ALLT A' CHOIRE GHLAIS: FRESHWATER INVERTEBRATE SURVEY

Report to EnviroCentre

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Allt a Choire Ghlais: Freshwater Invertebrate Survey 2011

1 Summary

1.1 Background

A proposed pumped storage scheme will enlarge Loch a' Choire Ghlais and produce fluctuating water levels, potentially impacting on freshwater invertebrate communities in the Allt a' Choire Ghlais outflow burn from the loch.

Macro-invertebrate communities were sampled using timed effort sampling methods from five sites on 26th September 2010 and 13th May 2011. Major groups were identified to species level to characterise the communities, identify presence of rare species and to provide a baseline assessment for the EIA and Environmental Statement.

Environmental variables including depth, macrophyte cover and substrate profile were recorded at each site. Conductivity and pH were recorded on site and water samples were taken for analysis of alkalinity. GPS generated grid references and photographs (Annex 1) were taken to enable future site identification.

1.2 Main findings: Allt a' Choire Ghlais

- 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 clean well-oxygenated conditions with no evidence of organic pollution or enrichment.
- Invertebrate populations were low to moderately diverse with low abundance.
- ASPT scores showed excellent (A1) water quality at all sites in the autumn and spring.
- Water Chemistry Status and Index of Acidity Scores indicated that the watercourses are circum-neutral or slightly acidic (>pH 5.5) with no significant acidification.
- LIFE scores showed moderate to fast conditions were the prevailing flow conditions in sampled riffles.
- ASPT indices and NTAXA both produced a WFD classification of high (H) ecological status for all sites for these parameters.
- pH records were circum-neutral with a mean of pH 6.48 in the autumn and pH 7.46 in the spring. Alkalinity levels were generally low with a mean of 12 mg $CaCO_3$ per litre in autumn and 9 $CaCO_3$ per litre, indicating low buffering capacity.
- 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

Macro-invertebrates 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 system. These scores were primarily developed for identifying organic pollution, but they are widely used as indicators of general stream health. Greater resolution of indices is obtained from combined autumn and spring samples.

Acidification is a potential problem across large areas of upland Scotland because of the potential to damage ecosystems, 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 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.

Quantitative abundance assessments of macroinvertebrates will also provide accurate characterisations of the community, and a measure of biodiversity and productivity of the watercourse.

3 Objectives and Methods

3.1 Objectives

The proposed scheme of work will produce:

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) LIFE scores as an assessment of prevailing flow conditions;

v) Ecological Status Classes for the NTAXA and ASPT elements;

vi) Semi - quantitative assessments of invertebrate abundance and measures of biodiversity and productivity; and

vii) A description of the environmental variables at each monitoring site including depth, width, flow, substrate profile, estimates of in-stream vegetation and canopy cover.

3.2 Field Sampling - Kick

Sampling was based on standard kick sampling methods (SEPA 2001, UKTAG 2008). A 25cm wide kick sample net with a 1mm mesh was used at all sites. The sampling procedure involved a total of 3 minutes of kick sampling at each site. Sampling covered the whole width of the stream. The net was held vertically, downstream from the sampler's feet and resting on the river bed. The sampler disturbed the river bed vigorously with the heels, by kicking or rotating, to dislodge the substrate to a depth of about 10cm. Dislodged invertebrates were washed into the sampling net.

A further 1 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 travelled during kicking in metres 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 by the addition of 80% Industrial Methylated Spirits (IMS) in sealed plastic containers.

Field Sampling - Sites

Sample sites were selected with riffle habitat wherever possible. Riffles are one of the most productive habitats in rivers and streams and are the standard habitat for water quality bio-monitoring (SEPA 2001).

Sites were accurately recorded using photographs 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.

Water temperature, pH and conductivity were recorded with a portable meter; Hanna HI 98129, resolution 0.1ºC, 0.01 pH and 1 µS/cm, 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 $CaCO_3$. Data was recorded on standard fieldsheets (Annex 7).

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, Aldrich & Oliver 2004, Macan 1959, Macan 1977, Nilsson 1996, 1997, Reynoldson & Young 2000, Timm & Veldhuijzen van Zanten 2002 and Wallace, Wallace & Philipson 1990).

Specimens from were identified to species level in most major groups (Malacostraca, Ephemeroptera, Trichoptera, Plecoptera, Mollusca, Odonata and adult Coleoptera) to provide data for a range of bio-monitoring indices

3.4 BMWP and ASPT Indices

These indices 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 (Annex 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 each group 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).

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 (Annex 3). Three classes were defined:

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 (Annex 3.). For samples collected between May and October the definitions used are:

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 LIFE index

The LIFE index was developed as a method to link qualitative and semi-quantitative change in riverine benthic macroinvertebrate communities to prevailing flow regimes. The LIFE technique is based on data derived from standard survey methods (principally three minute kick sampling).

Invertebrate species were assigned to six flow groups using data on their recognised flow associations from a wide range of sources. Some rare taxa and those with no clear affiliations to flow were left out of the groups. Flow groups can also be assigned at family level but use of groups at family level results in a possible loss of precision as some families contain species with wide ranging flow requirements (Extence *et al* 1999). The flow group classifications are shown in Table iv below:

Table iv. Flow Group Classification

Group	Ecological flow association	Mean current velocity
I	Taxa primarily associated with rapid flows	Typically>100cm s^{-1}
II	Taxa primarily associated with moderate to fast flows	Typically 20-100cm s^{-1}
III	Taxa primarily associated with slow or sluggish flows	Typically <20cm s^{-1}
IV	Taxa primarily associated with slow flow or standing waters	_
V	Taxa primarily associated with standing waters	-
VI	Taxa primarily associated with drying or drought impacted sites	_

In order to monitor quantitative changes the standard Environment Agency abundance categories are used as in Table v.

Table v. Abundance Categories

Category	Estimated abundance
A	1 - 9
B	10 - 99
C	100 - 999
D	1000 - 9999
E	10000 +

LIFE scores are assigned to each species in the sample using the following matrix.

Table vi. LIFE Scores

Flow groups	Abundance categories			
	A	B	C	D/E
I Rapid	9	10	11	12
II Moderate/fast	8	9	10	11
III Slow/sluggish	7	7	7	7
IV Flowing/standing	6	5	4	3
V Standing	5	4	3	2
VI Drought resistant	4	3	2	1

The LIFE index is then calculated from the total of LIFE scores for all species at a site divided by the number of scoring taxa.

3.8 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 (River Invertebrate Prediction and Classification System) was originally developed to use benthic macroinvertebrates to assess the biological quality of rivers by predicting macro-invertebrate 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 the benthic invertebrate biological quality 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 in the production of 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 the River Invertebrate Classification Tool (RICT), available for online data input.

4 Results

4.1 Sites: Environmental Factors

Sites were numbered in a downstream direction, CG 1 to CG 4, and the suffix S used to identify spring samples.
Site photographs are shown in Annex 1. The grid references for sites are given in Table 1 and the physical and chemical environmental factors recorded are found in Table 2.

The Allt a' Choire Ghlais, named the Kilfinnan Burn in the downstream reaches, is the outflow burn from Loch a' Choire Ghlais flowing into Loch Lochy. The burn is moderate in size with a wet width of 3.5 to 7.0 metres and a mean depth of 10 to 40 cm. Substrate is mainly cobble and boulders (mean 79%) and silt is absent. Macrophyte cover is low throughout the year with autumn samples having a mean of 15%. Cover consists of bryophytes, typical of the upper reaches of watercourses, and algae (absent in spring).

Water levels were elevated during the spring survey and no sampling was possible at site CG 4.

4.2 Invertebrate Communities

The numbers of each invertebrate species present in the samples are shown in Annex 4. The proportional abundances of invertebrate groups are shown in Plate 1 (expressed as percentages of the total population).

The common names of the invertebrate groups are given below:

Latin Name	Common Name	Latin Name	Common Name
Plecoptera	Stoneflies	Hemiptera	Bugs
Ephemeroptera	Mayflies	Crustacea	Shrimps, water fleas
Trichoptera	Caddis flies	Mollusca	Snails, mussels
Diptera	Two winged flies	Oligochaeta	Worms
Coleoptera	Beetles	Hirudinea	Leeches
Sialidae	Alderflies	Nematoda	Nematodes
Odonata	Dragonflies	Hydracarina	Mites

The categories in Plate 1 represent the groups Ephemeroptera, Plecoptera and Trichoptera, Diptera and 'Other'. The first three groups are generally intolerant of organic pollution. Diptera contains the chironomids which are very tolerant of organic pollution or enrichment. The 'Other' Category contains a wide mixture of groups including Coleoptera, Mollusca, Oligochaeta and Hirudinea. 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 invertebrate communities at all the Allt a' Choire Ghlais sites were dominated by Ephemeroptera, Plecoptera and Trichoptera combined (EPT). EPT in the autumn varied from 77% to 90% (mean 84%) and in the spring 75% to 97% (mean 83%). Common species such as the mayflies *Baetis rhodani*, *Baetis muticus, Ecdyonurus sp.* and *Rhithrogena semicolorata*; the stonefly *Amphinemura sulcicollis* were responsible for the high proportion for these groups.

No rare or designated species were found (JNCC 2011).

4.3 Invertebrate Abundance and Biodiversity

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

Invertebrate abundance varied from 30 to 318 per m² kicked (mean 132) in the Allt a' Choire Ghlais in the autumn and from 32 to 66 per m² kicked (mean 46) in the spring. The large variation in samples in the autumn was the result of higher numbers of species in most groups in the upstream sites, CG 1-3, compared to the downstream sites CG4 and KB. Overall invertebrate abundance is low. However the actual abundance is likely to be significantly higher than that collected through kick sampling.

It is difficult to assess biodiversity as there are a variety of taxonomic levels of identification used in scientific work and comparisons with other surveys are often invalid. Numbers of taxa present varied from 15-31 (mean 24) and 14-23 (mean 18) in autumn and spring samples respectively. At this taxonomic level the watercourse had moderate biodiversity. The two most upstream sites had the greater diversity in both autumn and spring samples.

Although the abundance was low and biodiversity moderate both were within the typical range for upland watercourses and the Allt a' Choire Ghlais could support a sustainable salmonid fish population if other variables are suitable.

4.4 *BMWP and ASPT Index scores*

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

The ASPT scores indicated excellent (A1) water quality at all sites in both autumn and spring.

The ASPT scores support the evidence from the proportions of different groups in the invertebrate community, indicating that the watercourse had 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 Annex 6.

All sites recorded Water Chemistry Class scores of 2 with the exception of KB in the autumn with a class of 1. This indicates that the Allt a' Choire Ghlais is unlikely to be acidified and the mean pH is likely to be 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 Annex 6.

Sites were recorded as Class I with the exception of CG3 and CG 4 where in the autumn samples a Class II was recorded. Overall the scores indicated the watercourse was not significantly acidified and that salmonids should be unaffected.

4.7 *pH and Alkalinity*

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

pH readings were lower in the autumn, range 6.26 to 6.56 (mean 6.48), compared to spring, range 7.28 to 7.69 (mean 7.46). These suggest that water conditions are circum-neutral.

Conductivity was low at all sites with a mean of 19.8 µS/cm in the autumn and 17.3 µS/cm in the spring. Conductivity is related linearly to total dissolved solids (TDS), usually mineral salts. The low conductivity therefore suggests a low loading of TDS and the Allt a' Choire Ghlais is unlikely to be polluted by substances containing mineral salts.

Alkalinity levels were low with means of 12 mg $CaCO_3$ per litre in autumn and 9 $CaCO_3$ per litre in the spring. The alkalinity indicates 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 $CaCO_3$ per litre), moderate (10-50), high (50-200) and very high (>200). The US Environmental Protection Agency classes watercourses with alkalinity levels of 10-20 mg $CaCO_3$ per litre as sensitive to acid rain. The buffering capacity of this watercourse is low, but there is no evidence of any episodic acidification.

4.8 *LIFE scores*
LIFE scores are given in Table 1.

Mean LIFE scores were 8.59 in the autumn and 8.57 in the spring indicating that the prevailing flow conditions are moderate to fast in the sampled riffles.

Some caution is required in the use of the LIFE index as it was developed using data from only English and Welsh rivers. The geographical range of applicability of the LIFE index has yet to be fully tested.

4.9 *EQI and WFD Class for ASPT and NTAXA parameters*
The EQI and WFD ecological status scores are given in Table 3.

The ASPT and NTAXA scores used in this calculation are combined autumn and spring scores. For both the ASPT and NTAXA parameters all sites were classified as high (H). This indicates that for these parameters the watercourse reaches the WFD requirement of good. Note that site CG 4 was omitted as a spring sample was not taken.

5 Potential Impacts

5.1 *Current Status*
The Allt a' Choire Ghlais invertebrate community indicates that the burn has clean water conditions with no evidence of organic pollution or enrichment, or significant acidification. The invertebrates present are common and widespread in upland watercourses in Scotland and no rarities were detected at the level of taxonomic resolution used. Diversity was moderate and abundance generally low. However the water quality remained good throughout the sampled reaches and the burn should be capable of supporting a salmonid fish population.

5.2 *Potential Impacts*
Hydro schemes impact on stretches of watercourses by direct replacement of flowing water with a reservoir and flow alteration downstream of the dam in storage systems; or flow reduction between the intake and the tailrace confluence in smaller scale 'run of the river' systems.

There will be a direct loss of burn habitat by replacement of 0.7 km of the upstream Allt a' Choire Ghlais by the enlarged Loch a' Choire Ghlais. A proposed compensation flow, of a constant Q95 for the catchment interrupted by the dam, will be released from the foot of the dam. Overall there will be a reduction in the flow in the Allt a' Choire Ghlais but as there are many small tributaries downstream of the proposed dam site, including the Allt na Feadaige and the Allt a Coire Bhuidhe, flow variations will become more natural with increasing distance from the dam, with a probable decrease in potential impacts. Whilst the impact on the upstream invertebrate communities will be the total loss of the invertebrate population, the downstream impact will depend upon a number of factors discussed briefly below.

Many freshwater invertebrates have precise requirements for particular current velocities or flow ranges (Extence *et al* 1999) and as flows decline taxa associated with low flows increase in abundance whilst taxa associated with faster flows decrease (Extence 1981, Cowx *et al* 1984). Flow variations can be lethal for some species and therefore result in both a decline in species diversity and abundance (Wood & Langford).

Alteration in the community structure may occur directly from this flow alteration or indirectly through associated habitat change (Petts & Maddock 1994, Petts & Bickerton 1997). Altered flow can result in reduced habitat diversity (SNH), for example reducing riffle areas, one of the most productive habitats in rivers and streams with a characteristic community in healthy watercourses. This in turn may lead to a change from lotic species, such as the common mayflies *Baetis* and *Rhithrogena*, to those more associated with lentic conditions, such as *Cloeon* and *Paraleptophlebia* (Wood & Langford). However the effects of increased duration and magnitude of flow reduction on invertebrate communities may be restricted to changes in the relative abundances of just a few taxa (James & Suren 2009).

Reduced flow affects sediment transport capacity and may result in changes in substrate composition, including the build-up of finer sediments. This can reduce intra-gravel flow and dissolved oxygen levels, reducing the availability of interstitial habitats for invertebrates. Riffle beetles are particularly vulnerable to changes in oxygen levels as the adults need water near oxygen saturation (Elliot 2008). Organic matter may also build up in the absence of high energy flushing and increases in periphyton biomass and macrophyte cover, including algae, may occur. Flow alterations may also affect the transport and distribution of invertebrates through drift. In pump storage schemes changes in water chemistry may occur.

Flow alterations and their cumulated affects can therefore result in changes in invertebrate community composition, diversity, abundance and distribution.

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Plate 1 *Invertebrate Groups: Proportions expressed as percentages of Total Population in Samples from each Site (Autumn above, Spring below)*

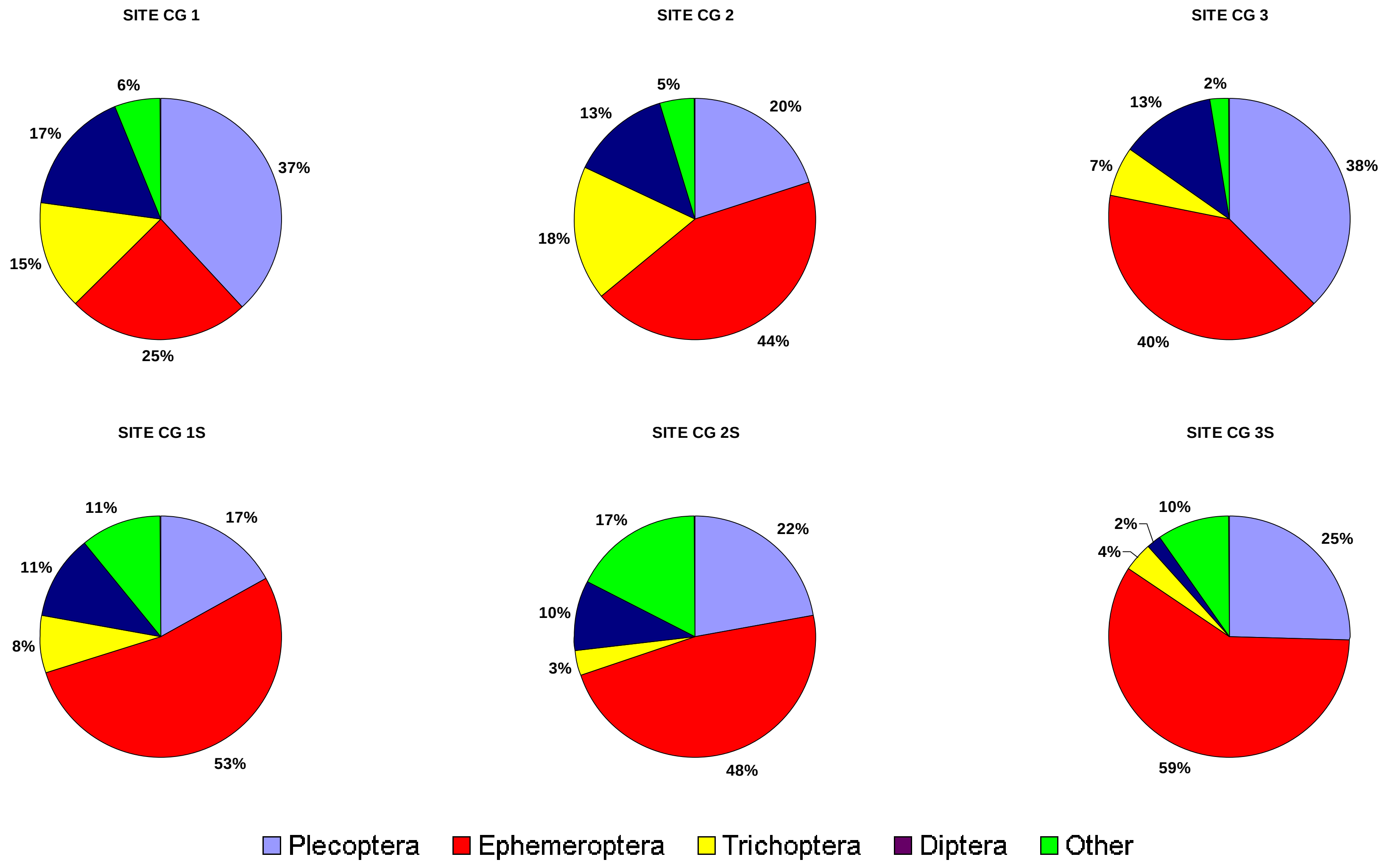


***Plate 1** Invertebrate Groups: Proportions expressed as percentages of Total Population in Samples from each Site (Autumn above, Spring below)*

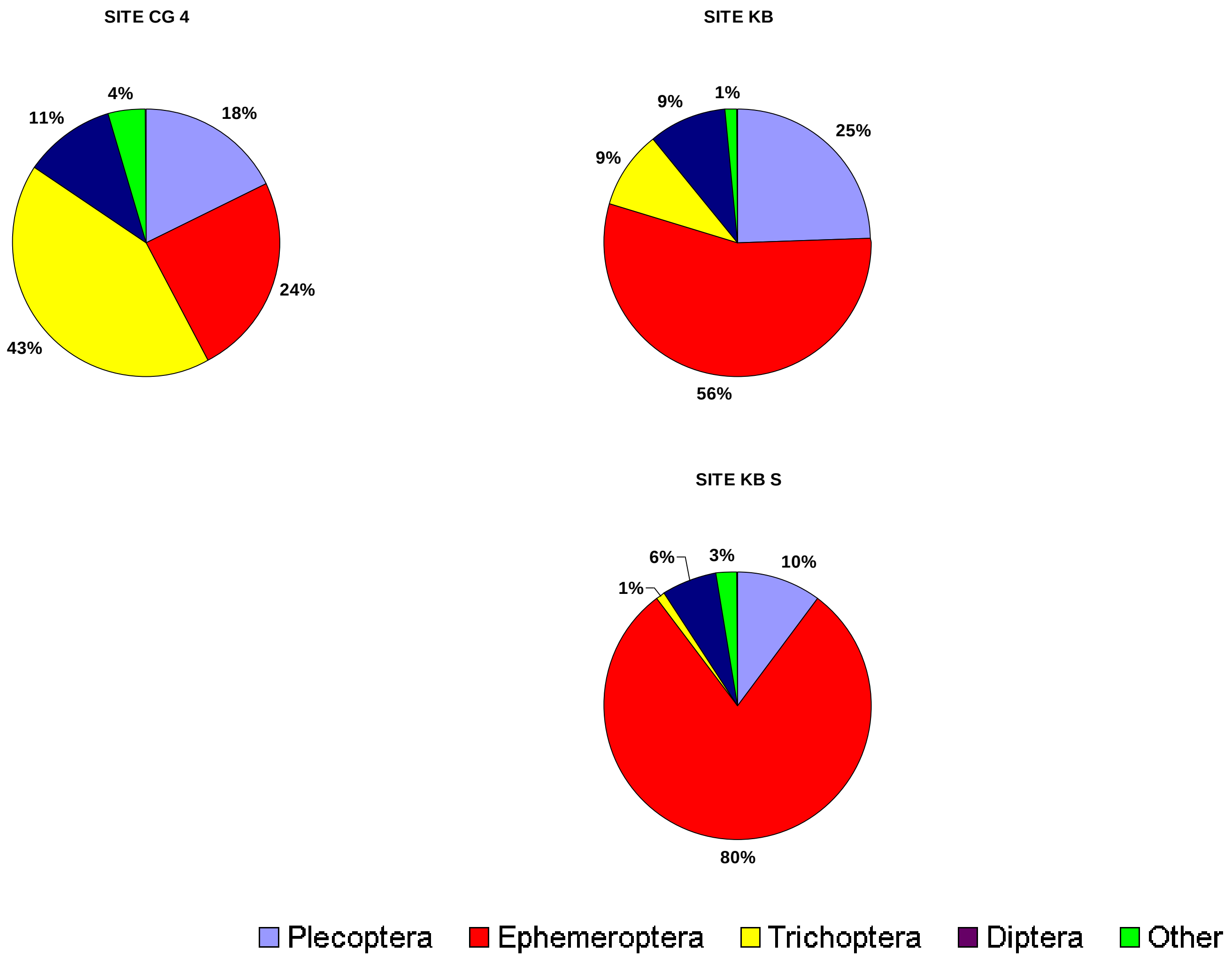


Plate 2 *Total number of Invertebrates per sample*

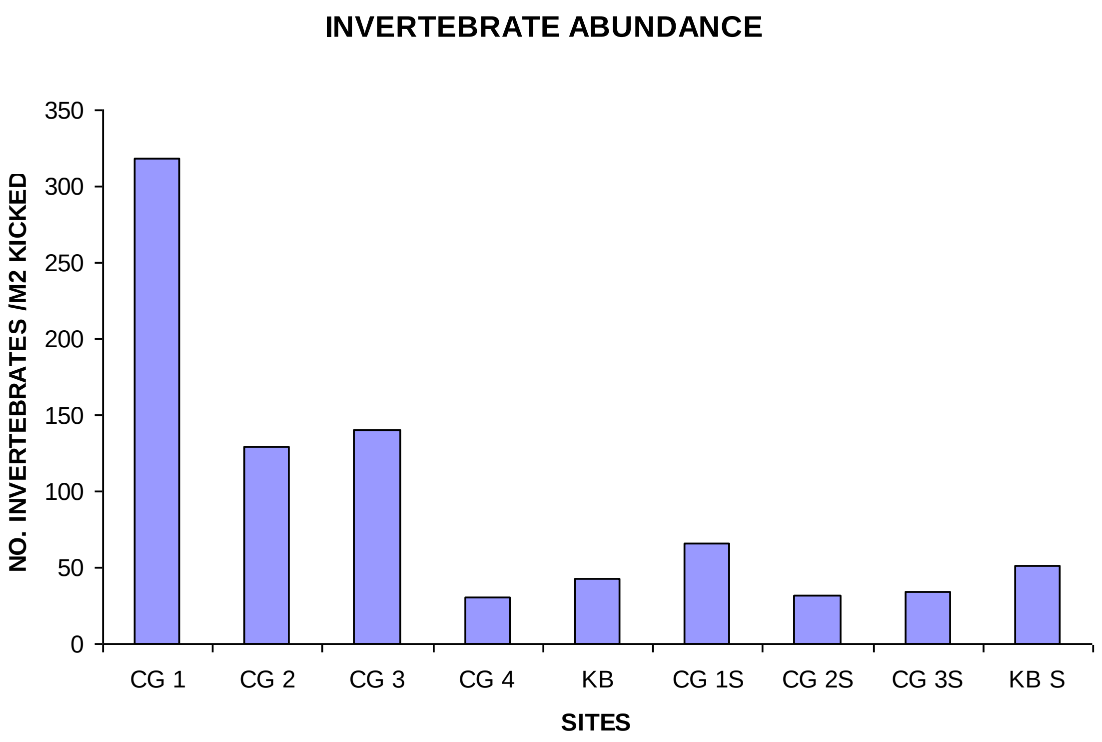


Table 1 *Invertebrate Abundances and Biological Monitoring Scores*

Watercourse	Site Code	Grid reference NN		Sampling date	Total invertebrate abundance (n)	BMWP score	Number of scoring taxa (n)	ASPT score	Water Chemistry Status	Index of Acidity	LIFE score
Autumn											
Allt a Choire Ghlais	CG 1	23492	95539	26/09/2010	556	134	20	6.70	2	I	8.75
Allt a Choire Ghlais	CG 2	24039	95825	26/09/2010	194	117	18	6.50	2	I	8.53
Allt a Choire Ghlais	CG 3	25165	96251	26/09/2010	210	94	14	6.71	2	II	8.94
Allt a Choire Ghlais	CG 4	25705	96368	26/09/2010	45	77	12	6.42	2	II	8.20
Kilfinnan Burn	KB	27698	95787	26/09/2010	74	106	14	7.57	1	I	8.53
Spring											
Allt a Choire Ghlais	CG 1	23492	95539	13/05/2011	166	111	17	6.53	2	I	8.44
Allt a Choire Ghlais	CG 2	24039	95825	13/05/2011	63	87	14	6.21	2	I	8.64
Allt a Choire Ghlais	CG 3	25165	96251	13/05/2011	51	101	14	7.21	2	I	8.62
Kilfinnan Burn	KB	27698	95787	13/05/2011	77	78	12	6.50	2	I	8.58

Table 2 *Environmental factors: Kick Samples*

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 %
Autumn																	
CG 1	7.0	6.5	6.5	5	10	10	0	0	10	20	55	15	0	clear	riffle	0.4	0
CG 2	6.0	3.5	3.5	8	15	15	0	0	5	20	65	10	0	clear	riffle	0.5	0
CG 3	6.0	6.8	9.8	15	30	15	0	0	0	15	65	20	0	clear	riffle	0.4	0
CG 4	6.0	6.5	6.5	25	40	30	0	5	5	10	55	25	0	clear	riffle	0.5	0
KB	7.0	7.0	11.0	10	15	15	0	0	0	15	65	20	0	clear	riffle	0.5	0
Spring																	
CG 1	10.0	6.2	6.2	15	18	15	0	5	5	20	65	5	0	clear	riffle	0.7	0
CG 2	8.0	3.6	3.6	20	20	35	0	2	3	10	75	10	0	clear	riffle	1.0	0
CG 3	6.0	9.7	9.7	20	30	20	0	5	5	10	55	25	0	clear	riffle	1.0	0
KB	6.0	11.0	13.0	20	35	-	0	0	5	10	55	30	0	clear	riffle	0.7	0

Table 2 continued

Site	pH	Temp ºC	Conductivity µS/cm	Alkalinity mg/L $CaCO_3$	Vegetation Cover %	Vegetation composition
Autumn						
CG 1	6.26	8.3	16	12.6	25	10% Blindia acuta, 15% Algae
CG 2	6.53	9.8	17	12.0	10	5% Blindia acuta, 5% Algae
CG 3	6.52	9.8	20	12.0	10	5% Blindia acuta, 5% Algae
CG 4	6.55	9.7	20	12.0	15	10% Blindia acuta, 5% Algae
KB	6.56	8.3	26	12.6	15	5% Racomitrium aciculare, 10% Algae
Spring						
CG 1	7.69	7.7	17	9.3	5	5% Blindia acuta
CG 2	7.47	9.2	16	9.0	5	5% Blindia acuta
CG 3	7.39	8.7	17	8.7	5	5% Blindia acuta
KB	7.28	9.4	19	8.4	5	5% Racomitrium aciculare

Table 3 *Ecological Quality Index and Water Framework Directive Ecological Status Class for ASPT and NTAXA (Spring and Autumn combined)*

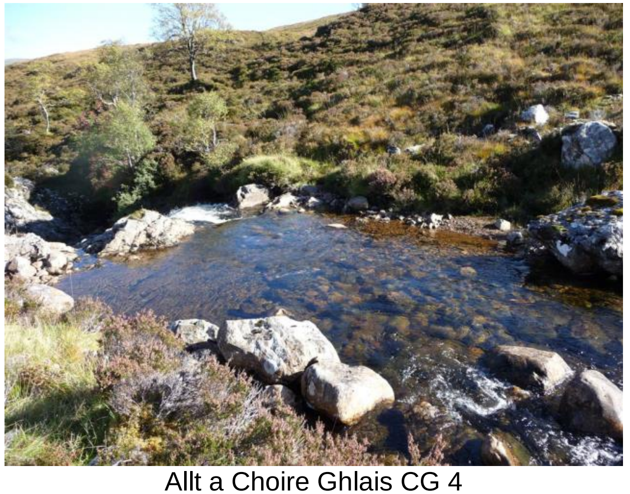
Site	Index	Observed	Reference Adjusted Expected	EQI (bias uncorrected)	Class (Bias uncorrected)	Most Probable Class	Probability of Most Probable Class
CG 1	ASPT	6.70	6.28	1.07	H	H	92.119
CG 1	NTAXA	20.00	17.36	1.15	H	H	98.96
CG 2	ASPT	6.50	6.25	1.04	H	H	78.348
CG 2	NTAXA	20.00	17.68	1.13	H	H	98.46
CG 3	ASPT	7.00	6.29	1.11	H	H	99.31
CG 3	NTAXA	18.00	16.60	1.08	H	H	95.47
KB	ASPT	7.53	6.31	1.19	H	H	100
KB	NTAXA	17.00	16.03	1.06	H	H	92.859

Annex 1 *Site photographs*


Allt a Choire Ghlais CG 1


Allt a Choire Ghlais CG 2


Allt a Choire Ghlais CG 3


Allt a Choire Ghlais CG 4


Kilfinnan Burn KB

Annex 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			

Annex 3 *Acid intolerant indicators: Water Chemistry Status Groups and Index of Acidity Lists*

Water Chemistry

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	

Annex 4 *Invertebrate Numbers Present in Samples (CG 1 Autumn 2010, CG 1S Spring 2011)*

Sample Code	**CG 1**	**CG 2**	**CG 3**	**CG 4**	**KB**	**CG 1S**	**CG 2S**	**CG 3S**	**KB S**
Plecoptera									
Chloroperlidae									
Chloroperla torrentium	1		1			1		1	1
Chloroperla tripunctata					1				
Leuctridae									
Leuctra sp.	82	17		1					
Leuctra fusca			1		4				
Leuctra hippopus	45		4	1	3	6	2		
Leuctra inermis							2	1	
Nemouridae									
Amphinemura sulcicollis	50	10	50	2	2	8	3	6	2
Protonemura meyeri	7	2	6	3					
Protonemura praecox		2	4		1				
Perlidae									
Perla bipunctata	2				5				
Dinocras cephalotes	9	4	2	1	1	7	6	2	4
Perlodidae									
Isoperla grammatica	15	4	10		1	6	1	2	1
Perlodes microcephala			1						
Taeniopterygidae									
Brachyptera risi								1	
Ephemeroptera									
Baetidae									
Baetis muticus	61	19	15		2	37	5	6	10
Baetis rhodani	45	34	18	4	22	10	11	3	2
Caenidae									
Caenis rivulorum	2				1	1		2	3
Heptageniidae									
Ecdyonurus sp.	16	23	18	6	7	28	1	13	38
Rhithrogena semicolorata	6	8	34		9	12	13	4	8
Leptophlebiidae									
Paraleptophlebia sp.	7	1		1				2	

Annex 4 *Invertebrate Numbers Present in Samples (CG 1 Autumn 2010, CG 1S Spring 2011)*

Sample Code	CG 1	CG 2	CG 3	CG 4	KB		CG 1S	CG 2S	CG 3S	KB S
Trichoptera										
Glossosomatidae										
Glossosoma boltonii					1					
Hydropsychidae										
Hydropsyche siltalai	1	1					1	1	2	
Hydroptilidae										
Oxyethira sp.	8	2		1						
Hydroptila sp.	40	15	9	15	2		1			
Lepidostomatidae										
Lepidostoma hirtum					1					
Limnephilidae										
Chaetopteryx villosa							1			1
Philopotamidae										
Philopotamus montanus	1				1			1		
Polycentropodidae										
Plectronemia conspersa	14	1	1		1		2			
Polycentropus flavomaculatus	17	10	3	3			8			
Rhyacophilidae										
Rhyacophila dorsalis	1	5	1							
Sericostomatidae										
Sericostoma personatum		1			1					

Annex 4 *Invertebrate Numbers Present in Samples (CG 1 Autumn 2010, CG 1S Spring 2011)*

Sample Code	**CG 1**	**CG 2**	**CG 3**	**CG 4**	**KB**	**CG 1S**	**CG 2S**	**CG 3S**	**KB S**
Diptera									
Chironomidae	63	20	27	4	7	14	3	1	3
Empididae		2							
Limoniidae		1							
Dicranota sp.	25	2				3	1		
Pediciidae									
Pedicia sp.	1								
Simulidae	3	1		1		2	2		2
Coleoptera									
Elmidae									
Elmis aenea			1						
Limnius volkmari	15	2			1	7	5		
Oulimnius sp.	6	3		1		4			
Hydraenidae									
Hydraena gracilis	2								1
Mollusca									
Sphaeriidae									
Pisidium sp.		1							
Oligochaeta									
Enchytraeidae	1	1	1			2	1	3	
Lumbricidae	8	1	1			4	4	1	1
Lumbriculidae	2	1							
Naididae			1	1					
Tricladida			1				1	1	
Nematoda						1			

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

Site Code		**CG 1**	**CG 2**	**CG 3**	**CG 4**	**KB**	**CG 1S**	**CG 2S**	**CG 3S**	**KB S**
Plecoptera	Chloroperlidae	10		10			10		10	10
	Leuctridae	10	10	10	10	10	10	10	10	
	Nemouridae	7	7	7	7	7	7	7	7	7
	Perlidae	10	10	10	10	10	10	10	10	10
	Perlodidae	10	10	10		10	10	10	10	10
	Taeniopterygidae								10	
Ephemeroptera	Baetidae	4	4	4	4	4	4	4	4	4
	Caenidae	7				7	7		7	7
	Heptageniidae	10	10	10	10	10	10	10	10	10
	Leptophlebiidae	10	10		10				10	
Trichoptera	Hydropschidae	5	5				5	5	5	
	Hydroptilidae	6	6	6	6	6	6			
	Lepidostomatidae					10				
	Limnephilidae						7			7
	Philopotamidae	8				8		8		
	Polycentropodidae	7	7	7	7	7	7			
	Rhyacophilidae	7	7	7						
	Sericostomatidae		10			10				
Diptera	Chironomidae	2	2	2	2	2	2	2	2	2
	Simulidae	5	5		5		5	5		5
	Tipuloidea	5	5				5	5		
Coleoptera	Elmidae	5	5	5	5	5	5	5		
	Hydraenidae	5								5
Mollusca	Sphaeriidae		3							
Oligochaeta		1	1	1	1		1	1	1	1
Tricladida				5				5	5	

Annex 6 *Acidity indicator groups and species present*

Site code	**CG 1**	**CG 2**	**CG 3**	**CG 4**	**KB**	**CG 1S**	**CG 2S**	**CG 3S**	**KB S**
Water chemistry class									
Group 1									
Glossosoma boltonii					✓				
Group 2									
Baetidae	✓	✓	✓	✓	✓	✓	✓	✓	✓
Heptageniidae	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hydropsyche sp.	✓	✓				✓	✓	✓	

Site code	**CG 1**	**CG 2**	**CG 3**	**CG 4**	**KB**	**CG 1S**	**CG 2S**	**CG 3S**	**KB S**
Acidity Index Class									
List A									
Dinocras cephalotes	✓	✓	✓	✓	✓	✓	✓	✓	✓
Perla bipunctata	✓				✓				
Baetis muticus	✓	✓	✓		✓	✓	✓	✓	✓
Caenis rivulorum	✓				✓	✓		✓	✓
Glossosoma boltonii					✓				
Philopotamus montanus	✓				✓		✓		
Sericostoma personatum		✓			✓				
List B									
Chloroperla tripunctata					✓				
Perlodes microcephala			✓						
Baetis rhodani	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ecdyonurus sp.	✓	✓	✓	✓	✓	✓	✓	✓	✓
Rhithrogena semicolorata	✓	✓	✓		✓	✓	✓	✓	✓
Hydraena gracilis	✓								✓

Annex 7 *Standard Field sheet*

Kick Samples Field Sheet: Allt a' Choire Ghlais 2011

Waterbody: **Date:** **Code:**

KICK SAMPLE

E **N:** **Altitude:**

wet width (m): **bed width (m):** **depth: ¼:** **½:** **¾:**

substrate

Type	*High org.*	*silt*	*sand*	*gravel*	*pebble*	*cobble*	*boulder*	*bedrock*
%								

Clarity (cm): **Flow**:glide/run/rifflle/ torrent **Speed (m.s^{-1}):**

Canopy cover (%): **pH** **Temperature**
Photographs: **Conductivity** **Water Sample**
Other (pollution, erosion etc)
Instream veg (%): Total **Bryophyte** **Algae** **Vascular**
☐ **Stone search competed**

Waterbody: **Date:** **Code:**

KICK SAMPLE

E **N:** **Altitude:**

wet width (m): **bed width (m):** **depth: ¼:** **½:** **¾:**

substrate

Type	*High org.*	*silt*	*sand*	*gravel*	*pebble*	*cobble*	*boulder*	*bedrock*
%								

Clarity (cm): **Flow**:glide/run/rifflle/ torrent **Speed (m.s^{-1}):**

Canopy cover (%): **pH** **Temperature**
Photographs: **Conductivity** **Water Sample**
Other (pollution, erosion etc)
Instream veg (%): Total **Bryophyte** **Algae** **Vascular**
☐ **Stone search competed**