercuts, especially at lower end of section.
RB5	240	1.5	1.6	good	good	stable	partly	0	0	360	0	0	
RB6	280	1.2	1.2	good	good	stable	uncompacted	0	0	336	0	0	Incised, vertical peat bank faces. Some slumping may contribute to siltation of sediments.
RB7	440	1.2	1.2	good	good	stable	uncompacted	240	0	288	0	0	Incised, vertical peat bank faces. Some slumping may contribute to siltation of sediments.
RB8	270	1.6	1.6	good	good	stable	partly	224	80	128	0	0	
RB9	270	1.5	1.5	good	good	stable	partly	300	45	60	0	0	Incised peat with some undercuts.
RB10	250	1.2	1.2	good	good	stable	partly	288	12	0	0	0	Incised peat with some undercuts.
RB11	300	1.3	1.4	good	good	stable	partly	364	26	0	0	0	Good fish cover alongside banks.
RB12	280	1.5	1.5	good	good	stable	partly	345	30	45	0	0	Good cover alongside banks.
RB13	250	1.5	1.5	good	good	stable	partly	330	45	0	0	0	Many undercuts providing cover.
RB14	120	1.5	1.5	good	good	stable	partly	180	0	0	0	0	Many undercuts providing cover.
MCG1	250	0.3	0.3	good	good	stable	partly	75	0	0	0	0	Many undercuts.
MCG2	260	0.4	0.5	good	good	stable	partly	104	0	0	0	0	Channel incised through peat with many undercuts.
MCG3	260	0.2	0.2	good	good	stable	compacted	42	0	0	0	10	Dense rushes on both banks.
MCG4	280	0.3	0.3	good	good	stable	compacted	75	0	0	0	9	Rushes and heather.
MCG5	250	0.4	0.4	good	good	stable	compacted	16	0	0	0	84	
MCG6	250	0.3	0.3	good	good	stable	partly	0	0	0	0	75	Dense rushes.
MF1	250	0.3	0.3	good	good	stable	compacted	75	0	0	0	0	50 cm high, incised peat banks.
MF2	250	0.25	0.25	good	good	stable	compacted	62	0	0	0	0	Conifers 10 – 20 m back from stream.
MF3	250	0.25	0.25	good	good	stable	compacted	34	0	0	0	16	
MF4	450	0.25	0.25	good	good	stable	compacted	0	0	0	0	90	
MFG1	480	0.2	0.2	NA	NA	stable	compacted	0	0	0	0	96	
MG1	300	<0.2	<0.2	NA	NA			0	0	0	0	60	

Appendix 3. Potential spawning habitats, Reay Burn catchment.

Section	**Code**	**Grid Ref**	**Area (m^2)**	**Washout likely?**	**Suitability**		**Notes**
					Salmon	Trout	
RB6	RB6.1	NC 9698 6187	2	No	No	Yes	Silted
RB6	RB6.2	various	4	No	No	Yes	High silt content and rather sandy
RB7	RB7.1	NC 9706 6166	1.5	No	No	Yes	Slightly silted
RB8	RB8.1	NC 9723 6143	2	No	No	Yes	Two areas on meanders. Silted.
RB8	RB8.2	NC 9719 6150	3	No	No	Yes	At run into pool. Silted.
RB8	RB8.3	NC 9717 6153	2.5	No	Yes	Yes	Good quality.
RB10	RB10.2	various	4	No	no	Yes	Little patches in various locations.
RB10	RB10.1	NC 9735 6118	2	No	Yes	Yes	At tail of corner pool.
RB12	RB12.2	NC 9741 6062	1	No	No	Yes	
RB12	RB12.1	NC 9733 6077	3	No	Yes	Yes	Good quality spawning habitat at tail of pool
RB11	RB11.1	various	5	No	No	Yes	Little patches throughout
RB14	RB14.1	various	4	No	No	Yes	Numerous patches
RB13	RB13.1	NC 9747 6050	2	No	Poor	Yes	On meanders
RB13	RB13.2	NC 9741 6061	1	No	Poor	yes	

Appendix 4. Stream survey sections and habitat descriptions: Achvarasdal Burn catchment.

Watercourse	Section Code	NGR		Habitat description
		Downstream	Upstream	
Achvarasdal Burn	AB1	NC 9862 6374	NC 9877 6371	Some bedrock among stable mixed juvenile habitat. Much sand.
Achvarasdal Burn	AB2	NC 9877 6371	NC 9890 6352	Some bedrock among stable mixed juvenile habitat and sand. Macrophytes provide additional cover.
Achvarasdal Burn	AB3	NC 9890 6352	NC 9909 6347	Stable, mossy cobbles and boulders with coarse sand and some pebble. Glides and runs.
Achvarasdal Burn	AB4	NC 9909 6347	NC 9913 6326	Stable, mossy cobbles and boulders with coarse sand and some pebble. Small pockets of spawning habitat only.
Achvarasdal Burn	AB5	NC 9913 6326	NC 9905 6307	Good juvenile habitat. Moderate flow. Stable mossy boulders with cobble, pebble and coarse sand. Good cover alongside banks. Little pockets of potential spawning habitat for small trout.
Achvarasdal Burn	AB6	NC 9905 6307	NC 9897 6284	Angular cobbles and boulders (different from rounded substrates further upstream). Juvenile habitat 10 – 30 cm deep. Lacks spawning. Some bedrock near top of section.
Achvarasdal Burn	AB7	NC 9897 6284	NC 9891 6261	Stable mossy boulder with coarse sand. Moss covered bedrock at downstream end.
Achvarasdal Burn	AB8	NC 9891 6261	NC 9892 6237	Run and glide sequences. Mossy cobbles provide little cover. Some pebble and gravel areas provide good spawning potential. Runs 10 – 15 cm deep. Glides 20-60 cm.
Achvarasdal Burn	AB9	NC 9892 6237	NC 9897 6217	Stable mossy cobble and a few boulders surrounded by coarse sand. Poor cover on stream bed. A few macrophytes.
Achvarasdal Burn	AB10	NC 9897 6217	NC 9891 6191	Much of this section is stable mossy boulder surrounded by coarse sand. Some bedrock. Moderate to low gradient.
Achvarasdal Burn	AB11	NC 9891 6191	NC 9906 6170	Some bedrock (limestone?) near top of section. Downstream end of section is decent quality juvenile salmonid habitat.
Achvarasdal Burn	AB12	NC 9906 6170	NC 9922 6158	Juvenile habitat with cobble habitats at downstream end of section. Upstream is pool and glide. Much sand throughout with little cover on stream bed.
Achvarasdal Burn	AB13	NC 9922 6158	NC 9935 6143	Small substrates of coarse sand, pebble and small cobbles. Little cover on streambed other than macrophyte (5%). Fish plentiful. Pool and run sequences with patchy spawning.
Achvarasdal Burn	AB14	NC 9935 6143	NC 9941 6119	Pebble, cobble and sand provide poor cover on stream bed. Bank cover is good and trout plentiful. High sand content reduces quality of potential spawning habitat. Broad pools and narrower runs and glides.
Achvarasdal Burn	AB15	NC 9941 6119	NC 9939 6035	Stable mossy cobble and boulder in shallow run and glide interspersed with deep pools on bends. Coarse sand surrounds larger substrates. Poor instream cover.
Achvarasdal Burn	AB16	NC 9939 6035	NC 9946 6075	Stable mossy cobble and boulder in shallow run and glide interspersed with deep pools on bends. Coarse sand surrounds larger substrates. Poor instream cover.
Achvarasdal Burn	AB17	NC 9946 6075	NC 9949 6062	Low gradient. Mainly glide. Some with good cover in cobbles. Some deep pools.
Achvarasdal Burn	AB18	NC 9949 6062	NC 9950 6041	Stable, mossy boulder and cobble with coarse sand. Some broad pools but mainly shallow run and glide.
Achvarasdal Burn	AB19	NC 9950 6041	NC 9952 6019	Stable, mossy boulder with cobble and pebble. Some vegetation. Riffle and glide. Some deeper glides and pools towards downstream end of section. Good habitat for fry and parr.
Achvarasdal Burn	AB20	NC 9952 6019	NC 9956 6000	Mainly cobble with some boulder and pebble. Riffle/run/glide sequences. Some deeper pools. Good juvenile habitat. Pockets of potential spawning habitat.
Achvarasdal Burn	AB21	NC 9956 6000	NC 9957 5969	Some bedrock with mossy boulders.
Achvarasdal Burn	AB22	NC 9957 5969	NC 9951 5949	Mainly bedrock with some significant obstacles. Pools are suitable for trout. Deep holding pool at NC 9957 5967.

Appendix 4 contd.

Watercourse	Section Code	NGR		Habitat description
		Downstream	Upstream	
Achvarasdal Burn	AB23	NC 9951 5949	NC 9939 5935	Downstream end is bedrock. Remainder is decent trout habitat.
Achvarasdal Burn	AB24	NC 9939 5935	NC 9942 5910	Good juvenile trout habitat with lots of spawning potential.
Achvarasdal Burn	AB25	NC 9942 5910	NC 9949 5891	Cobble, pebble and coarse sand. Patchy spawning (main areas recorded). Mainly 10 – 20 cm deep with some deeper pools (~30 cm).
Achvarasdal Burn	AB26	NC 9949 5891	NC 9949 5870	As AB25
Achvarasdal Burn	AB27	NC 9949 5870	NC 9950 5851	Some bedrock at top of section. Good quality juvenile salmonid habitat. Varied depths and flows.
Achvarasdal Burn	AB28	NC 9950 5851	NC 9956 5826	Good quality juvenile salmonid habitat. Varied depths and flows.
Achvarasdal Burn	AB29	NC 9956 5826	NC 9962 5802	Good quality juvenile salmonid habitat. Varied depths and flows.
Achvarasdal Burn	AB30	NC 9962 5802	NC 9957 5774	Riffle, run and pool sequences. Varied depths. Cobble and some boulder surrounded by sand and gravel. Pockets of spawning.
Allt Cnoc an Fhraoich	ACF1	NC 9947 5864	NC 9914 5860	Embedded substrates with some gravel & pebble but very shallow.
Allt Cnoc an Fhraoich	ACF2	NC 9914 5860	NC 9905 5835	Wet flush with rushes and *Sphagnum*. Unsuitable for fish.

Appendix 5. Stream survey data, Achvarasdal Burn.

Section Code	Length (m)	Width (m)		Bankside cover		Substrate		Habitats (area in m^2)					Bankside notes
		Wet	*Bank*	*Left*	*Right*	*Stability*	*Compaction*	*Juvenile*	*Pool*	*Glide*	*Bedrock*	*Incised peat*	
AB1	250	3.5	3.5	good	good	stable	partly	595	105	0	175	0	Much gorse so very difficult to survey fully. Draped gorse and willow provide cover.
AB2	250	3.5	3.5	good	good	stable	partly	420	70	175	210	0	
AB3	250	2.5	2.5	good	good	stable	partly	400	75	150	0	0	
AB4	250	2.5	2.5	good	good	stable	partly	475	0	150	0	0	
AB5	250	2.3	2.4	good	good	stable	partly	460	46	0	69	0	Dense bracken throughout. Steep, undercut, stable bank faces.
AB6	250	3.2	3.5	moderate	moderate	moderate	uncompacted	608	96	0	96	0	Some bedrock bank but mainly stable and vegetated. 100 m of bare bank face at middle of section.
AB7	250	3.5	3.5	moderate	moderate	stable	partly	525	0	0	350	0	Lack of erosion throughout. Very stable.
AB8	260	2	2	good	good	stable	partly	320	60	140	0	0	Stable, undercut with much bracken.
AB9	250	3	3	good	good	stable	partly	600	0	150	0	0	Stable, undercut with much bracken.
AB10	280	2.3	2.3	good	good	stable	partly	391	46	115	92	0	Undercut banks provide cover. Dense bracken.
AB11	270	3	3	moderate	moderate	stable	partly	630	0	0	180	0	Dry, stable, bracken covered banks.
AB12	250	1.9	1.9	good	good	stable	partly	247	95	133	0	0	
AB13	300	1.8	1.8	good	good	stable	partly	198	72	270	0	0	Good bankside cover. Stable and undercut.
AB14	250	1.8	1.8	good	good	stable	partly	198	90	162	0	0	Stable, grassy banks. Lots of undercuts.
AB15	250	1.8	1.8	good	good	stable	partly	288	72	90	0	0	
AB16	260	1.8	1.8	good	good	stable	partly	324	72	72	0	0	
AB17	250	1.9	1.9	good	good	stable	partly	304	76	95	0	0	
AB18	320	1.9	1.9	good	good	stable	partly	513	95	0	0	0	
AB19	250	2	2.1	good	good	stable	partly	440	60	0	0	0	Bracken covered left bank. Right is grassy with some rush.
AB20	250	2	2	good	good	stable	uncompacted	440	60	0	0	0	Rushes and grass in wetter areas. Much bracken. Steep bank faces. Stable undercuts.
AB21	280	2	2.1	moderate	moderate	stable	uncompacted	340	60	0	160	0	Dense bracken.
AB22	250	4	5	poor	poor	stable	uncompacted	0	320	0	680	0	Stable bedrock banks.
AB23	250	3	3	moderate	moderate	stable	uncompacted	300	120	150	180	0	
AB24	250	2	2	good	good	stable	uncompacted	340	80	80	0	0	Heather and grasses. Banks quite stable.
AB25	250	1.7	1.8	good	good	moderate	uncompacted	340	85	0	0	0	Grass, rushes and bracken.

Appendix 5 contd.

Section Code	Length (m)	Width (m)		Bankside cover		Substrate		Habitats (area in m²)					Bankside notes
		Wet	*Bank*	*Left*	*Right*	*Stability*	*Compaction*	*Juvenile*	*Pool*	*Glide*	*Bedrock*	*Incised peat*	
AB26	290	1.4	1.5	good	good	moderate	uncompacted	406	0	0	0	0	Grass, rushes and bracken.
AB27	250	1.8	1.9	good	good	moderate	uncompacted	378	0	0	72	0	Broad grassy buffer strip and thicket conifer.
AB28	280	1.8	1.9	good	good	moderate	uncompacted	504	0	0	0	0	Broad grassy buffer strip and thicket conifer.
AB29	260	1.7	1.9	moderate	moderate	stable	uncompacted	442	0	0	0	0	Grasses and soft rush.
AB30	310	1.7	1.8	good	good	stable	uncompacted	527	0	0	0	0	
ACF1	260	0.5	0.5	moderate	moderate	stable	compacted	595					Much dense bracken.
ACF2	310	0.3	0.3	na	na	stable	na	420					Grasses and soft rush.

Appendix 6. Potential spawning habitats, Achvarasdal Burn catchment.

Section	Code	Grid Ref	Area (m^2)	Washout likely?	Suitability		Notes
					Salmon	Trout	
AB8	AB8.1	NC 9890 6245	5	No	Yes	Yes	At island
AB8	AB8.2	NC 9888 6254	3	No	Yes	Yes	
AB10	AB10.1	NC 9890 6193	2	No	Poor	Yes	
AB10	AB10.2	NC 9893 6198	1	No	No	Yes	
AB12	AB12.1	NC 9916 6160	4	No	No	Yes	
AB13	AB13.1	NC 9933 6144	5	No	Yes	Yes	Sub-optimal due to proportion of coarse sand
AB13	AB13.2	various	15	No	Yes	Yes	Several patches throughout section
AB14	AB14.1	NC 9942 6130	2	No	Yes	Yes	Sub-optimal due to proportion of coarse sand
AB14	AB14.2	NC 9939 6140	2	No	Yes	Yes	
AB16	AB16.1	NC 9941 6081	3	No	Yes	Yes	
AB15	AB15.1	NC 9939 6097	2	Possibly	Yes	Yes	
AB17	AB17.1	NC 9953 6069	3	No	Yes	Yes	At tail of pool
AB17	AB17.2	NC 9945 6073	2	No	No	Yes	
AB19	AB19.1	NC 9947 6027	1.5	No	No	Yes	
AB19	AB19.2	NC 9950 6041	1.5	No	No	Yes	
AB21	AB21.1	NC 9958 5983	2	No	Yes	Yes	
AB24	AB24.1	NC 9938 5912	8	No	No	Yes	Three patches.
AB24	AB24.2	NC 9938 5918	10	No	Yes	Yes	Four patches.
AB24	AB24.3	NC 9938 5931	15	No	Yes	Yes	Several patches.
AB25	AB25.1	NC 9951 5892	3	No	Yes	Yes	
AB25	AB25.2	NC 9951 5895	3	No	Yes	Yes	Tail of pool
AB25	AB25.3	NC 9941 5910	7	No	Yes	Yes	Two patches. Good quality.
AB26	AB26.1	NC 9952 5877	1	No	Yes	Yes	Tail of pool at meander.
AB26	AB26.2	NC 9948 5877	1	No	Yes	Yes	
AB26	AB26.3	NC 9952 5883	4	No	Yes	Yes	Tail of long glide.
AB26	AB26.4	NC 9947 5887	8	No	Yes	Yes	Three patches.
AB27	AB27.1	NC 9947 5865	1	No	Yes	Yes	Tail of pool at meander.
AB30	AB30.1	NC 9957 5778	1	Possibly	No	Yes	

Appendix 7. Suitable patches of habitat for larval lampreys, Achvarasdal Burn catchment.

Watercourse	Survey section	NGR	Area (sq m)	Quality	Woody debris	Permanence
Achvarasdal Burn	AB3	NC9914 6329	2	sub-optimal	Absent	Permanent
Achvarasdal Burn	AB5	NC9805 6311	0.5	sub-optimal	Absent	Semi-permanent
Achvarasdal Burn	AB6	NC9897 6287	2	optimal	Absent	Permanent
Achvarasdal Burn	AB12	NC9915 6162	3	optimal	Absent	Permanent
Achvarasdal Burn	AB13	NC9928 6147	4	sub-optimal	Absent	Permanent
Achvarasdal Burn	AB13	NC9928 6149	1	sub-optimal	Absent	Permanent
Achvarasdal Burn	AB13	NC9927 6152	2	sub-optimal	Absent	Permanent
Achvarasdal Burn	AB14	NC9943 6132	3	sub-optimal	Absent	Permanent
Achvarasdal Burn	AB14	NC9940 6128	3	optimal	Absent	Permanent
Achvarasdal Burn	AB14	NC9942 6132	2	sub-optimal	Absent	Permanent
Achvarasdal Burn	AB14	NC9939 6140	3	sub-optimal	Absent	Permanent
Achvarasdal Burn	AB16	NC9951 6082	1.5	sub-optimal	Absent	Semi-permanent
Achvarasdal Burn	AB16	NC9941 6081	1	sub-optimal	Absent	Semi-permanent
Achvarasdal Burn	AB16	NC9943 6085	2	optimal	Absent	Permanent
Achvarasdal Burn	AB16	NC9941 6116	3	optimal	Absent	Permanent
Achvarasdal Burn	AB17	NC9953 6069	2	optimal	Absent	Permanent

Appendix 8.1 Electric fishing site and event details

Site	NGR	Location	Runs	Width	Length	Area	Equipment	Voltage	Amps	Effective?	Conductivity (µS.cm^{-1})	Temp (°C)	Stopnets?	Water level
R1	NC 9711 6292	Top of site is run-out from big pool. Bottom is sharp left bend.	1	1.8	54	97.2	backpack	180	0.7	yes	187	12.7	no	low
R2	NC 9711 6292	Top of site is apex of very sharp (U-shaped) left bend.	3	1.4	66.5	93.1	backpack	180	0.6	yes	189	13.1	yes	low
R3	NC 9749 6052	Top of site is confluence. Bottom is tail of pool at bend.	1	1.4	64	89.6	backpack	180	0.6	yes	174	11.8	no	low
MF1	NC 9801 6022	Various small patches where stream was wide enough to allow survey.	PA			0.0	backpack	180	0.6	yes	190	12	no	low
MCG1	NC 9776 6028	In open reach of stream (much of rest is too narrow for survey).	1	1	55	55.0	backpack	180					no	low
MCG2	NC 9779 6005	Various small patches where stream was wide enough to allow survey.	PA			0.0	backpack	180					no	low
MCG3	NC 9783 5998	Various small patches where stream was wide enough to allow survey.	PA			0.0	backpack	180					no	low
A1	NC 9912 6324	On bends at deer fence. Bottom of site is 12 m down from old water gate and ~ 20m down from sharp bend. Top is green point at right bank.	1	2.5	56	140.0	backpack	180	0.8	yes	230	13	no	low
A2	NC 9896 6201	Top of site is riffle at neck of pool. Bottom is riffle at upstream end of sharp bends.	1	2.9	41.8	121.2	backpack	180	0.8	yes	210	16	yes	low
A3	NC 9947 6061	Top of site is the riffle about 15 m upstream from left bank confluence.	3	2.9	51.5	149.4	backpack	180	1	yes	205	16	no	low
A4	NC 9950 5869	Down from Allt Cnoc an Fhraioich. Top is riffle at downstream end of U-bend. Bottom is 2 m upstream from right bend.	1	1.8	46	82.8	backpack	180	0.8	yes	174	14	no	low

PA = qualitative survey only

Appendix 8.2 Depletions attained at fully quantitative survey sites

Site	**Trout fry**			**Trout parr**		
	run 1	run 2	run 3	run 1	run 2	run 3
R2	42	16	9	13	4	0
A3	16	8	2	37	6	2

Appendix 9. Instream habitats at quantitative electric fishing sites.

SITE	DEPTH						SUBSTRATE									FLOW TYPES							
	<10	*11-20*	*21-30*	*31-40*	*41-50*	*>50*	*HO*	*SI*	*SA*	*GR*	*PE*	*CO*	*BO*	*BE*	*OB*	*SM*	*DP*	*SP*	*DG*	*SG*	*RU*	*RI*	*TO*
R1	10	45	20	20	5	0	0	0	8	2	5	45	40	0	0	5	25	25	0	0	45	5	0
R2	10	55	20	14	1	0	2	0	18	5	15	55	5	0	0	10	10	20	0	10	40	10	0
R3	15	35	25	20	5	0	5	0	10	10	20	50	5	0	0	0	25	20	0	10	40	5	0
MCG1	30	45	20	5	0	0	5	0	10	5	30	30	20	0	0	10	5	35	0	5	40	5	0
A1	10	30	35	20	5	0	0	0	10	10	5	35	40	0	0	0	5	20	0	10	55	10	0
A2	2	18	25	35	18	2	0	0	15	10	5	45	25	0	0	0	55	10	0	5	30	0	0
A3	5	20	20	20	20	15	2	0	3	5	10	50	30	0	0	0	50	10	0	10	25	5	0
A4	10	40	30	15	5	0	3	0	5	5	10	67	10	0	0	5	20	5	0	20	40	10	0

Substrates: HO = high organic (peat); SI = silt; SA = sand; GR = gravel; PE = pebble; CO = cobble; BO = boulder; BE = bedrock; OB = obscured.
Flow types: SM = shallow marginal; DP = deep pool; SP = shallow pool; DG = deep glide; SG = shallow glide; RU = run; RI = riffle; TO = torrent.

SITE	Left Bank				Right Bank				Cover in wider channel
	UC	DR	BA	MA	UC	DR	BA	MA	
R1	20	0	80	0	25	0	75	0	Good
R2	40	0	60	0	40	0	60	0	Moderate
R3	40	0	60	0	40	0	60	0	Moderate
MCG1	90	0	10	0	90	0	10	0	Poor
A1	50	10	50	0	50	10	0	50	Excellent
A2	60	0	40	0	70	0	30	0	Good
A3	50	0	50	0	50	0	50	0	Good
A4	40	0	60	0	50	0	50	0	Moderate

Bankside fish cover: UC = undercut bank; DR = draped vegetation; BA = bare (no cover); MA = marginal vegetation (incl. tree toots).

Appendix 10. Salmonid density classification system for North Region (Godfrey 2006). These classifications are based on large data sets held by SFCC. The quintile densities allow for comparison of fishery performance against regionally based reference points.

	Stream width Class	
	<6m	**>6m**
Salmon 0+		
0^{th} percentile	1.0	0.5
20^{th} percentile	7.1	4.5
40^{th} percentile	9.3	13.1
60^{th} percentile	12.7	28.4
80^{th} percentile	20.1	32.7
100^{th} percentile	48.9	67.4
% zero density	34.5	9.5
Salmon 1++		
0^{th} percentile	1.2	1.1
20^{th} percentile	1.7	4.4
40^{th} percentile	4.6	7.0
60^{th} percentile	8.5	13.3
80^{th} percentile	13.0	19.1
100^{th} percentile	21.3	27.7
% zero density	24.1	9.5
Trout 0+		
0^{th} percentile	1.0	0.5
20^{th} percentile	4.4	0.8
40^{th} percentile	5.2	1.9
60^{th} percentile	8.5	2.9
80^{th} percentile	12.6	4.2
100^{th} percentile	98.5	5.5
% zero density	6.9	19.0
Trout 1++		
0^{th} percentile	1.2	0.6
20^{th} percentile	3.0	0.6
40^{th} percentile	4.4	0.9
60^{th} percentile	7.1	1.1
80^{th} percentile	8.6	1.6
100^{th} percentile	14.7	3.6
% zero density	20.7	38.1

NB: All densities are based on single-run, semi quantitative survey.

Appendix 11. Selected photographs, Reay Burn catchment.

Reay Burn section RB1.

Reay Burn section RB2.

Reay Burn section RB4. Sluggish flow, small substrates and much weed growth.

Appendix 11 contd.

Reay Burn section RB10. Good quality habitat for juvenile salmonids.

Reay Burn section RB12 at NC 973 608. Good quality habitat for juvenile salmonids.

Meur an Fhuarain Ghil, section MFG1. This tiny stream is incised through peat, lacks hard substrate and in places flows below ground.

Appendix 11 contd.

Meur an Fhraoich, section MF2. Although small and narrow, this stream has some habitat suited to spawning and to trout fry.

Meur an Chrochain Ghill, section MCG2.

Meur an Chrochain Ghill, section MCG4. Tiny stream, very shallow with larger substrates embedded in a hard peat matrix.

Appendix 11 Selected photographs Achvarasdal Burn catchment

Achvarasdal Burn, good quality salmonid habitat with mixed depths, flows and overhead cover (section AB1).

Achvarasdal Burn, section AB6. Typical salmonid habitat.

Achvarasdal Burn section AB13. Glide habitats with small substrates providing little streambed cover. Undercut banks provide overhead cover.

Appendix 11 contd.

Achvarasdal Burn. Suitable habitat for larval lampreys in section AB16.

Obstacle 21.1 is non-vertical. The concentration of flow towards the left bank may permit fish passage at higher water levels.

Obstacle 22.1 on Achvarasdal Burn at NC9956 5963. This seems likely to be passable to salmonids on higher flows. The mossy substrate is likely to allow eels to climb up.

Appendix 11 contd.

Obstacle 22.2 on the Achvarasdal Burn at NC 9955 5960. This seems likely to be impassable to upstream migrating salmonids. The top tier is over 2 m high and the ledge below this where the surveyor is standing is broad, flat and shallow. This is likely to make jumping difficult or impossible for salmonids.

The mossy substrate is likely to allow eels to climb up.

Obstacle 22.3 on Achvarasdal Burn at NC9953 5954. This seems likely to be passable to salmonids on higher flows. The mossy substrate is likely to allow eels to climb up.

Potential spawning habitat in section AB24 at NC 9939 5120.

Appendix 12. Electric fishing sites

R1. Looking downstream to bottom end of site.

R2. Looking up from downstream end of site.

R3. Looking upstream to top of site.

MCG1. Habitat in more open reach.

MCG 3. Tiny, shallow pool where one trout fry was caught.

A1. Typical habitat in middle of survey reach.

A2, looking down to bottom of site (marked by net).

A2. Run and riffle habitat.

A3 looking downstream to bottom net.

A3. Middle of survey site.

Juvenile salmon (top) and trout at site A3.

A4. Looking downstream to bottom of site (marked by net).

Appendix 11.H
Freshwater Pearl Mussel Survey Report

Limekiln Wind Farm:

Survey of freshwater pearl mussels *Margaritifera margaritifera*

Report to Infinergy Ltd

June 2012

Waterside Ecology
Druimindarroch
Arisaig
Inverness-shire
PH39 4NR
T: 01687 450298
M: 07788 717605
jon@watersideecology.co.uk

www.watersideecology.co.uk

Table of Contents **Page**

List of Figures **Page**

List of Tables **Page**

1 Summary

1.1 Background

A survey of freshwater pearl mussels *Margaritifera margaritifera* was commissioned to inform the Environmental Impact Assessment for the proposed Limekiln Wind Farm in Caithness. The proposed wind farm is anticipated to have 30 to 50 turbines and would be constructed to the south of the village of Reay. The site extends to approximately 11 km^2 and is currently used mainly for commercial forestry. Two main watercourses the Achvarasdal Burn and Reay Burn drain the site, both running south to north. The Achvarasdal Burn runs along the eastern site boundary and the Reay Burn runs close to its western edge. Both of these streams are fed by a number of small tributaries that drain the site.

Two experienced surveyors carried out the survey during summer 2011. The survey involved careful searches for freshwater pearl mussels along all potentially suitable reaches of stream in the proposed wind farm site. Survey conditions were good with low water levels and good light.

1.2 Main findings

- No freshwater pearl mussels were found in the streams draining the proposed development site.
- Suitable habitat for freshwater pearl mussels is present in the Reay Burn and Achvarasdal Burn.
- Most habitat in the smaller tributary streams is very poor or entirely unsuitable for freshwater pearl mussels.

1.3 Implications

The lack of any evidence of freshwater pearl mussels in the survey reaches suggests that the proposed development will not impact negatively on this species. As it is possible that relict populations of freshwater pearl mussel may persist further downstream, standard mitigation measures to avoid negative impacts on watercourses, streambed habitats and host salmonid populations should be implemented.

2 Introduction

2.1 Proposed scheme

The proposed Limekiln Wind Farm is anticipated to have 30 to 50 turbines and would be constructed to the south of the village of Reay, in Caithness. A survey of freshwater pearl mussels *Margaritifera margaritifera* was commissioned to inform the Environmental Impact Assessment for the proposed development. The development site extends to approximately 11 km^2 and is currently used mainly for commercial forestry. The trees are at a ‘thicket’ stage. Two main watercourses the Achvarasdal Burn and Reay Burn drain the site, both running south to north. The Achvarasdal Burn runs along the eastern site boundary and the Reay Burn runs close to its western edge. Both of these streams are fed by a number of small tributaries that drain the site. Both stream catchments provide potential habitat for freshwater pearl mussels, a globally threatened bivalve mollusc. The proposed development has potential to impact on freshwater pearl mussels through damage to stream habitats, changes in water quality or direct disturbance to mussels e.g. at stream crossings.

2.2 Freshwater pearl mussel status

Recent estimates suggest that Scotland holds perhaps half of the world’s known viable populations of freshwater pearl mussel (Cosgrove *et al*. 2000). Even here the species has undergone rapid decline during the last 100 years as a result of pollution, over-exploitation by pearl fishermen, declines in salmonid host stocks and habitat degradation (Young *et al*. 2001). Under the Wildlife and Countryside Act (1981) of Great Britain as amended by the Nature Conservation Scotland Act (2004), it is an offence to intentionally or recklessly kill, injure, take or disturb freshwater pearl mussels or to damage their habitat. The species is also listed on Annexes II and V of the EC Habitats Directive and Appendix III of the Bern Convention. The freshwater pearl mussel is a ‘Priority Species’ under the UK Biodiversity Action Plan requiring the implementation of a Species Action Plan dedicated to its survival (Biodiversity Steering Group 1995).

2.3 Relevant aspects of freshwater pearl mussel ecology

2.3.1 Lifecycle

Freshwater pearl mussels mature at an age of 10–15 years and a length of approximately 65 mm. They are typically dioecious, populations consisting of separate males and females. Males release sperm in summer. Females inhale these and the fertilised eggs develop in a pouch in the gills. The larvae, called glochidia, are released in late summer. The glochidia are parasitic and to survive they must settle on a suitable host fish, where they encyst in the gills. The glochidia look like tiny mussels, but the valves of their shells remain open until they encounter a host fish, when they snap shut on the gill filaments (Young & Williams 1984). Each female mussel ejects over 1 million glochidia, most of which will fail to settle on a host. Those that do successfully settle will remain in the hyper-oxygenated environment until the following spring, when they will drop off and begin their life as a free-living mussel. They must drop into suitable substrate of clean sand or gravel, or they will fail to establish. Huge losses are associated with each stage of this lifecycle, making the freshwater pearl mussel particularly vulnerable to adverse conditions. Pearl mussels are long lived, and can live for more than 100 years, reaching 12-15 cm in length.

2.3.2 Habitat requirements

Freshwater pearl mussels live buried or partly buried in the beds of clean, unpolluted streams and rivers where they subsist by filter feeding on minute organic particles (Skinner *at al.* 2003). They are found in oligotrophic streams with a moderate or fast flow. Detailed studies suggest an optimum water depth of 0.3-0.4 m and optimum current velocities of 0.25 to 0.75 ms^{-1} at intermediate water levels (Hastie *et al.* 2000). Riverbed substrate characteristics are critical for freshwater pearl mussels. Preferred substrate consists of small sand patches stabilised among stones and boulders. In slower flowing streams, riffle areas with a mixture of cobbles, boulders and sand provide important, oxygen rich and relatively silt free habitats. Pearl mussels are thought to be at their most vulnerable at the stage where they leave the host fish and settle into the substrate. At this stage they are much less tolerant of siltation, eutrophication or pollution than are adult mussels. Stability of the streambed is important for both juvenile and adult mussels. Large beds of mussels can be found in stable substrates of the correct composition. In contrast, they are rarely found in loose sand or unstable cobbles and pebbles. Densely vegetated habitats are also considered sub-optimal, as these tend to trap silt.

2.3.3 Host requirements

Glochidia are host-specific and in the UK can only complete their development on Atlantic salmon *Salmo salar* or brown trout *Salmo trutta*. Usually juvenile fish (fry and parr) are utilised as hosts (Young & Williams 1984) and the presence of good densities of young salmonids may be critical to maintaining healthy populations of freshwater pearl mussels (Hastie & Young 2003). In many rivers, juvenile salmon greatly outnumber juvenile trout and in these circumstances salmon may be the primary host. However, it is known that some populations of freshwater pearl mussels are dependent on trout and the presence of salmon is not essential.

2.4 Local status

Freshwater pearl mussels are known to occur in a number of rivers and streams in the northern Highlands. As pearl mussels are still subject to illegal exploitation, despite the ban on pearl fishing, exact locations are confidential.

3 Objectives

The objective of the study was to determine the presence and distribution of freshwater pearl mussels in stream reaches that may be impacted during construction or operation of the proposed wind farm.

4 Survey areas and methods

4.1 Survey area, dates and conditions

At the time of survey no fixed layout of the proposed wind farm was available. Therefore all potentially suitable habitats in or adjacent to the proposed wind farm site were surveyed for freshwater pearl mussels. The survey area is shown on Figure 1. The survey was carried out on 27th to 28th July and 17th August 2011. Survey conditions were excellent with low water levels and good light.

4.2 Survey methods

Stream habitats were searched for mussels by a team of two experienced surveyors (Jon Watt & Isabel Isherwood) using standard freshwater pearl mussel survey protocols (SEPA 2010; Young *et al*. 2003). The streams were sub-divided into contiguous sections. Searches were made in an upstream direction using glass-bottomed viewing buckets. All favourable areas for mussels were searched. Loose debris and trailing weed were moved gently aside but no disturbance of fixed substrate was undertaken.

Data recorded for each survey section included up and downstream grid references and number of mussels encountered. Notes were maintained on substrate stability, typical depth and flow types, substrate composition and any threats to mussels. Habitat quality for freshwater pearl mussels in each section was broadly categorised as optimal, sub-optimal or unsuitable based on the criteria in Table 1. Adult freshwater pearl mussels have, very occasionally, been found on firm, peat-based substrates (Cosgrove & Harvey 2004). However, given the highly specific habitat requirements of juvenile mussels, there is doubt that the species can reproduce in such substrate unless some sand is present to support the early juvenile stages (L. Hastie, pers. comm.). Nevertheless, given the relatively broad tolerance of adult mussels searches were not confined solely to the most favourable mussel habitats.

In addition to the extensive surveys described above, a series of 50 m transects were conducted in each stream. Detailed habitat data were collected at these locations in order to underpin the assessments made during the extensive survey. The following variables were assessed and recorded in each 50 m habitat transect:

(i) Mean channel width and depth (m);
(ii) Riverbed substrate stability (Table 2);
(iii) Riverbed habitat suitability for mussels (Table 1);
(iv) Surface substrate cover (%) using the Wentworth (1922) scale;
(v) Riparian vegetation type(s);
(vi) Riparian/catchment land-use(s), and
(vii) Number of mussels found.

Table 1 Freshwater pearl mussel habitat suitability criteria

Suitability	Assessment criteria
Optimal	Evidence of long-term riverbed stability. Significant pockets of fine sediments (clean sands and gravels) stabilised by primary substrates (e.g. boulders). Considered to be suitable habitat for juvenile *M. margaritifera*. Generally characterised by mixed sediments and intermediate flows.
Sub-optimal	Evidence of long-term, intermediate riverbed stability and/or a few areas that could support significant numbers of adult *M. margaritifera*. Generally characterised by partly sorted sediments and variable flows.
Unsuitable	No significant optimal or sub-optimal habitat observed. Generally characterised by extreme flows, mobile, well-sorted sediments and/or unsuitable substrate types.

Table 2 Criteria used to characterise riverbed substrate stability

Substrate stability	Assessment criteria
Stable	Signs of long-term riverbed stability (e.g. significant aquatic macrophytic growth, dark coloured stones and boulders). Generally characterised by extensive areas of mixed substrates.
Moderate	Riverbed sediments generally mobile but with a few relatively stable patches throughout and/or along river margins adjacent to banks. Generally characterised by small, confined areas of mixed substrates.
Unstable	Signs of large-scale sediment mobility, often with smooth, clean stones and boulders. Usually dominated by well-sorted substrates, recent sediment deposits on riverbed and/or significant depositional features (e.g. gravel/shingle bars).

Standard pearl mussel survey procedure requires that where live mussels and/or empty shells are detected, a standard 50 m x 1 m transect should be surveyed. Should mussels be found, a total count of mussels would be made in each transect and 1 m x 1 m quadrats would be stationed at 10, 20, 30, 40 and 50 m along that transect. All mussels within these quadrats would be counted, removed and measured. Loose stones and debris would be removed to search for hidden mussels. The number of juvenile mussels (<65 mm shell length) would be recorded.

5 Results

5.1 Reay Burn catchment

5.1.1 Overview

The Reay Burn contains many patches of potentially suitable habitat for freshwater pearl mussels (see Appendix 1). This and the presence of host salmonid fish suggest that the stream would be capable of supporting freshwater pearl mussels. Despite intensive searches no freshwater pearl mussels were found in the Reay Burn or any of its tributary streams.

Figure 1 Survey sections and survey transect locations.

5.1.2 Stream habitats

Throughout most of the survey area the Reay Burn has a low or moderate gradient. Gradient is greatest in the lower 0.75 km. Typical depths range from 10 to 30 cm. Substrates vary and their composition is influenced by gradient. In the steeper, lowermost reaches substrates are a mixture of bedrock and patches of stable boulder surrounded by gravel and sand. The latter type of habitat provides some potentially suitable habitat for mussels. The middle reaches of the Reay Burn in survey sections R5 to R7 have a relatively low gradient and the channel appears to have been straightened. Substrate composition appears superficially suitable for freshwater pearl mussels with some gravel and sand, but these generally form a very thin, unstable layer over peat and habitat quality is very poor (mainly unsuitable). Transect RT2 was in this type of habitat (Table 3). The rest of the Reay Burn, upstream to the confluence of the Meur a' Chrochain Ghill Meur an Fhraoich consists of run and glide sequences with mixed substrates of cobble, pebble and coarse sand typified by transects R3 and R4 (Table 3). This part of the stream is sub-optimal mussel habitat with small patches of suitable mussel habitat and host fish appeared to be quite abundant.

Table 3 Habitat data from 50 m transects, Reay Burn

Transect no.	**Downstream NGR**		**Substrate stability**		**Width (m)**	**Depth (m)**		**Land use**	
RT1	NC 9711 6287		Stable		1.4	0.10		Moorland heath	
	Substrate:	**Bedrock**	**Boulder**	**Cobble**	**Pebble**	**Gravel**	**C. sand**	**F. sand**	**Peat**
	%:	5	50	20	5	10	10	0	0
Mussels (n)	**Comment:** Stable boulders, some embedded and mossy, surrounded by grit. Sub-optimal mussel habitat. Some siltation/peat deposition on top in slower reaches.								
None									

Transect no.	**Downstream NGR**		**Substrate stability**		**Width (m)**	**Depth (m)**		**Land use**	
RT2	NC 9694 6212		Unstable		1.0	0.15		Rough pasture	
	Substrate:	**Bedrock**	**Boulder**	**Cobble**	**Pebble**	**Gravel**	**C. sand**	**F. sand**	**Peat**
	%:	0	0	0	5	30	45	5	15
Mussels (n)	**Comment:** Unstable sand and gravel in thin layer over peat. Unsuitable habitat.								
None									

Transect no.	**Downstream NGR**		**Substrate stability**		**Width (m)**	**Depth (m)**		**Land use**	
RT3	NC 9727 6137		Moderate		0.8	0.15		Rough pasture	
	Substrate:	**Bedrock**	**Boulder**	**Cobble**	**Pebble**	**Gravel**	**C. sand**	**F. sand**	**Peat**
	%:	0	2	58	20	10	5	0	5
Mussels (n)	**Comment:** Run/glide sequences. Some stable mussel habitat in small patches – sub-optimal. Vertical peat bank faces. Fish present.								
None									

Transect no.	**Downstream NGR**		**Substrate stability**		**Width (m)**	**Depth (m)**		**Land use**	
RT4	NC 9743 6058		Stable		0.8	0.15		Rough pasture	
	Substrate:	**Bedrock**	**Boulder**	**Cobble**	**Pebble**	**Gravel**	**C. sand**	**F. sand**	**Peat**
	%:	0	5	65	10	10	5	0	5
Mussels (n)	**Comment:** Run and glide sequences. Sub-optimal mussel habitat overall, with patches of suitable habitat among coarse substrate. Host fish present.								
None									

Of the tributary streams, only the Meur an Fhraoich and Meur a' Chrochain Ghill contained any habitat potentially capable of supporting freshwater pearl mussels. The Meur Fhraoich is typically 0.2 to 0.3 m wet width and 5 to 10 cm deep. It runs through a channel incised in peat. There are a few small patches of grit among embedded cobbles that might support mussels but habitat quality is generally very poor. Substrate was generally quite compacted and contained a proportion of deposited peat that might smother juvenile mussels. Habitat in the Meur a' Chrochain Ghill is very similar. Small numbers of salmonid fish, probably trout, were seen in both streams but mussels were absent.

suited to freshwater pearl mussels than do the sections downstream from Esvarasdal. The upstream 1 km of the survey area was classified as unsuitable due to instability and lack of suitable substrate. Transect AT6 (Table 5) was in this reach and typifies available habitat in the upstream survey reaches.

The stream draining Milton Moss lacks any suitable substrates for freshwater pearl mussels, being primarily peat-based. Substrates in the lower reaches of the Allt Cnoc an Fhraoich are mainly cobble embedded in a peat matrix. There are some patches of gravel & pebble but the stream is very shallow and generally unsuited to mussels or host fish. The upper survey reach (section A34) is mainly a simple peat-based channel or an ill-defined seep through soft rush. It is entirely unsuitable for freshwater pearl mussels.

Table 5 Habitat data from 50 m transects, Achvarasdal Burn (Esvarasdal upstream)

Transect no.	**Downstream NGR**		**Substrate stability**		**Width (m)**	**Depth (m)**		**Land use**	
AT5	NC 9946 5900		Moderate		1.5	0.20		Wet rough pasture	
	Substrate:	**Bedrock**	**Boulder**	**Cobble**	**Pebble**	**Gravel**	**C. sand**	**F. sand**	**Peat**
	%:	0	0	50	30	5	10	0	5
Mussels (n)	**Comment:** A few patches sub-optimal, but mostly unsuitable. No macrophyte but some mossy cobbles suggests moderate stability.								
None									

Transect no.	**Downstream NGR**		**Substrate stability**		**Width (m)**	**Depth (m)**		**Land use**	
AT6	NC 9953 5833		Unstable		2	0.20		Rough pasture	
	Substrate:	**Bedrock**	**Boulder**	**Cobble**	**Pebble**	**Gravel**	**C. sand**	**F. sand**	**Peat**
	%:	5	15	65	10	3	2	0	0
Mussels (n)	**Comment:** Unstable and mainly unsuitable. Angular cobble and a little unstable grit. Some bedrock. Fish present.								
None									

6 Evaluation

6.1 Freshwater pearl mussels at Limekiln

Survey conditions were ideal with clear water and good light. As such, survey efficiency would be expected to be good. Despite the presence of some suitable habitats, no freshwater pearl mussels were found in any of the survey reaches, suggesting that they are absent from all stream reaches. The limitations of the standard methodology apply to any freshwater pearl mussel survey carried out using this technique. As a proportion of freshwater pearl mussels including smaller juveniles may be buried in the substrate, any complete census would require the destructive searching of all loose material including all potentially suitable mussel habitats. Clearly this is both impractical and unacceptable for extensive surveys. In those habitats that were accessible for survey, the use of experienced surveyors meant that potentially suitable areas were thoroughly searched. Given that no evidence of live or dead freshwater pearl mussels or empty shells was found, it is unlikely that freshwater pearl mussels occur in any of the survey reaches.

Cosgrove *et al.* (2000) reviewed published and anecdotal accounts of freshwater pearl mussels in Scotland. It was clear from this and subsequent studies (e.g. Young *et al.* 2001) that many, perhaps most, sites that are accessible to pearl fishing are likely to have been destructively pearl fished over prolonged periods. As a result, mussels at many Scottish sites are likely to have been driven to extinction decades, or even centuries, ago. Unfortunately, destructive pearl fishing continues and, were mussels ever present at any of the survey sites assessed during the current study, it is quite probable that they would have been subject to exploitation. The areas of optimal mussel habitat that were identified were all in places where any mussels potentially present during past years would have been easily fished out. While this is conjecture, it might well explain the apparent absence of freshwater pearl mussels from some apparently suitable sites.

Appendix 11.I
Freshwater Invertebrate Survey Report

LIMEKILN WIND FARM:

FRESHWATER INVERTEBRATE SURVEY

Report to: Infinergy Ltd

March 2012

Aquaterra Ecology

Aquaterra Ecology, Crombie Cottage, Aberchirder, Huntly, Aberdeenshire AB54 7QU

Table of Contents

Limekiln Wind Farm: Freshwater Invertebrate Surveys. March 2012

1 Summary

1.1 Background

This survey was commissioned to assess the water quality and invertebrate communities of watercourses subject to possible impact from the construction of the Limekiln Wind Farm. The key objectives of the survey were to provide baseline information for the Environmental Impact Assessment (EIA) and the Environmental Statement (ES) by:

- Characterisation of the invertebrate community of the watercourses to species level highlighting any rarities or notable species present.
- Assessment of the water quality (including WFD ecological status) of the watercourses using a range of biotic indices and pH, alkalinity and conductivity measurements.

Macroinvertebrate communities were sampled using standard kick sampling methods (SEPA 2001) from six sites: three each in the Achvarasdal Burn and the Reay Burn. Sampling was conducted on the 9th October 2011.

Major groups (Malacostraca, Ephemeroptera, Trichoptera, Plecoptera, Mollusca, Odonata and adult Coleoptera) were identified to species level to establish presence of any rare species and to provide data for production of biological indices: Biological Monitoring Working Party (BMWP), Average Score Per Taxon (ASPT), Water Framework Directive (WFD) class, Water Chemistry Status and Index of Acidity.

Physical environmental variables including bed width, depth, flow and substrate profile were recorded at each site. pH and conductivity were recorded on site and water samples were taken for analysis of alkalinity. GPS generated grid references and photographs were taken to enable future site identification.

1.2 Main Findings

- Invertebrate communities largely consisted of common and widespread species typical of Scottish upland watercourses and no rarities were identified.
- The relative proportions of invertebrate groups indicated healthy and well-oxygenated water conditions and no significant organic pollution in the watercourses.
- Abundance and biomass of invertebrates were both low and taxon richness was moderate for both the Achvarasdal Burn and the Reay Burn.
- The ASPT index indicated excellent (A1) water quality at all sites.
- Water Chemistry Status and Index of Acidity scores showed the watercourses to have slightly acidic water chemistry.
- Conductivity and alkalinity were both low and the burns have low buffering capacity.
- The WFD ecological status class was high (G-H) for the ASPT parameter at all of the sites and moderate to high (M-H) for the NTAXA parameter. Overall the watercourses should meet the WFD requirements for these parameters.
- Overall the water quality, invertebrate communities and productivity should support sustainable salmonid populations if other environmental factors are suitable.

2 Introduction

2.1 Bio-monitoring

Macroinvertebrates are a diverse group with a wide range of environmental tolerances and preferences and consequently communities exhibit both qualitative and quantitative responses to a spectrum of environmental changes (Sykes *et al.* 1999). Aquatic invertebrate species can therefore be used as biological indicators to both broadly assess the general quality of freshwater burns and rivers, and to assess more specific chemical status, for example acidity. The production of biotic indices to assess water quality is an established method using the BMWP (Biological Monitoring Working Party) and ASPT (Average Score Per Taxon) scoring systems. These scores were primarily developed for identifying organic pollution, but they are widely used as indicators of general stream health.

Acidification is a potential problem across large areas of upland Scotland, but evidence of ecological damage is mainly confined to fresh waters in Galloway, smaller areas of the Cairngorms and the western and central Highlands (SEPA 2006). Biotic indices can be used to overcome the difficulties associated with direct monitoring of pH, which tends to fluctuate markedly in acidic streams. Macro-invertebrates integrate recent (weeks to months) pH conditions at a site (Davy-Bowker *et al.* 2005) and are therefore well suited for bio-monitoring where the sampling frequency is constrained. In general the relationship between the tolerance of most acid-sensitive invertebrates and that of salmonid fish is fairly close, although trout can survive slightly more acid conditions than some of the invertebrate indicators (Patterson and Morrison 1993).

Bio-monitoring is an important component of the classification of water bodies' ecological status for the Water Framework Directive. RIVPACS 4 (River Invertebrate Prediction and Classification System) has been used in the development of the River Invertebrate Classification Tool (RICT) available for online data input. RICT can be used to generate WFD classes of ecological status using a standard set of site specific environmental variables and observed values of taxa and ASPT.

Assessment of macroinvertebrates can therefore both augment the interpretation of chemical analysis of water quality and monitor the biological consequences of changes in water chemistry. The recommended sampling periods are April-May and September-October (SEPA 2001). Greater resolution of indices is achieved through combined spring and autumn samples, although single sampling periods are also used.

Semi-quantitative abundance assessments of macroinvertebrates can also provide accurate characterisations of the community, and a measure of biodiversity and productivity of the watercourse.

2.2 Objectives

The freshwater invertebrate survey of the Limekiln watercourses provides:

i. A description of the macroinvertebrate community including species level identification in most major groups (Malacostraca, Ephemeroptera, Trichoptera, Plecoptera, Mollusca [excepting Sphaeriidae], Odonata and adult Coleoptera);
ii. BMWP and ASPT scores as an assessment of water quality (SEPA 2001);
iii. Indices of acidity: Water Chemistry Status (Patterson & Morrison 1993) and Index of Acidity (Clyde River Purification Board 1995);
iv. WFD ecological status class for ASPT and NTAXA parameters;
v. Semi-quantitative assessments of invertebrate abundance and biomass;
vi. A description of the environmental variables at each monitoring site including depth, width, flow, substrate profile, estimates of in-stream vegetation and canopy cover; and
vii. Measures of pH, conductivity and alkalinity.

3 Methods

3.1 Field sampling

Sampling was based on standard kick sampling methodologies employed by Scottish Environment Protection Agency (SEPA 2001, UKTAG 2008). A 25 cm wide kick sample net with a 1 mm mesh was used at all sites. Sampling at sites was conducted in riffle-type habitat when available. Riffles are one of the most productive habitats in rivers and streams and are the standard habitat for water quality bio-monitoring (SEPA 2001).

The sampling procedure involved a total of three minutes of kick sampling at each site. Sampling covered the range of micro-habitats within the riffle area, for example moss covered stones and patches of fine sediment at stream edges. The net was held vertically, downstream from the sampler's feet and resting on the riverbed. The sampler disturbed the river bed vigorously with the heels, by kicking or rotating, to dislodge the substrate to a depth of about 10 cm. Dislodged invertebrates were washed into the sampling net.

A further one minute period of hand sampling was carried out at all sites, searching on and under stones and rocks for attached invertebrates such as molluscs and cased caddis.

Kick samples are produced by timed effort sampling and are therefore semi-quantitative. Variations in the area kicked result from different individual approaches to sampling and from physical factors at each site such as substrate composition, depth and flow rate. The area kicked in this survey was estimated by the approximate distance in metres travelled during kicking multiplied by the width of the net. Although this is an approximation it does facilitate comparison between sites within a watercourse and between watercourses if all kicks have been taken by the same sampler.

Samples from kicking and hand collecting were preserved together in 70% Industrial Methylated Spirits (IMS) in sealed plastic containers.

3.2 Sites

A total of six sites were sampled: three each in the Achvarasdal Burn and the Reay Burn. Sites were accurately recorded using photographs (Appendix 1) and ten figure GPS generated grid references (Garmin etrex, accuracy of <15 metres RMS). Physical environmental factors including stream width, depth, flow and substrate profiles based on the Wentworth scale (Wentworth 1922) were recorded for the kick habitat. Width and depth were measured; substrate proportions and macrophyte cover were estimated by eye.

pH and conductivity were recorded with a portable meter (Hanna HI 98129) with a resolution of 0.1ºC, 0.01 pH and 1 µS/cm and accuracy ± 0.5ºC, ± 0.01 pH and conductivity ± 2%. Water samples were taken and total alkalinity was measured using a Hanna Alkalinity Test Kit H3811, smallest increment 3mg/L CaCO3. Data were recorded on standard fieldsheets.

Surveys were conducted on the 9th October 2011. To reduce variation in techniques all sampling was undertaken by one person, Sara Emes. Sara has ten years of experience in freshwater invertebrate sampling and has been trained in bryophyte (Birmingham University/Natural History Museum) and aquatic macrophyte (Stirling University) identification.

3.3 Invertebrate identification

Invertebrates were examined using a Wild binocular microscope at 6-50X magnification and a Brunel compound microscope at 100X. Identification employed standard keys (Brooks & Lewington 1999; Edington & Hildrew 1995; Elliot 2009; Elliot & Humpesch 2010; Elliot, & Mann 1979; Friday 1988; Hynes 1977; Killeen *et al.* 2004; Macan 1959; Macan 1977; Nilsson 1996, 1997; Reynoldson & Young 2000; Timm & Veldhuijzen van Zanten 2002 and Wallace *et al.* 1990).

Specimens were identified to the appropriate taxonomic level to provide a biological assessment of water quality using BMWP and ASPT scores. Species level identification for major groups provided data for acidity indices. A measure of productivity was obtained by a total count of invertebrates in each sample.

Species were checked for rarities using the JNCC Taxon Designations spreadsheet (JNCC 2011). This includes all major conservation designations, for example 'Habitats Directive', 'Red Lists', UKBAP and the Scottish Biodiversity List.

3.4 BMWP and ASPT Indices

These scores were primarily developed for identifying organic pollution, but they are widely used as indicators of general stream health. The scoring system is based on the pollution sensitivity of each invertebrate family. The scale is approximately 1-10 and a score of 1 is allocated to the most pollution tolerant families and 10 to the most pollution sensitive (Appendix 2). The BMWP index is the sum of the group scores for the sample. The ASPT (Average Score Per Taxon) index is the average score for the groups present in the sample.

Low scores for the BMWP or ASPT indices indicate possible pollution; high scores indicate good water quality.

The physical nature of the watercourse and the sampling effort of different individual samplers can influence the BMWP score. ASPT is viewed as a more stable and reliable index of pollution.

The number of scoring taxa is also an indicator of water status. A fall in the number of taxa is a general index of ecological damage, including overall pollution encompassing organic, toxic and physical pollution such as siltation, and damage to the habitats or the river channel, (General Quality Assessment of Rivers, Environment Agency website). The indices are used to provide a classification of the watercourses, see Table i below.

Table i Simplified Scottish River Classification Scheme as used by SEPA.

Class	Description	BMWP	ASPT	Comments
A1	Excellent	≥85	≥6.0	Sustainable* salmonid population
A2	Good	70-84	5.0-5.9	Sustainable* salmonid population
B	Fair	50-69	4.2-4.9	Salmonids may be present
C	Poor	15-49	3.0-4.1	Fish may be present
D	Seriously Polluted	<15	<3.0	Fish absent or seriously restricted

* If other environmental variables are suitable

3.5 Water Chemistry Status

Patterson and Morrison (1993) developed a Definition of Classes for water chemistry status based on the presence of invertebrate indicator groups. Two indicator groups are used: Group 1 taxa with a normal minimum pH of 6.0 and Group 2 with a normal minimum pH of 5.5 (Appendix 3). Three classes were defined (Table ii).

Table ii. Water Chemistry Classes

Class	Description	Comment
Class 1	Circumneutral	Group 1 taxa present. The water chemistry is suitable for the great majority of plants and animals. Alkalinity should be sufficient to buffer against most acid spate waters and the mean pH is ≥6.0 and unlikely to drop below 5.6. Salmonid fish are not stressed by the water chemistry.
Class 2	Not significantly acidified	Group 1 absent, group 2 present. The water chemistry is suitable for all except the most sensitive taxa. The mean pH is likely to be 5.6 or above. Where heavy metal and aluminium levels are low and/or organic content is high mean pH could be as low as 5.3. The water chemistry is likely to be suitable for salmonid fish but such streams may be vulnerable to future acidification.
Class 3	May be acidified	Groups 1 and 2 absent. Water chemistry may be acid to the point where wildlife is significantly affected including reduction of invertebrate diversity and reduction of salmonid fish populations, especially salmon. Further survey and chemical analysis is recommended to improve the diagnosis.

3.6 *Index of Acidity*

An Index of Acidity Classes was developed by the Clyde River Purification Board as an indication of the probability and likely magnitude of acidification of freshwaters (Clyde River Purification Board 1995). Although developed for streams in Ayrshire and Argyll, the system has been applied by SEPA for more northern rivers and has shown good correspondence with juvenile salmon densities (Ian Milne, SEPA Dingwall, pers. comm.). As with the index of Water Chemistry Status, this index is based on the presence or absence of taxa with varying degrees of acid sensitivity from two lists: A and B (Appendix 3). For samples collected between May and October the definitions used for classification are set out in Table iii:

Table iii. Index of Acidity Classes

Class	**Description**	**Comment**
Class I	Non-acid or slightly acid	At least three taxa from both Lists A and B present. Salmonid populations probably undamaged.
Class II	Intermediate	One or two List A taxa present or if List A taxa absent more than two List B taxa are present. Salmonid populations may show some signs of acid damage, for example reduced densities and missing or weak age classes.
Class III	Acid	List A absent and two or fewer List B taxa present. Trout populations reduced or absent and probably unable to sustain juvenile salmon.

3.7 *Ecological Quality Index (EQI) and Water Framework Directive (WFD) Class*

The Water Framework Directive requires the assessment of the ecological status of water bodies using a set of reference sites largely unaffected by anthropogenic activity. RIVPACS was originally developed to use benthic macroinvertebrates to assess the biological quality of rivers by predicting macroinvertebrate fauna expected in the absence of major environmental stress (Wright *et al.* 2000). Using a standard set of environmental variables for sampling sites the observed invertebrates and resultant indices can be compared to predicted (expected) indices produced by RIVPACS. These calculations are now used to produce one biological element of the WFD classification of the ecological status. The resulting EQI values are the ratio of the observed to expected values (O/E) and are used to produce the WFD class of the water body. This standardises biotic indices so that a particular value of EQI ratio implies the same ecological quality for that index, no matter what type of river or stream. RIVPACS 4 has been used in the development of RICT available for online data input.

3.8 *Biomass*

The invertebrates from kick samples were dried at a constant temperature of 60ºC for 48 hours. The dried sample was then weighed on an Ohaus Explorer Pro analytical balance (readability 0.1 mg) to produce a biomass g/m² kicked (dry weight).

4 Results and Discussion

4.1 *Sites and watercourse description*

The grid references for sites are given in Table 1 and the physical and chemical environmental variables recorded are found in Table 2. The approximate locations of sites are shown in Map 1.

The Achvarasdal Burn and the Reay Burn were identified as the main receptor burns from the proposed wind farm development site. The burns run in a northerly direction; the Reay Burn is sited entirely within the west of the site and the Achvaradal Burn forms the eastern boundary, with a source to the south of the site. Both burns are fed by a number of smaller watercourses within the site.

Both burns are small, the Achvarasdal Burn had a mean width of 2.3 metres at sampling sites and the Reay Burn mean width was 1.5 metres. The substrate in the burns consisted of mainly cobbles with a mean of 62% for both burns. Silt was absent from all sites on the Achvarasdal Burn but present in small amounts (5%) in the lower Reay Burn sites.

Macrophyte cover in the burns was generally high with a mean of 25% in both the Achvarasdal Burn and the Reay Burn. Vegetation was mainly common bryophyte species including *Fontinalis antipyretica* and *Platyhypnidium riparioides*, typical of the upper reaches of watercourses in Scotland, and the substrate was moderately stable. The vascular plant, alternate leaved water milfoil *Myriophyllum alterniflorum* was present at Reay Burn RB 2. Algal growth was absent at all sites.

4.2 Invertebrate communities

The proportional abundances of invertebrate groups are shown in Figure 1 (expressed as percentages of the total population). The numbers of each species found in the samples are recorded in Appendix 4.

The categories in Figure 1 represent the groups Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddis flies), Diptera (two-winged flies) and 'Other'. The first three groups are generally intolerant of organic pollution. Diptera contains the chironomids, a group very tolerant of organic pollution or enrichment. The 'Other' Category contains a wide mixture of groups including Coleoptera (beetles), Mollusca, Crustacea, Oligochaeta (worms) and Hirudinea (leeches). They are mainly moderately tolerant of organic pollution.

Macroinvertebrate communities of flowing water typical of large areas of upland Britain are dominated by the aquatic stages of the insect orders Ephemeroptera, Plecoptera and Trichoptera (Ormerod *et al.* 1993).

Stoneflies are generally found in fast flowing, clean, cold well oxygenated streams and an abundance of mayflies is generally a sign of reasonably healthy and productive water (FIN Abundance and Indicator Taxa, Environmental Change Network website). The mayfly families Heptageniidae and Baetidae and species from these families are consistently used as acid sensitive indicators and are known to be vulnerable to both chronic and episodic acidification (Merret *et al.* 1991; Ormerod *et al.* 1993; Patterson & Morrison 1993 and Rutt *et al.* 1990).

All the sites had communities dominated by a combined proportion of Ephemeroptera, Plecoptera and Trichoptera (EPT) with a mean of 74% EPT in the Achvarasdal Burn and a mean of 58% in the Reay Burn. With the exception of the Achvarasdal Burn AB 1 all sites had high proportions of Plecoptera. As acidity increases Plecoptera become increasingly dominant in streams (Patterson and Morrison 1993).

Macrophytes including mosses were present at all sites and these provide a microhabitat within the riffle and have a proportionately different invertebrate community to uncovered areas. The nemourid stoneflies *Amphinemura sulcicollis* and *Protonemura meyeri* comprise a greater part of the community living in moss than bare areas, conversely *Rhithrogena semicolorata* and *Chloroperla torrentium* are absent from moss (Egglishaw 1969). At the Achvarasdal Burn site AB 1 where bryophyte cover was low (5%) Ephemeroptera, mainly *Rhithrogena semicolorata*, were abundant. The highest numbers of *Protonemura meyeri* were found in the Reay Burn at sites RB 2 and RB 3 where macrophyte cover was 35% and 30% respectively.

There were higher numbers of the riffle beetle *Elmis aenea* in the Reay Burn samples (mean 22) than in the Achvarasdal Burn (mean 5). Riffle beetles feed on micro-organisms and detritus scraped from the substrate (Nilsson 1996) and their presence is used as an indicator of high oxygen levels by USEPA (United States Environmental Protection Agency).

Invertebrate communities largely consisted of common and widespread species typical of upland, rural Scottish watercourses and no rarities were identified (JNCC 2011). Overall the EPT proportion and the invertebrate communities indicated healthy and well-oxygenated water conditions in the watercourses with no significant organic pollution.

4.3 Invertebrate Abundance, Biomass and Diversity

Invertebrate abundance is shown numerically in Table 1 (total invertebrates per kick) and graphically in Figure 2 (invertebrates per m² kicked). Biomass is shown graphically in Figure 3 (g per m² kicked).

In the Limekiln watercourses invertebrate abundance was similar and low in both the Achvarasdal Burn (mean 88 per m² kicked), and the Reay Burn (mean 83 per m² kicked). The actual abundance is likely to be significantly higher than that collected through kick sampling, since not all invertebrates present will be captured by this method.

The biomass results were similar to the abundance results with low biomass in the Achvarasdal Burn (mean 0.11g per m² kicked), and the Reay Burn (mean 0.05 g per m² kicked).

It is difficult to assess diversity as there are a variety of taxonomic levels of identification used in scientific work and comparisons with other surveys are often invalid. Diversity is related to taxon richness and both the Achvarasdal Burn (mean taxa per sample 21) and the Reay Burn (mean 25) had communities of moderate taxon richness.

4.4 BMWP and ASPT scores

BMWP and ASPT scores are summarised in Table 1. The scoring taxa recorded at each site are shown in Appendix 5.

The BMWP index was good (A2) for the Achvarasdal Burn site AB 3 and excellent (A1) for all other sites. However, the more reliable ASPT index indicated excellent (A1) water quality at all sites.

Both watercourses had good to excellent water quality with no sign of organic pollution.

4.5 Water Chemistry Status

The classifications are shown in Table 1 and the indicator groups recorded as present are listed in Appendix 6.

All sites were Class 2 with the exception of Class 1 at the Achvarasdal Burn AB 1. Both watercourses are unlikely to be significantly acidified, with water chemistry of a mean pH of 5.6 or above.

4.6 Index of Acidity

The classifications are shown in Table 1 and the indicator species recorded as present are listed in Appendix 7.

All sites recorded Class II with the exception of the Achvarasdal Burn AB 2 with a Class I. As with the Water Chemistry Status index it is likely that the watercourses are slightly acidic.

4.7 pH, Conductivity and Alkalinity

pH, conductivity and alkalinity recordings are shown in Table 2.

The mean pH was 6.82 in the Achvarasdal Burn, indicating circumneutral conditions. The mean pH for the Reay Burn was lower at 5.95 indicating slightly acid conditions. The most upstream Reay Burn site RB 1 had a pH of 5.51, a borderline level for the absence of some acid sensitive taxa.

Conductivity was low at all sites, with means of 73 µS/cm in the Achvarasdal Burn and 97 µS/cm in the Reay Burn. Conductivity is related linearly to total dissolved solids (TDS), usually mineral salts. The low conductivity therefore suggests a low loading of TDS and the Limekiln watercourses are mainly unlikely to be polluted by substances containing mineral salts.

Akalinity is a measure of the degree to which a waterbody can resist change to pH, known as the buffering capacity. In the summary of river typography used in river macrophyte classification the United Kingdom Technical Advisory Group (UKTAG) classifies alkalinity as low (<10 mg/L $CaCO_3$), moderate (10-50), high (50-200) and very high (>200). The US Environmental Protection Agency classes watercourses with alkalinity levels of <20 mg/L $CaCO_3$ as sensitive to acid rain.

Alkalinity was low at all sites with a mean of 9.8 mg $CaCO_3$ per litre, in the Achvarasdal Burn and 8.3 mg $CaCO_3$ per litre in the Reay Burn. The buffering capacity of the Limekiln watercourses indicated they may be vulnerable to episodic acidification.

4.8 Ecological Status Class for ASPT and NTAXA

The EQI and WFD ecological status scores are given in Table 3.

For the ASPT parameter all sites were classified high (H) with the exception of the Reay Burn RB 3 classified as good (G). The NTAXA parameter was also classified as high (H) at all but one site, AB 3 on the Achvarasdal Burn, classified as moderate (M). Ecological status classification conducted by SEPA is based on spring and autumn samples combined; this survey is based on single season autumn sampling.

Overall the watercourses were clean and healthy with no significant organic pollution and are likely to meet the WFD requirements for these parameters.

5 Assessment

5.1 Invertebrate Communities

Invertebrate species found are mostly common and widespread in upland Scottish streams. Siltation was largely absent from the burns and the substrate was moderately stable and un-compacted providing good physical habitat for stream biota including both invertebrates and fish. Abundance and biomass of invertebrates were both low and taxon richness was moderate for both the Achvarasdal Burn and the Reay Burn. The watercourses were slightly acid but with no significant acidification. Overall the invertebrate community and indices indicated there was no organic pollution and that the watercourses are healthy and well-oxygenated. The invertebrate communities were within the typical range for upland Scottish watercourses with low anthropogenic impacts. The water quality, invertebrate communities and productivity should support sustainable salmonid populations if other environmental factors are suitable.

5.2 Potential Impacts

The watercourses and invertebrate communities are subject to a number of potential impacts from the conifer felling and construction of the wind farm. These include increased sediment loading from suspended solids in surface water when construction works and tree felling disturb and expose substrates including peat to possible erosion. The build-up of fine sediments in watercourses can reduce intra-gravel flow and dissolved oxygen levels, reducing the availability of interstitial habitats for invertebrates. Riffle beetles for example are particularly vulnerable to changes in oxygen levels as the adults need water near oxygen saturation (Elliot 2008).

Acidification of the watercourses may also occur through leaching of mineral soils with acidic waters draining off the peats and leaf litter from the conifer plantations, particularly in times of high precipitation. The most likely cause of concern following conifer harvesting is increased stream acidity (due to nitrate leaching) and increased aluminium levels during the first four years following felling (Environment Agency 1998). This combination can result in changes in the invertebrate community structure and decreased taxon richness as vulnerable groups such as Baetid and Heptageniid mayflies become reduced or absent. Potential impact of aluminium toxicity may be reduced at Limekiln because high levels of organic matter in the peaty soils may result in binding to the aluminium, producing an inactive form. However the potential impact of increased acidity on the watercourses at Limekiln may be exacerbated by the low alkalinity levels of the Reay and Achvarasdal burns.

Other potential impacts come from the spillage of construction materials including fuels and concrete. These can result in both toxic and physical effects on biota and habitats. Watercourses are particularly vulnerable to spillage at stream crossings, but may be affected by contamination of surface water elsewhere on site.

Given these potential impacts consideration could be given to the role of invertebrate bio-monitoring if the wind farm construction goes ahead. Invertebrate bio-monitoring can detect both chronic and episodic impacts including acidification and eutrophication from nutrient release.

6 References

Brooks, S. & Lewington, R. 1999 Field Guide to the Dragonflies and Damselflies of Great Britain and Ireland. British Wildlife Publishing.

Clyde River Purification Board 1995 Provisional Biological Index of Acidity.

Davy-Bowker, J., Murphy, J.F., Rutt, G.P., Steele, J.E.C. & Furse, M.T. 2005 The development and testing of a macroinvertebrate biotic index for detecting the impact of acidity on streams. Archiv fur Hydrobiologie 163:383-403

Edington, J.M. & Hildrew, A.G. 1995 Caseless Caddis Larvae of the British Isles. Pub. No. 53 Freshwater Biological Association.

Egglishaw, H.J. 1969 The Distribution of Benthic Invertebrates on Substrata in fast-flowing Streams. Journal of Animal Ecology 38, 1, 19-33.

Elliot, J.M. 2008 The ecology of riffle beetles (Coleoptera: Elmidae) *Freshwater Reviews.* **1**, 189-203

Elliot, J.M. 2009 Freshwater Megaloptera and Neuroptera of Britain and Ireland. Pub. No. 65 Freshwater Biological Association.

Elliot, J.M. & Humpesch, U. H. 2010 Mayfly Larvae (Ephemeroptera) of Britain and Ireland: Keys and a Review of their Ecology. Pub.No. 66 Freshwater Biological Association.

Elliot, J.M. & Mann, K.H. 1979 A Key to the British Freshwater Leeches. Pub.No. 40 Freshwater Biological Association.

Environment Agency (1998). The impact of conifer harvesting and replanting on upland water quality. R & D Technical report P211. C Neal and B Reynolds

Friday, L.E. 1988 A Key to the Adults of British Water Beetles. Field Studies Council

Hynes, H.B.N. 1977 Adults and Nymphs of the British Stoneflies (Plecoptera). Pub. No. 17 Freshwater Biological Association.

JNCC 2011 Taxon designations 20110121 Excel spreadsheet. (see - http://jncc.defra.gov.uk/page-3408)

Killeen, I., Aldridge, A. & Oliver, G. 2004 Freshwater Bivalves of Britain and Ireland. Aidgap

Macan, T.T. 1959 A Guide to Freshwater invertebrate Animals. Longmans.

Macan, T.T. 1977 British Fresh- and Brackish-Water Gastropods. A key. Pub. No. 13 Freshwater Biological Association.

Merret, W.J., Rutt, G.P., Weatherly, N.S., Thomas, S.P. & Ormerod, S.J. 1991 The response of macroinvertebrates to low pH and increased aluminium concentrations in Welsh streams: multiple episodes and chronic exposure. Arch Hydrobiol 121, 1, 115-125.

Nilsson, A. (ed.) 1996 Aquatic Insects of North Europe Vol1. Apollo Books

Nilsson, A. (ed.) 1997 Aquatic Insects of North Europe Vol2. Apollo Books

Ormerod, S.J., Rundle, S.D., Lloyd, E.C. & Douglas, A. A. 1993 The influence of riparian management on the habitat structure and macroinvertebrate communities of upland streams draining plantation forests. Journal of Applied Ecology 30, 13-24.

Patterson, G. & Morrison, B. 1993 Invertebrate Animals as Indicators of Acidity in Upland Streams. HMSO London

Reynoldson, T.B. & Young, J.O. 2000 A key to the Freshwater Triclads of Britain and Ireland. Freshwater Biological Association.

Rutt, G.P., Weatherly, N.S. & Ormerod, S.J. 1990 Relationships between the physicochemistry and macroinvertebrates of British upland streams: the development of modelling and indicator systems for predicting fauna and detecting acidity. Freshwater Biology 24, 463-480

SEPA 2001 Sampling of Freshwater Benthic Invertebrates. Method number NWM/ECOL/002.

SEPA 2006 State of Scotland's Environment 2006

Sykes, J.M., Lane, A.M.J. & George, D.C. (eds) 1999 The United Kingdom Environmental Change Network. Protocols for Standard Measurements at Freshwater Sites. Natural Environment Research Council.

Timm, T. & Veldhuijzen van Zanten, H. H. 2002 Freshwater Oligochaeta of North-West Europe. Expert Center for Taxonomic Identification, University of Amsterdam.

United Kingdom Advisory Group (UKTAG) 2008 UKTAG River Assessment Methods Benthic Invertebrate Fauna. River Invertebrate Classification Tool (RICT).

Wallace, I.D., Wallace, B. & Philipson, G.N. 1990 A Key to the Case-Bearing Caddis Larvae of Britain and Ireland. Pub. No. 51 Freshwater Biological Association.

Wentworth, C.K. 1922 A scale of grade and class terms for clastic sediments, Journal of Geology V. 30, 377-392

Wright, J.F., Sutcliffe, D.W. & Furse, M.T. 2000 Assessing the Biological Quality of Fresh Waters. RIVPACS and other techniques. Freshwater Biological Association.

Map 1 *Approximate locations of sampling sites, marked in blue.*

Table 1 *Biological monitoring scores and classifications*

Watercourse	**Site Code**	**Grid reference NC**		**Sampling date**	**Total invertebrate abundance (n)**	**BMWP score**	**Number of scoring taxa (n)**	**ASPT score**	**Water Chemistry Status**	**Index of Acidity**
Achvarasdal Burn	**AB 1**	99430	59048	09/10/2011	198	104	16	6.50	1	II
Achvarasdal Burn	**AB 2**	99474	60534	09/10/2011	120	134	20	6.70	2	I
Achvarasdal Burn	**AB 3**	98913	62669	09/10/2011	65	72	11	6.55	2	II
Reay Burn	**RB 1**	97453	60530	09/10/2011	105	93	15	6.20	2	II
Reay Burn	**RB 2**	97311	61268	09/10/2011	170	120	19	6.32	2	II
Reay Burn	**RB 3**	97127	62901	09/10/2011	123	92	15	6.13	2	II

__Table 2__ Environmental variables

Site	Kick length m	Wet width m	Bed width m	Depth 1/4 cm	Depth 1/2 cm	Depth 3/4 cm	SI %	SA %	GR %	PE %	CO %	BO %	BE %	clarity	flow	speed ms-1	canopy %
AB 1	6.0	2.5	2.5	25	25	25	0	0	5	35	60	0	0	clear brown	run/riffle	1.0	0
AB 2	6.0	2.1	2.1	20	30	45	0	0	5	30	65	0	0	clear brown	run/riffle	1.0	0
AB 3	5.0	2.2	2.2	40	40	40	0	0	10	20	60	10	0	clear brown	run/riffle/ torrent	1.0	0
RB 1	6.0	1.8	1.8	20	20	35	0	0	5	10	75	10	0	clear brown	run/riffle	0.5	0
RB 2	7.0	1.0	1.0	20	20	10	0	5	25	20	50	0	0	clear brown	run/riffle	1.0	0
RB 3	6.0	1.7	1.7	20	30	10	0	5	10	10	60	15	0	clear brown	run/riffle	1.0	0

SI = silt SA = sand GR = Gravel PE = Pebble CO = Cobble BO = Boulder BE = Bedrock

Site	pH	Conductivity µS/cm	Alkalinity mg/L $CaCO_3$	Vegetation Cover %	Vegetation composition
AB 1	6.88	61	6.6	5	5% Leptodictyum riparium
AB 2	6.95	71	8.4	20	20% Platyhypnidium riparioides, Brachythecium plumosum
AB 3	6.62	87	14.4	50	50% Platyhypnidium riparioides
RB 1	5.51	83	6.0	5	5% Fontinalis antipyretica, Scapania undulata
RB 2	6.09	94	8.7	35	5% Fontinalis antipyretica, 30% Myriophyllum alterniflorum
RB 3	6.25	113	10.2	35	30% Racomitrium aciculare, Platyhypnidium riparioides

Table 3 *Ecological Quality Index and Water Framework Directive Ecological Status Class for ASPT and NTAXA*

Site	Index	Observed	Reference Adjusted Expected	EQI (Bias uncorrected)	Class (Bias uncorrected)	Most Probable Class	Probability of Most Probable Class
AB 1	NTAXA	16	14.111	1.134	H	H	92.649
AB 1	ASPT	6.50	6.156	1.056	H	H	79.738
AB 2	NTAXA	20	14.451	1.384	H	H	99.83
AB 2	ASPT	6.70	6.153	1.089	H	H	91.619
AB 3	NTAXA	11	14.74	0.746	G	M	36.584
AB 3	ASPT	6.55	6.174	1.061	H	H	81.998
RB 1	NTAXA	15	14.473	1.036	H	H	81.738
RB 1	ASPT	6.20	6.119	1.013	H	H	53.955
RB 2	NTAXA	19	14.58	1.303	H	H	99.22
RB 2	ASPT	6.32	6.106	1.035	H	H	68.167
RB 3	NTAXA	15	14.353	1.045	H	H	82.938
RB 3	ASPT	6.13	6.145	0.998	G	G	52.455

Figure 1 *Invertebrate groups: percentages of sample by number*

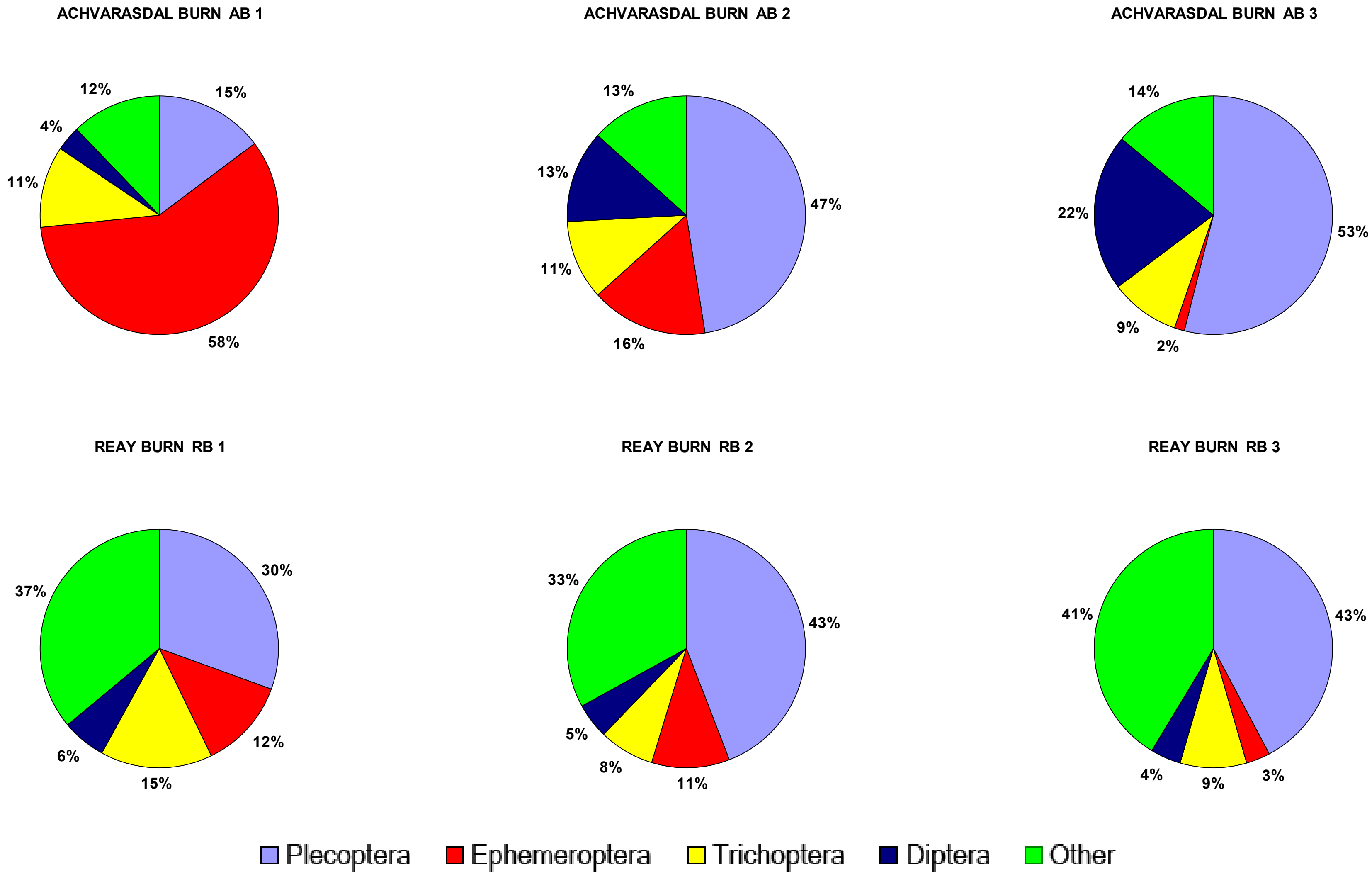


Figure 2 *Invertebrate abundance (number of animals per m² kicked)*

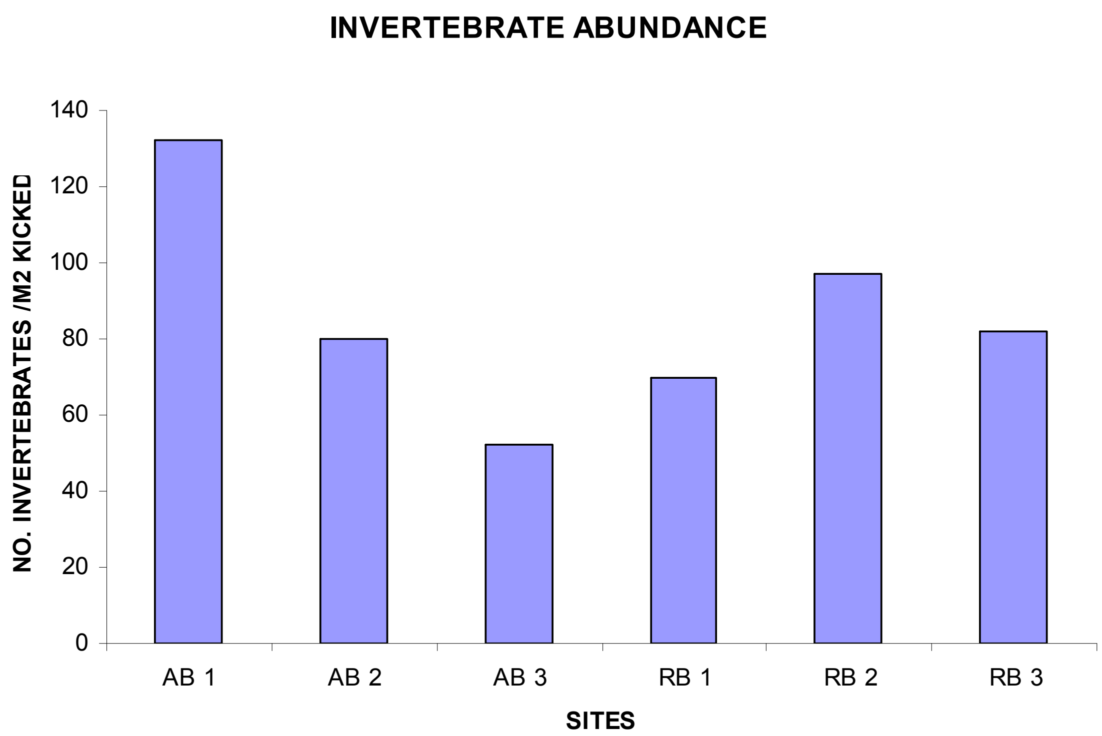
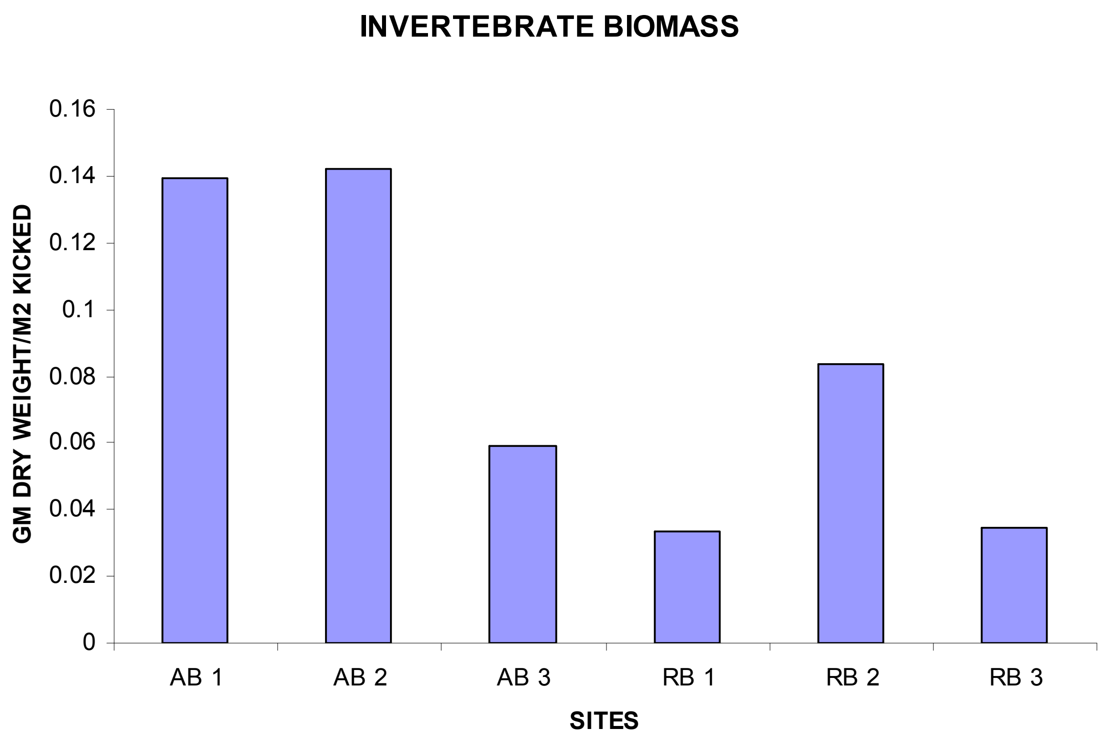


Figure 3 *Invertebrate biomass by dry weight (g per m² kicked)*



Appendix 1 *Site photographs*


Achvarasdal Burn AB 1


Achvarasdal Burn AB 2


Achvarasdal Burn AB 3


Reay Burn RB 1


Reay Burn RB 2


Reay Burn RB 3

Appendix 2 *Pressure sensitivity* ***(****BMWP) scores for individual taxa*

Common Name	Family	BMWP Score	Common Name	Family	BMWP Score
Flatworms	Planariidae	5	Bugs	Mesoveliidae	5
	Dendrocoelidae	5		Hydrometridae	5
Snails	Neritidae	6		Gerridae	5
	Viviparidae	6		Nepidae	5
	Valvatidae	3		Naucoridae	5
	Hydrobiidae	3		Aphelocheiridae	10
	Lymnaeidae	3		Notonectidae	5
	Physidae	3		Pleidae	5
	Planorbidae	3		Corixidae	5
Limpets and Mussels	Ancylidae	6	Beetles	Haliplidae	5
	Unionidae	6		Hygrobiidae	5
	Sphaeriidae	3		Dytiscidae	5
Worms	Oligochaeta	1		Gyrinidae	5
Leeches	Piscicolidae	4		Hydrophilidae	5
	Glossiphoniidae	3		Clambidae	5
	Hirudididae	3		Scirtidae	5
	Erpobdellidae	3		Dryopidae	5
Crustaceans	Asellidae	3		Elmidae	5
	Corophiidae	6		Chrysomelidae	5
	Gammaridae	6		Curculionidae	5
	Astacidae	8	Alderflies	Sialidae	4
Mayflies	Siphlonuridae	10	Caddisflies	Rhyacophilidae	7
	Baetidae	4		Philopotamidae	8
	Heptageniidae	10		Polycentropidae	7
	Leptophlebiidae	10		Psychomyiidae	8
	Ephemerellidae	10		Hydropsychidae	5
	Potamanthidae	10		Hydroptilidae	6
	Ephemeridae	10		Phryganeidae	10
	Caenidae	7		Limnephilidae	7
Stoneflies	Taeniopterygidae	10		Molannidae	10
	Nemouridae	7		Beraeidae	10
	Leuctridae	10		Odontoceridae	10
	Capniidae	10		Leptoceridae	10
	Perlodidae	10		Goeridae	10
	Perlidae	10		Lepidostomatidae	10
	Chloroperlidae	10		Brachycentridae	10
Damselflies	Platycnemidae	6		Sericostomatidae	10
	Coenagriidae	6	True flies	Tipulidae	5
	Lestidae	8		Chironomidae	2
	Calopterygidae	8		Simuliidae	5
Dragonflies	Gomphidae	8			
	Cordulegasteridae	8			
	Aeshnidae	8			
	Corduliidae	8			
	Libellulidae	8			

Appendix 3 *Acid intolerant indicators: Water Chemistry Status groups and Index of Acidity lists*

Water Chemistry Status

Species	**Normal Minimum pH**
Group 1	
Gammarus pulex	≥ 6.0
Glossosoma & Agapetus spp.	6.0
Ancylus fluviatilis	6.0
Radix peregra	6.0
Asellus aquaticus	6.0
Group 2	
Hydropsyche	5.5 - 6.0
Baetis sp.	5.5 Occasionally 5.2
Heptageniidae	5.5 Occasionally 5.2

Index of Acidity

List A taxa (absent at pH <6.0)	**List B taxa (absent at pH <5.5)**
Gammarus pulex	*Baetis rhodani*
Radix peregra	*Rhithrogena semicolorata*
Ancylus fluviatilis	*Ecdyonurus spp.*
Potamopyrgus jenkinsi	*Electrogena lateralis*
Baetis scambus	*Perlodes microcephala*
Baetis muticus	*Chloroperla bipunctata*
Caenis rivulorum	*Hydraena gracilis*
Serratella ignita	*Hydropsyche pellucidula*
Perla bipunctata	
Dinocras cephalotes	
Esolus parallelipipidus	
Glossosoma spp.	
Agapetus spp.	
Hydropsyche instabilis	
Silo pallipes	
Odontocerum albicorne	
Philopotamus montanus	
Wormaldia sp.	
Sericostoma personatum	

Appendix 4 *Invertebrate numbers present in kick samples*

Sample Code	**AB 1**	**AB 2**	**AB 3**	**RB 1**	**RB 2**	**RB 3**
Plecoptera						
Chloroperlidae						
Chloroperla sp	1	1			6	
Leuctridae						
Leuctra sp			3		1	
Leuctra hippopus	1	1				7
Nemouridae						
Amphinemura sulcicollis		1			2	2
Nemoura avicularis				1		
Protonemura meyeri	11	29	12	25	54	37
Perlidae						
Dinocras cephalotes		24	17			
Perlodidae						
Isoperla grammatica	2	1	3	4	11	6
Perlodes microcephala	14			2	1	
Ephemeroptera						
Baetidae						
Baetis muticus		1		3		2
Baetis rhodani	11	2				
Baetis vernus				4	8	
Ephemerellidae						
Serratella ignita	1					
Heptageniidae						
Ecdyonurus sp.	1	6			1	2
Rhithrogena semicolorata	103	10	1	4	8	
Leptophlebiidae						
Paraleptophlebia sp					1	
Siphlonuridae						
Ameletus inopinatus				2		
Trichoptera						
Beraeidae						
Beraea maurus					1	1
Hydropsychidae						
Hydropsyche sp					1	
Hydropsyche siltalai	5	3	3	1		8
Hydroptilidae						
Limnephilidae						
Early instars	1			1	1	
Drusus annulatus				7	1	
Ecclisopteryx guttulata	9			1	4	
Odontoceridae						
Odontocerum albicorne		1		1		
Polycentropodidae						
Plectronemia conspersa				1		
Polycentropus flavomaculatus		2				
Rhyacophila dorsalis	7	2	3	4	5	1
Sericostomatidae						
Sericostoma personatum		4				

Appendix 4 *Invertebrate numbers present in kick samples*

Sample Code	**AB 1**	**AB 2**	**AB 3**	**RB 1**	**RB 2**	**RB 3**
Diptera						
Ceratopogonidae			1		1	1
Chironomidae	3	7	11	2	2	2
Empididae			1	1		
Limoniidae	3	6	1	2	5	1
Muscidae		2		1		1
Simulidae	1					
Coleoptera						
Dytiscidae						
Oreodytes sanmarkii				1		
Elmidae						
Elmis aenea	7	2	5	13	26	28
Limnius volkmari	3	1		1	9	
Oulimnius sp.	1	4			5	3
Hydraenidae						
Hydraena gracilis		1			2	
Scirtidae						
Elodes sp		1		8	2	6
Megaloptera						
Sialis fuliginosa					2	
Mollusca						
Ancylidae						
Hydrobiidae						
Potamopyrgus jenkinsii					1	
Oligochaeta						
Enchytraeidae	9	3	3	7	2	8
Lumbricidae	1	3	1		2	
Tubificidae				5	1	
Tricladida						
Polycelis sp.		1				6
Nematoda				1		

Appendix 5 *BMWP, ASPT indicator groups present with scores*

Site Code		AB 1	AB 2	AB 3	RB 1	RB 2	RB 3
Plecoptera	Chloroperlidae	10	10			10	
	Leuctridae	10	10	10		10	10
	Nemouridae	7	7	7		7	7
	Perlidae		10	10			
	Perlodidae	10	10	10	10	10	10
Ephemeroptera	Baetidae	4	4		4	4	4
	Ephemerellidae	10					
	Heptageniidae	10	10	10	10	10	10
	Leptophlebiidae					10	
	Siphlonuridae				10		
Trichoptera	Beraeidae					10	10
	Hydropschidae	5	5	5	5	5	5
	Hydroptilidae		6				6
	Limnephilidae	7			7	7	
	Odontoceridae		10		10		
	Polycentropodidae		7		7		
	Rhyacophilidae	7	7	7	7	7	7
	Sericostomatidae		10				
Diptera	Chironomidae	2	2	2	2	2	2
	Simulidae	5					
	Tipuloidea	5	5	5	5	5	5
	Elmidae	5	5	5	5	5	5
	Hydrophilidae		5			5	
Mollusca	Ancylidae	6					
	Hydrobiidae					3	
Oligochaeta		1	1	1	1	1	1
Tricladida			5				5

Appendix 6 *Water Chemistry Status indicator groups and species present*

Site code	AB 1	AB 2	AB 3	RB 1	RB 2	RB 3
Group 1						
Ancylus fluiviatilis	✓					
Group 2						
Baetidae	✓	✓		✓	✓	
Heptageniidae	✓	✓	✓	✓	✓	✓
Hydropsyche sp.	✓	✓	✓	✓	✓	✓

Appendix 7 *Index of Acidity indicator groups and species present*

Site code	C1	C2	P1	P2	W1	W2
List A						
Dinocras cephalotes		✓	✓			
Baetis muticus		✓		✓		✓
Seratella ignita	✓					
Odontocerum albicorne		✓		✓		
Sericostoma personatum		✓				
Ancylus fluiviatilis	✓					
Potamopyrgus jenkinsii					✓	
List B						
Perlodes microcephala	✓			✓	✓	
Baetis rhodani	✓	✓				
Ecdyonurus sp.	✓	✓			✓	✓
Rhithrogena semicolorata	✓	✓	✓	✓	✓	
Hydraena gracilis		✓			✓	