BEAW FIELD WIND FARM:

Aquatic Marco-invertebrate Survey Report 2015

Report to: Alba Ecology Ltd

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Aquaterra Ecology




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

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1. SUMMARY

1.1. Background

This survey was commissioned to assess the water quality and invertebrate communities of watercourses present within the proposed development boundary of the Beaw Field Wind Farm. The key objectives of this survey were to provide:

- Characterisation of the invertebrate community of the receptor watercourses to species level highlighting any rarities or notable species present; and
- Assessment of the water quality of the watercourses using a range of biotic indices.

Macro-invertebrate communities were sampled using standard kick sampling methods (SEPA 2001, UKTAG 2008) from 11 sites on five watercourses (Annex 1), Burn of Arisdale, Burn of Hamnavoe, Burn of Kettlester, Green Burn and Burn of Horsewater. Sampling was conducted on the 16th, 17th and 19th of August 2015.

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: BMWP, ASPT, 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. GPS generated grid references and photographs were taken (Annex 1) to enable future site identification.

1.2. Main Findings

- Invertebrate communities largely consisted of common and widespread species typical of Scottish upland or rural watercourses and no rarities were identified.
- Proportionately the largest invertebrate group at all sites was Diptera, mainly chironomids. Abundance of these detritivores was low however, indicating the absence of organic pollution.
- Abundance and diversity of macro-invertebrates, as measured by taxon richness, was generally low. Macro-invertebrate communities may be depauperate as a result of Shetland's geographic isolation.
- The ASPT index indicated good (A2) water quality at four sites, fair (B) at four sites and poor (C) at three sites. These classifications should be regarded with caution as they may be low because some high scoring taxa, present in comparable mainland burns, appear to be absent from Shetland.
- The Water Chemistry Status Class was 1 (circum-neutral) for the Burn of Arisdale, Burn of Kettlester and Swarta Shun; and Class 2 (slightly acidic with a mean pH 5.6 or above) for the remaining watercourses.
- The watercourses overall should reach the WFD required standard of good for both the ASPT and NTAXA parameters with the exception of Swarta Shun for the ASPT parameter. These classifications are more reliable as they use an observed-predicted comparison utilising reference site data.
- Overall the water quality, invertebrate communities and productivity of the watercourses 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 system. 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. Macroinvertebrates 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 Water Framework Directive (WFD) classes of ecological status using a standard set of site specific environmental variables and observed values of TAXA and ASPT.

Assessment of macro-invertebrates 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. Greater resolution of indices is achieved through combined spring and autumn samples, although single sampling periods are also used.

Semi-quantitative abundance assessments of macro-invertebrates will also provide accurate characterisations of the community, and a measure of invertebrate diversity and productivity of the watercourse.

2.2. Objectives

The overall aim is to characterise the invertebrate communities and use the resulting data set to assess water quality using a range of biotic indices. The freshwater invertebrate survey of the Beaw Field watercourses provides:

i) A description of the macro-invertebrate 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;

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.

vii) Recordings of temperature, 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 25cm wide kick sample net with a 1mm 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 10cm. 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.

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

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 the surveys will be 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 undertaken in a consistent manner.

In small streams with limited size of suitable riffles multiple riffles may be used to produce a composite sample. Where substrate and/or depth prevented kick sampling, timed sweep netting was employed.

3.2. Sites

A total of eleven sites were sampled, multiple sites on watercourses were coded with site numbers increasing in an upstream direction.

Sites were accurately recorded using photographs (Annex 2) and ten figure GPS generated grid references. 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.

Temperature, pH and conductivity were recorded with a portable calibrated meter. 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 field sheets.

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; Dobson *et al* 2012; Edington & Hildrew 1995; Elliot 2009; Elliot & Humpesch 2010; Elliot, & Mann 1979; Foster & Friday 2011; Friday 1988; Gledhill *et el.* 1993; Hynes 1977; Killeen *et al.* 2004; Macan 1959; Macan 1977; Nilsson 1996, 1997; Reynoldson & Young 2000; Savage 1989; Savage 1999; Scourfield & Harding 1994; Smallshire & Swash 2010; Timm & Veldhuijzen van Zanten 2002 and Wallace *et al.* 1990).

Specimens from kick samples were identified to species level to provide data for a range of biotic indices.

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 1-10 and a score of 1 is allocated to the most pollution tolerant families and 10 to the most pollution sensitive (Annex 3). 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 normally with a tolerance of a minimum pH of 6.0 and Group 2 with a tolerance of a minimum pH of 5.5 (Annex 4). 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 (Annex 4). For samples collected between May and October the definitions used are 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, including a biological element. Parts of the assessment of the benthic invertebrate quality element are the parameters ASPT and NTAXA, sensitive to organic enrichment and also to toxic pollution. Assessment of the ASPT and NTAXA parameters is achieved using a set of reference sites largely unaffected by anthropogenic activity, established for RIVPACS. The RIVPACS methods were originally developed to use benthic macro-invertebrates 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. The resulting EQI values are the ratio of the observed to expected values (O/E) and 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. The EQI values are used to produce the Ecological Quality Ratio (Eqr) and WFD class of the water body.

For the ASPT and NTAXA parameters the following classes are assigned from EQR values (Environment Agency 2011):

Table iv. ASPT and NTAXA status classification

Classification	ASPT	NTAXA
High	≥0.97	≥0.85
Good	0.86-0.96	0.71-0.84
Moderate	0.75-0.85	0.57-0.70
Poor	0.63-0.74	0.47-0.56
Bad	<0.63	<0.47

4. RESULTS AND DISCUSSION

4.1. Sites

The grid references for sites are given in Table 1. Physical and chemical environmental variables are found in Table 2.

Land use in the study area is mainly sheep grazing and the intensification of this with the associated use of fertilisers and the possible erosion from high stocking densities have been identified as two areas of concern for water quality (Hardy 2004). The watercourses do not flow through any significant populated areas and it is likely that anthropogenic pressures are limited.

The bedrock geology of the study site is complex consisting of metamorphic rocks including gneiss and quartzite. Overlaying these rocks are a mixture of peat, mainly at the north of the site, and glacial deposits. These solid and drift geologies are important in determining the characteristics of the stream chemistries.

The watercourses were all small (<3m wide), shallow (<20cm deep) and open with no canopy cover. The Burn of Arisdale was an exception being about six meters wide. The catchments were small with each flowing directly to the sea.

At nine sample sites the main component of substrates was pebbles, cobbles and boulders combined. The exceptions were Swarta Shun (SS1), where sampling was conducted in a glide and a pool, and Loch of Kettlester inflow (KE1). The latter site was a static pool or lentic habitat. Both these sites had a high proportion of peat and hardpan in their sediment profile.

Macrophyte cover was variable, mean 19% (range 0-45%). Bryophytes were the main component at most sites. Algae coverage was low but constituted 25% at Swarta Shun.

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 Annex 5.

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.

Macro-invertebrate 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 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).

As the majority of species of Ephemeroptera, Plecoptera and Trichoptera (EPT) are pollution sensitive, a combined proportion of these taxa as a percentage of invertebrates present, is an indication of water quality. If EPT is >50% then water quality is likely to be good, 25-50% indicating moderate quality.

The mean proportion of EPT at the study sites was only 18% (range 0-33%) and sites were dominated by Diptera with a mean proportion of 61% (range 43-81%). Although the proportion of Diptera and consequently that of the detritivorous chironomids is high, the actual abundance is low (mean 84 per m² kicked) when compared with organically polluted sites where densities downstream of a point source can be as much as 50,000 per m² (Mason 2002). It is not thought likely that the watercourses are organically polluted.

One important characteristic of the watercourses was the low biodiversity of the invertebrate communities. The main reason for this in lotic waters is probably the isolation of Shetland (Hardy 2004). Many islands have depauperate fauna in comparison to the nearest mainland. Low diversity was present in most groups, only two species of Ephemeroptera were present, one genera of Plecoptera and six species of Trichoptera. Many of the taxa associated with the fast flowing well-oxygenated water of riffles on the Scottish mainland were absent. These included the Plecoptera families Perlidae and Perlodidae, and the Ephemeroptera family Heptageniidae. Interpretation of the invertebrate community data in Shetland has therefore to be viewed with some caution, in particular when used for the generation of biotic indices.

Most species present were common and widespread such as the mayfly *Baetis rhodani*, and the predatory caddis flies *Plectronemia conspersa*, *Polycentropus flavomaculatus* and *Rhyacophila dorsalis*.

No rarities were identified and invertebrate communities largely consisted of common and widespread species typical of upland and/or rural Scottish watercourses. The water quality is likely to be good if the probable depauperate island character of the macro-invertebrate communities is considered.

4.3. Invertebrate Abundance and Diversity

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

Invertebrate density in the study area watercourses varied from 16 per m² kicked in the Burn of Hamnavoe HV1 to 176 per m² kicked in the Burn of Kettlester KO1. The invertebrate density was low with a mean of 93 per m² kicked.

It is difficult to assess diversity as a variety of taxonomic levels of identification have been used in scientific works and comparisons with other surveys are often invalid. Mean taxon richness (numbers of taxa present) was 13 (range 4-21), with diversity at eight sites low (≤ 15) and moderate (16-25) for three sites.

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 Annex 6.

The BMWP scores were low for all sites with a mean of 39 (range 13-61) producing classifications of fair (B) at two sites, poor (C) at seven sites and seriously polluted (D) at two sites. This was the result of both low numbers of scoring taxa (mean 8, range 4-13) and the absence of high scoring taxa such as Chloroperlidae, Perlodidae, Perlidae and Heptageniidae. The first three Plecoptera families are likely to be present in comparable slightly acidic burns on the Scottish mainland. It is not considered likely that serious organic pollution has occurred.

Generally ASPT scores are regarded as more reliable and these produced higher classifications with four sites classed as good (G), four sites as fair (B) and three as poor (C). It is possible however that these scores may also be lower through reduced diversity in Shetland.

4.5. Water Chemistry Status

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

The Water Chemistry Status Class was 1 (circum-neutral) for Burn of Arisdale, Loch Kettlester outflow and Swarta Shun; and Class 2 (slightly acidic with a mean pH 5.6 or above) for the remaining watercourses.

4.6. Index of Acidity

The classifications are shown in Table 1 and the indicator species recorded as present are listed in Annex 8.

Index of Acidity classifications were either Class II (Burn of Arisdale, Loch Kettlester outflow, Swarta Shun) or Class III. Class III indicates possible significant acidification but unlike the Water Chemistry scores the Index of Acidity indices are generated by the presence/absence of a wide range of species. If diversity is reduced by factors other than acidification (possibly geographic isolation) then this scoring system may be unreliable.

Morris (1987) found there was little evidence of significant acidification of Shetland streams and the water chemistry results and pH records of this survey support this.

4.7. Ecological Status Class for ASPT and NTAXA

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

At eight sites the watercourses were classed as high (H) for the ASPT parameter, and the remaining three were good (G) at HV1, moderate (M) at SS1 and bad (B) at KE1. The WFD parameters are not considered applicable to the Loch of Kettlester inflow KE1 as this is a lentic habitat.

With the exception of KE1 bad (B) watercourses were classified as high (H) for the NTAXA parameter at nine sites and moderate (M) at Burn of Hamnavoe HV1.

SEPA classifies the Burn of Arisdale as high for ASPT and good for the NTAXA parameter (SEPA 2010). Ecological status classification conducted by SEPA is based on spring and autumn samples combined; this survey is based on single season summer sampling.

The results of this survey indicates that the watercourses overall should reach the WFD required standard of good for both the ASPT and NTAXA parameters with the exception of Swarta Shun for the ASPT parameter, and Loch of Kettlester inflow. The overall indication is that these watercourses are not organically enriched and that the invertebrate element of stream biota is healthy.

4.8. pH, Conductivity and Alkalinity

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

The pH of small burns flowing through areas of peat may be considerably variable with increased acidity in times of high flows, these samples were taken as waters were returning to normal levels after a spate. The pH on survey days was >6.0 in the Burn of Arisdale (A1, A2), Swarta Shun and Burn of Horsewater indicating these watercourses may be circum-neutral. In other watercourses the pH was between 5.0 and 6.0 (4.8 at the Kettlester inflow pool KE1). These watercourses are likely to be slightly acidic intermediate streams with possible episodic acidic events.

The typical range of conductivity for streams is 50 – 1500 µS/cm with the optimum range for invertebrate diversity of 150 – 500 µS/cm (Behar 1997). Conductivity was generally low to moderate for all sites, with a mean of 151 µS/cm (range 113-201 µS/cm). Conductivity is related linearly to total dissolved solids (TDS), usually mineral salts. The moderate conductivity therefore suggests a low to moderate loading of TDS and the watercourses are 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 mainly low with a mean of 10 mg/L $CaCO_3$ (range 5-21 mg/L $CaCO_3$). The buffering capacity of the watercourses is generally low and they may be vulnerable to episodic acidification.

5. ASSESSMENT

5.1. Invertebrate Community

Invertebrate species found were mostly common and widespread and the communities generally had low abundance with low taxon richness. The main reason for the low taxon richness in the watercourses is probably the isolation of Shetland (Hardy 2004). Island may have depauperate fauna dependent upon distance from the nearest mainland.

Interpretation of the invertebrate community data in Shetland has therefore to be viewed with some caution, in particular when used for the generation of biotic indices. SEPA have found the monitoring results of RIVPACS unreliable in Shetland because of low diversity (David Okill, pers comm. 2008). An earlier survey, comprising 30 kick samples and 90 Hess/Surber samples, found similar low taxon richness to this survey (Aquaterra Ecology 2008).

With this caveat the overall the invertebrate communities and indices indicated there was no significant organic pollution and that the watercourses are healthy and well-oxygenated with low anthropogenic impacts. The biotic indices showed the watercourses are slightly acidic and some of the most acid sensitive taxa were absent or present in only small numbers. The water quality, invertebrate communities and productivity should support sustainable salmonid populations, if other environmental factors are suitable.

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Table 1 *Biological Monitoring Scores and Classifications*

Watercourse	Sample/ Site Code	Grid Reference HU		Sampling date	Total invertebrate abundance (n)	Number of Taxa Present	BMWP score	Number of scoring taxa (n)	ASPT score	Index of Acidity	Water Class
		East	North								
Burn of Arisdale	A1	48545	81124	17/08/2015	137	15	51	10	5.10	II	1
Burn of Arisdale	A2	48386	81668	17/08/2015	215	14	48	10	4.80	II	1
Burn of Hamnavoe	HV1	49647	81175	16/08/2015	22	6	14	4	3.50	III	2
Burn of Hamnavoe	HV2	49699	81630	16/08/2015	69	9	36	7	5.14	III	2
Burn of Hamnavoe	HV3	49967	82524	16/08/2015	121	14	43	8	5.38	III	2
Loch Kettlester inflow	KE1	51372	81128	17/08/2015	35	4	13	4	3.25	III	2
Burn of Kettlester	KO1	51584	80869	17/08/2015	265	18	61	13	4.69	II	1
Green Burn	G1	52018	83238	19/08/2015	108	13	39	8	4.88	III	2
Green Burn	G2	51902	82820	19/08/2015	93	11	41	8	5.13	III	2
Swarta Shun outflow	SS1	52380	81480	17/08/2015	248	21	43	11	3.91	II	1
Burn of Horsewater	H1	52921	81767	17/08/2015	235	17	44	10	4.40	III	2

Table 2 *Environmental variables: Kick samples*

Site Code	Wet width m	Bed width m	Depth 1/4 cm	Depth 1/2 cm	Depth 3/4 cm	HO/SI %	SA %	GR %	PE %	CO %	BO %	BE %	clarity	flow	speed ms^{-1}	canopy %
A1	6.5	6.5	10	15	10	0	0	10	30	50	10	0	15	run/riffle	0.5	0
A2	6.0	6.0	20	10	10	0	0	20	40	35	5	0	-	riffle	0.8	0
HV1	3.0	3.5	10	15	15	0	1	4	20	30	45	0	40	riffle	0.3	0
HV2	3.2	3.2	15	18	10	0	2	10	18	40	30	0	40	riffle	0.5	0
HV3	1.9	1.9	20	16	20	0	5	15	40	20	20	0	20	glide/riffle	-	0
KE1	0.5	0.5	2	2	10	40	0	1	5	30	0	0	10	static	0.0	0
KO1	1.6	1.6	10	20	15	0	0	5	30	55	10	0	20	run/riffle	0.7	0
G1	1.8	2	11	10	11	0	0	10	15	45	30	0	20	run/riffle	0.7	0
G2	1.0	1.1	7	10	10	0	0	10	35	50	5	0	20	run/riffle	0.8	0
SS1	0.4	0.4	10	10	5	60	0	0	0	0	0	0	20	glide/pool	0.2	0
H1	0.8	0.8	7	10	10	0	0	10	20	55	15	0	20	run/torrent	1.0	0

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

Site Code	Temperature °C	pH	Conductivity µS/cm	Alkalinity mg/L $CaCO_3$	Vegetation Cover %	Vegetation composition
A1	12.8	6.68	150	-	10	10% Bryophytes.
A2	13.6	6.50	146	11.0	30	28% Bryophytes, 2% Vascular.
HV1	11.9	5.70	113	6.0	0	
HV2	13.7	5.90	113	5.0	5	1% Bryophytes, 4% Algae.
HV3	14.6	5.40	130	8.0	30	30% Bryophytes.
KE1	16.8	4.80	169	5.0	20	20% Bryophytes.
KO1	16.7	5.78	201	16.0	45	40% Bryophytes, 5% Vascular
G1	16.0	5.41	126	5.0	4	2% Bryophytes, 2% Algae.
G2	16.0	5.56	131	8.0	0	
SS1	14.5	6.00	193	21.0	30	20% Algae, 25% Vascular. Algae present within vascular.
H1	15.0	6.20	187	16.0	35.0	30% Bryophyte, 5% Vascular.

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

Site	Index	Observed	Reference Adjusted Expected	Average (Bias corrected) EQI	Eqr factor	Average Face value Band Eqr	Most Probable Class	Probability of Most Probable Class (%)
A1	ASPT	5.1	4.128	1.235	0.9643	1.191	H	98.92
	NTAXA	10	9.21	1.271	0.9573	1.216	H	94.23
A2	ASPT	4.8	4.128	1.172	0.9643	1.13	H	95.82
	NTAXA	10	9.21	1.271	0.9573	1.216	H	94.23
HV1	ASPT	3.5	4.128	0.92	0.9643	0.887	G	33.65
	NTAXA	4	9.21	0.619	0.9573	0.592	M	27.18
HV2	ASPT	5.14	4.128	1.233	0.9643	1.189	H	97.94
	NTAXA	7	9.21	0.945	0.9573	0.904	H	57.49
HV3	ASPT	5.38	4.128	1.286	0.9643	1.24	H	99.47
	NTAXA	8	9.21	1.053	0.9573	1.008	H	74.75
KE1	ASPT	3.25	5.599	0.645	0.9643	0.622	B	53.45
	NTAXA	4	19.997	0.284	0.9573	0.272	B	98.31
KO1	ASPT	4.69	4.128	1.152	0.9643	1.111	H	94.74
	NTAXA	13	9.211	1.597	0.9573	1.529	H	99.67
G1	ASPT	4.88	4.128	1.184	0.9643	1.142	H	95.93
	NTAXA	8	9.21	1.053	0.9573	1.008	H	74.75
G2	ASPT	5.13	4.128	1.235	0.9643	1.191	H	98.41
	NTAXA	8	9.21	1.053	0.9573	1.008	H	74.75
SS1	ASPT	3.91	4.959	0.819	0.9643	0.79	M	54.52
	NTAXA	11	12.839	0.988	0.9573	0.946	H	68.97
H1	ASPT	4.4	4.128	1.088	0.9643	1.049	H	81.44
	NTAXA	10	9.21	1.271	0.9573	1.216	H	94.23

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

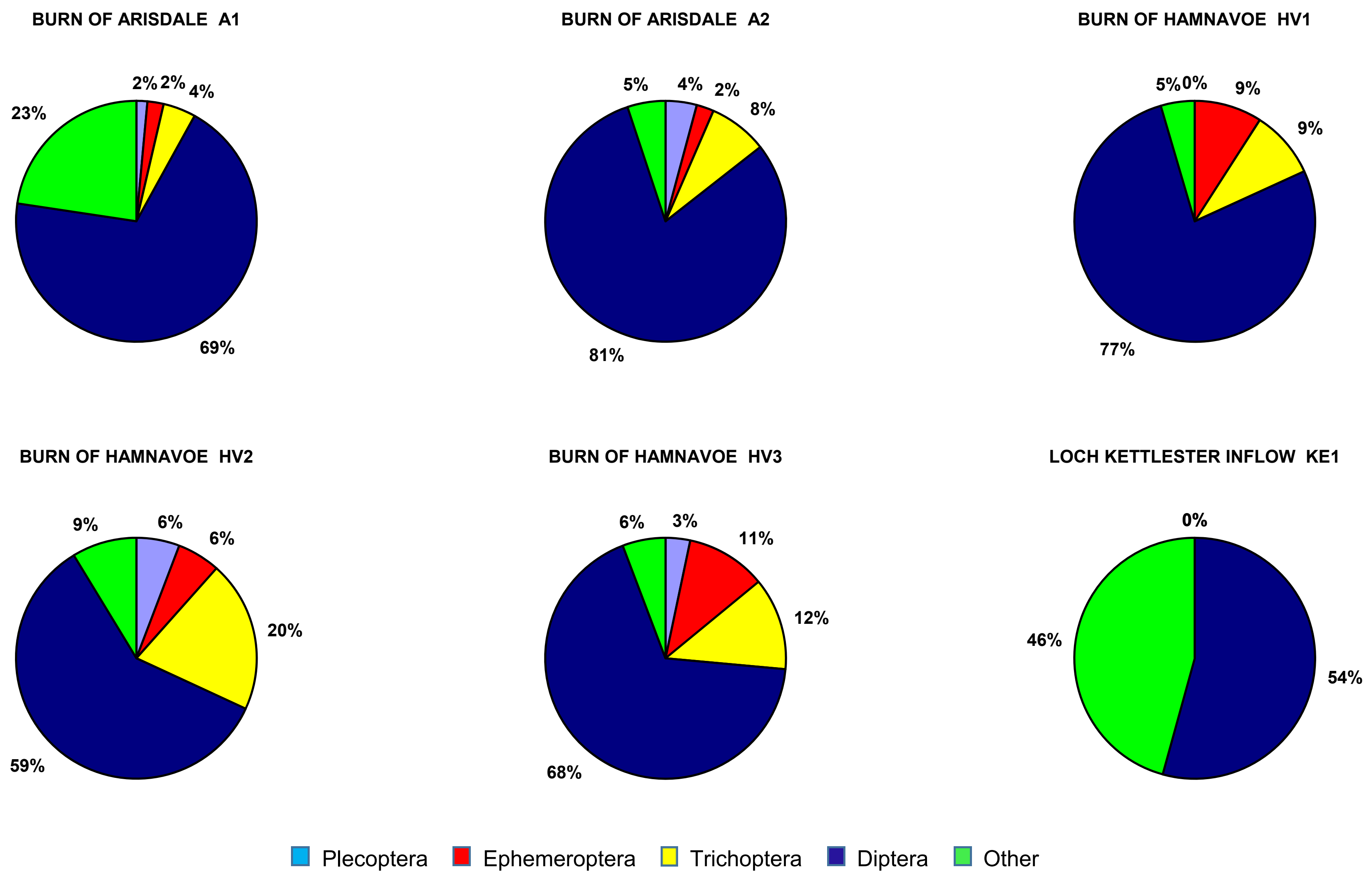


Figure 1 continued *Invertebrate groups: percentages of sample by number*

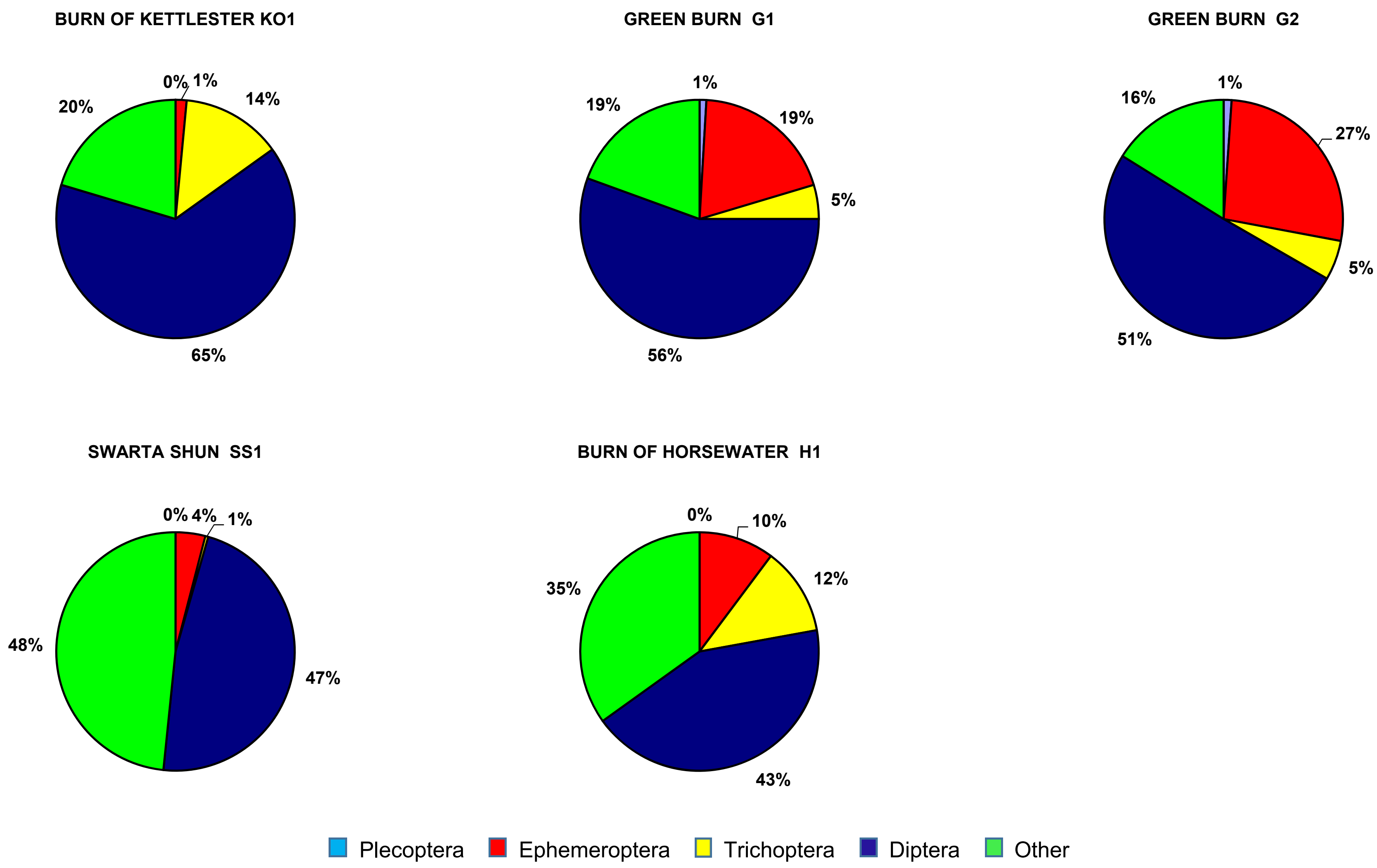
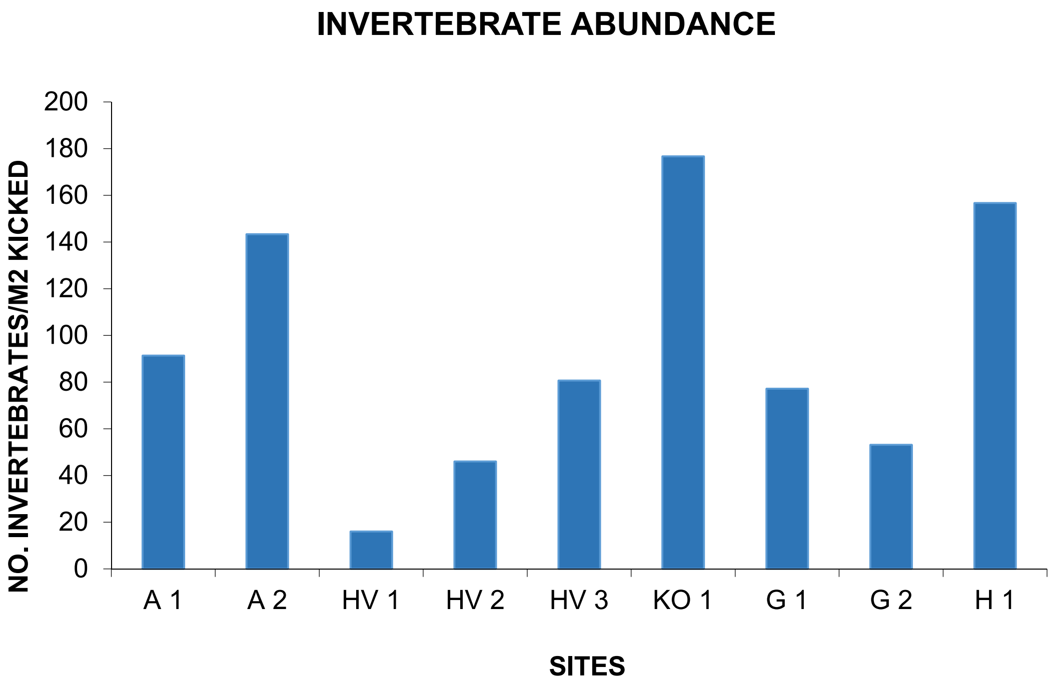
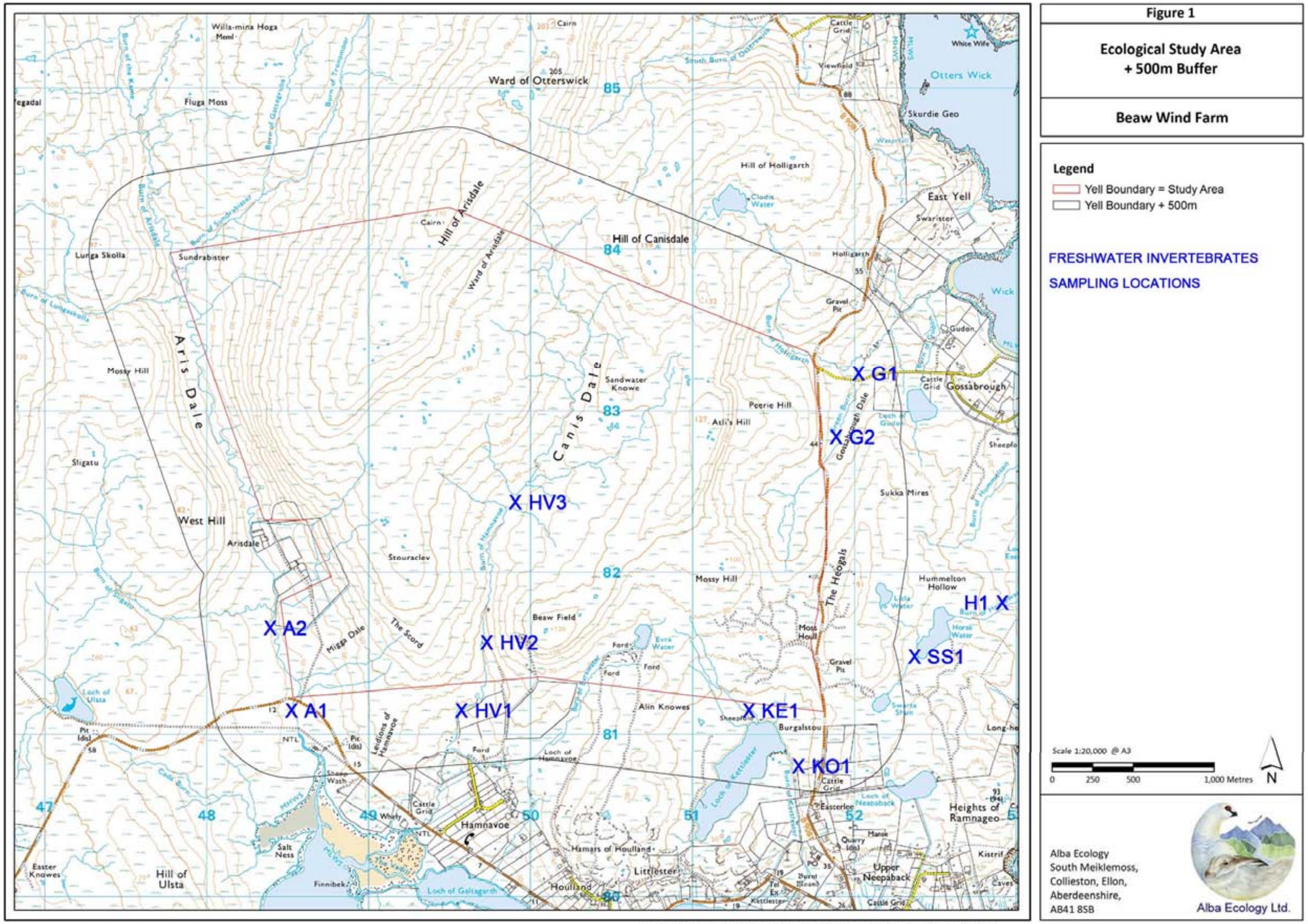


Figure 2. *Density (number/m²) of invertebrates in kick samples. Loch of Kettlester inflow KE1 and Swarta Shun excluded as no three minute kick sample was possible.*



Annex 1 *Approximate Sampling Locations*



Annex 2 *Site photographs*

Burn of Arisdale A1

Burn of Arisdale A2

Burn of Hamnavoe HV1

Burn of Hamnavoe HV2

Burn of Hamnavoe HV3

Loch Kettlester inflow KE1

Annex 2 *Site photographs*

Burn of Kettlester KO1

Green Burn G1 One of two riffles sampled.

Green Burn G2

Swarta Shun SS1 Pool.

Swarta Shun SS1 Glide

Burn of Horsewater H1

Annex 3 *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 4 *Acid intolerant indicators: Water Chemistry Status Groups and Index of Acidity Lists*

Water Chemistry Status

Species	Normal Minimum pH
Group 1	
Gammarus pulex	$\geq$ 6.0
Glossosoma & Agapetus spp.	6.0
Ancylus fluviatilis	6.0
Radix balthica	6.0
Asellus aquaticus	6.0
Group 2	
Hydropsyche sp.	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 balthica	*Rhithrogena semicolorata*
Ancylus fluviatilis	*Ecdyonurus spp.*
Potamopyrgus jenkinsi	*Electrogena lateralis*
Baetis scambus	*Perlodes microcephala*
Alaites 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 5 *Invertebrate numbers present in kick samples*

Sample Code	**A 1**	**A 2**	**HV 1**	**HV 2**	**HV 3**	**KE 1**	**KO 1**	**G 1**	**G 2**	**SS 1**	**H 1**
Plecoptera											
Leuctridae											
Early nymphs	2	9		4	4			1	1		
Ephemeroptera											
Baetidae											
Baetis rhodani	3	5	2	4	13		4	20	25	10	24
Baetis vernus								1			
Trichoptera											
Hydroptilidae											
Oxyethira sp.		1					1				
Limnephilidae											
Early instars	2	1			2		3		3		10
Halesus radiatus	1	4			1						
Potamophylax sp.					1				1	1	16
Polycentropidae											
Plectronemia conspersa	2		1		3				1		2
Polycentropus flavomaculatus			1	6			26				
Rhyacophilidae											
Rhyacophila dorsalis	1	11		8	8		6	5			
Diptera											
Ceratopogonidae	1						4				
Chironomidae	86	149	15	38	73	19	143	29	19	111	48
Empididae	7	10	2	1	7			22	11	1	6
Dixidae										1	
Limoniidae											2
Muscidae		1					9				13
Pediciidae							10	6	11		13
Psychodidae				1	1					2	1
Simulidae	1	13		1				2	6	1	18
Tipulidae					1		5	1		1	

Annex 5 continued *Invertebrate numbers present in kick samples*

Sample Code	**A 1**	**A 2**	**HV 1**	**HV 2**	**HV 3**	**KE 1**	**KO 1**	**G 1**	**G 2**	**SS 1**	**H 1**
Coleoptera											
Dytiscidae											
Agabus guttatus										1	
Agabus sp.						4				10	2
Colymbetes sp.										1	
Hydroporus sp.							1				
Illybius sp										1	
Dryopidae											
Dryops sp.										1	
Elmidae											
Limnius volckmari							1				
Hydraenidae											
Hydraena gracilis	1										
Scirtidae											
Elodes sp.								1			32
Hemiptera											
Corixidae											
Nymphs						11				16	
Callicorixa wollastoni						1					
Crustacea											
Gammaridae											
Gammarus lacustris							14				
Mollusca											
Hydrobiidae											
Potamopyrgus jenkinsii										8	
Lymnaeidae											
Radix balthica	1	1					7			3	
Sphaeriidae											
Pisidium sp.		3					4			70	36
Oligochaeta											
Enchytraeidae	20	2			2		1	3		1	5
Lumbricidae	7	5	1		1		9	10	9	3	6
Lumbriculidae	2			6	4		17	7	6	4	
Naididae										1	
Nematomorpha											1

Annex 6 *BMWP, ASPT indicator groups present in kick samples with scores*

	Sample Code	A 1	A 2	HV 1	HV 2	HV 3	KE 1	KO 1	G 1	G 2	SS 1	H 1
Plecoptera	Leuctridae	10	10		10	10			10	10		
Ephemeroptera	Baetidae	4	4	4	4	4		4	4	4	4	4
Trichoptera	Hydroptilidae		6					6				
	Limnephilidae	7	7			7		7		7	7	7
	Polycentropidae	7		7	7	7		7		7		7
	Rhyacophilidae	7	7		7	7		7	7			
Diptera	Chironomidae	2	2	2	2	2	2	2	2	2	2	2
	Simulidae	5	5		5				5	5	5	5
	Tipuloidea					5		5	5	5	5	5
Coleoptera	Dytiscidae						5	5			5	5
	Elmidae							5				
	Hydraenidae	5										
	Scirtidae								5			5
Hemiptera	Corixidae						5				5	
Crustacea	Gammaridae							6				
Mollusca	Hydrobiidae										3	
	Lymnaeidae	3	3					3			3	
	Sphaeriidae		3					3			3	3
Oligochaeta		1	1	1	1	1	1	1	1	1	1	1

Annex 7 *Water Chemistry indicator groups and species present in kick samples*

Sample code	A 1	A 2	HV 1	HV 2	HV 3	KE 1	KO 1	G 1	G 2	SS 1	H 1
Group 1											
Gammarus lacustris							✓				
Radix bathica	✓	✓					✓			✓	
Group 2											
Baetis rhodani	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓

Annex 8 *Index of Acidity indicator groups and species present in kick samples*

Sample code	A 1	A 2	HV 1	HV 2	HV 3	KE 1	KO 1	G 1	G 2	SS 1	H 1
List A											
Gammarus lacustris							✓				
Radix balthica	✓	✓					✓			✓	
Potamopyrgus jenkinsii										✓	
List B											
Baetis rhodani	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Hydraena gracilis	✓										