ENVIRONMENTAL CHANGE RESEARCH CENTRE

University College London

RESEARCH REPORT

No. 80

Land-Use Experiments in the Loch Laidon Catchment:
Sixth report on Stream Water Quality to the Rannoch Trust.

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June 2001

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1. Introduction

This report presents and summarises data from the Stream Water Quality project instigated by the Rannoch Trust in 1992. The project is a component of the Loch Laidon Catchment land-use experiment, which is investigating the effects of differing cattle grazing regimes on the terrestrial and aquatic upland environment. Allott *et al* (1994) described the project rationale and background whilst progress reports (see References) have provided ongoing updates of the accumulating dataset.

2. Methodology

Sampling methodologies followed those of Allot *et al* (1994). Annual biological surveys of fish, epilithic diatoms, aquatic macroinvertebrates and aquatic macrophytes continue to be undertaken. Aquatic macroinvertebrates were not surveyed in 1995. Biological sampling dates are given in Appendix 5. Spot water chemistry samples have been collected at approximately monthly intervals.

A total of 33 cattle (1 bull, 16 cows and 16 calves) were introduced within the fenced experimental plot from mid July to late September 1993. A similar grazing period has been practiced in subsequent years though stocking levels were reduced by one cow and one calf in 1994.

In summer 1995 an additional four spot water chemistry sampling points were added to the project:

a. a lower station on the experimental burn
b. an upper station on the Allt Riabhach na Bioraich burn
c. a lower station on the Allt Riabhach na Bioraich burn
d. the Loch Laidon Outflow

Since 1996 the Allt Riabhach na Bioraich burn has also been sampled for epilithic diatoms, aquatic macrophytes, aquatic macroinvertebrates and fish following the pre-existing protocols.

Sampling locations are presented in Figure 2.

3. Data Analysis and Presentation

Data are held on a central Access database at the Environmental Change Research Centre (ECRC) and in this report are presented as raw data, graphs and summary statistics.

The following biotic and diversity indices have been used for macroinvertebrates:

Hill's N1 approximates to the number of abundant species
Hill's N2 approximates to the number of very abundant species in the sample**.**
Hill's E5 is a measure of the evenness of species occurrences in a sample. E5 approaches zero as a single species becomes more dominant in the community.
Richness (rareftn 100) predicts the expected number of taxa in a sample of 100 individuals.
BWMP is a scoring system for macroinvertebrates based on a scale of 1 to 10 given to each taxonomic family. It provides an indication of water quality by assigning families very sensitive to organic pollution a score of 10 whilst those that thrive in organically polluted systems, such as bloodworms, are assigned a score of 0.
ASPT is the Average Score Per Taxon, based on the BMWP score divided by the number of taxa in the sample. A range of 6.3 to 6.7 is typical for a diverse fauna.

Multivariate statistical methods were applied to the epilithic diatom and aquatic macroinvertebrate data from the Control, Experimental and Allt Riabhach na Bioraich burns to examine the extent of between year variability and test for time trends; these included Detrended Correspondence Analysis (DCA), Principal Components Analysis (PCA) and Redundancy Analysis (RDA). DCA was used as an initial test on the data to check their suitability for the subsequent linear models of PCA and RDA. PCA is an indirect gradient approach that provides a sensitive measure of between sample variance in the species assemblage. RDA is a form of PCA in which the components are constrained to be linear combinations of explanatory variables. For the purpose of this study the single explanatory variable was "time", coded as year of sampling. Statistical significance of the results was tested using a restricted version of the Monte Carlo permutation test, running 999 permutations. All analyses were performed using the program CANOCO (ter Braak 1988, 1990). For a fuller explanation of the statistical methodologies see Patrick *et al* (1995).

4. Results

4.1 Water Chemistry

4.1.1 Comparison of the Control and Upper Experimental Burn

Figures 3.1 to 3.3 show the relationship between Control and Experimental burn concentrations of key chemical determinands. In general the ratios between the streams continue to demonstrate the consistency of the relationship over time. These therefore provide strong evidence that the water quality of the upper reaches of the Experimental burn remain unaffected by the cattle-grazing regime. Conductivity and alkalinity persist in being relatively elevated in the Experimental Burn during the summer period and Figure 3.4 strengthens the case made by Monteith (1999) that this change in the ratio occurs during periods of lower flow. The effect is less pronounced during the relatively wet summer of 2000.

Nitrate concentrations have remained low in the two burns over the last two years with the exception of a summer peak in 1999 in the Experimental Burn. This echoes a similar occurrence in 1998 and possibly arises from minor nitrification within the stream channel after periods of particularly low flow. Within stream biological uptake of nitrate may account for the reduction in these peak levels between the upper sampling point (Figure 3.3) and the lower sampling point (Figure 3.5).

4.1.2 Comparison of the Control and Lower Experimental Burn

Although the time series for the lower station of the Experimental burn is relatively short, the effects of changes in catchment management are more likely to be detectable here than in the upper reaches. In Figures 3.5, 3.6 and 3.7 however, the ratios of selected chemical variables between the lower sampling site on the Experimental Burn and the Control Burn demonstrate a lack of any discernable trends since cattle grazing began. Conductivity is consistently higher at the lower site than the Control Burn though alkalinity in the two is more closely matched.

4.1.3 Comparison of the Allt Riabhach na Bioraich with the Control And Lower Experimental Burn

The conductivity plot (Figure 3.9) illustrates how better matched the chemistry of the Allt Riabhach na Bioraich burn is to the Control burn, in comparison with the Experimental burn. This is particularly the case for summer peak values and suggests better hydrological compatibility. Alkalinity and Total Organic Carbon graphs (Figure 3.8 and 3.11), like conductivity, reveal a propensity for higher values in the Lower Experimental Burn during the late summer months. Nitrate (Figure 3.10) values in the three burns again fluctuate seasonally but peaks are seen during the winter months when biological activity is at a minimum. The Lower Experimental Burn exhibits generally lower nitrate values than the other burns.

4.2 Biology

4.2.1 Epilithic Diatoms

Epilithic diatom data is presented graphically in Figures 4.1, 4.2 and 4.3. Trend test statistics are provided in Table 1.

The Control burn diatom assemblage continues to be dominated by three species. The most abundant taxon alternates between, *Tabellaria flocculosa* and *Synedra miniscula*. *Brachysira vitrea* is almost always the third most abundant species.

The diatom flora of the Experimental burn continues to show strong inter-annual fluctuations, as identified in previous years. The most persistently abundant species are *Tabellaria flocculosa*, *Peronia fibula*, *Eunotia naegelii*, *Brachysira vitrea*, *Eunotia incisa* and *Frustulia rhomboides*.

In the Allt Riabhach na Bioraich burn diatom assemblage composition has remained much more stable than in the other two study burns. *Tabellaria flocculosa* has dominated the assemblages every year, with *Brachysira vitrea* usually the next most abundant species.

Detrended Correspondence Analysis was performed on the diatom data from the Experimental Burn and the Control Burn. Both datasets proved to have short time constrained gradient lengths of less than 3 standard deviation units and were thus appropriate for subsequent Principal Components Analysis. The PCA first axis eigenvalues ($?_1^{PCA}$), which provide the maximum proportion of total between-year variance that can be explained by a single hypothetical variable, are provided in Table 1. Also provided in this table are RDA Axis 1 eigenvalues, which give the variance that can be explained by a time trend ($?_1^{RDA}$). Variance explained by time at both sites is small relative to variance on the first Principal Component and is not deemed significant by Monte Carlo permutation tests ($P > 0.05$) This suggests that it is unlikely that there is any time trend in the data at either site and that cattle grazing is having no discernible effect on the diatom flora of the Experimental burn.

Table 1 Diatom Trend Test Statistics

	λ_1^{PCA}	λ_1^{RDA}	$\lambda_1^{RDA}/\lambda_1^{PCA}$	Restricted P Value
Control Burn	0.42	0.15	0.36	0.38
Experimental Burn	0.42	0.21	0.49	0.27

4.2.2 Macroinvertebrates

Macroinvertebrate data are presented in Table 4 and Figures, 5.1, 5.2 and 5.3. Macroinvertebrate summary statistics in Table 5 demonstrate that the total numbers of individual animals caught have tended to increase at all three burns in the last four years. Over the same period the number of species found per sample has fluctuated at each site, demonstrating no obvious trends (Figures 5.4, 5.5 and 5.6). The Allt Riabhach na Bioraich, however, is consistently slightly less species rich than the other burns.

The Control and Allt Riabhach na Bioraich continue to show close resemblance in their stonefly dominated assemblages. *Amphinemura sulcicollis* was the most abundant species in both burns in 2000, while *Siphonoperla torrentium* has declined slightly in both streams over the last three years. Another stonefly, *Isoperla grammatica* is the third consistently abundant species in the Allt Riabhach na Bioraich whereas in the Control Burn the beetle *Limnius volckmari* is the next most frequent taxon.

Unlike the stonefly dominated assemblages of the other burns the Experimental Burn has been dominated by midge larvae (CHIRONIMIDAE) and larvae of the caddis family, Limnephilidae, over the past three years with these constituting approximately half of the sampled macroinvertebrates. The beetle *Oulimnius tuberculatus* and the stonefly *Amphinemura sulcicollis* have represented the most abundant of the other species in this burn.

Detrended Correspondence Analysis on the macroinvertebrate data from the Control, Experimental and Allt Riabhach na Bioraich Burns confirmed their suitability for Principal Components Analysis. Statistical results for the macroinvertebrates can be found in Table 2. Similar to the diatom data, variance explained by time is small relative to variance on the Principal Component, while significance tests suggest that there are no time trends at any of the three sites.

Table 2 Macroinvertebrate Trend Test Statistics

	λ_1^{PCA}	λ_1^{RDA}	$\lambda_1^{RDA}/\lambda_1^{PCA}$	Restricted P Value
Control Burn	0.39	0.17	0.44	0.43
Experimental Burn	0.34	0.20	0.60	0.36
Allt Riabhach na Bioraich Burn	0.50	0.26	0.52	0.39

4.2.3 Aquatic Macrophytes

Aquatic macrophyte data for the three study burns is summarized in Table 6. No major changes in assemblage species composition have been observed at any site, though very small amounts of *Racomitrium aciculare* were recorded in the Allt Riabhach na Bioraich Burn more recently. This species tends to colonise rocks above normal water level and these records are likely to result from elevated flow conditions at the time of sampling, effectively increasing the area of survey. The Experimental burn continues to show significantly greater aquatic macrophyte cover than the other two burns and is the only one regularly to host *Juncus bulbosus* var. *fluitans*. The Control Burn consistently displays lesser amounts of cover and the Allt Riabhach na Bioraich Burn has least of all.

4.2.4 Fish

Fish population data are presented in Table 7.and Figures 6.1, 6.2 and 6.3, which show that trout spawning and recruitment continues in all three burns studied. With the exception of older classed fish in the Experimental burn, densities for the year 2000 were generally low. However sampling was hampered by the exceptionally high flow conditions that followed a prolonged period of high rainfall. There has been an apparent gradual rise in the density of more mature fish since 1995 in the Experimental burn though this has merely brought levels back to those at the start of the study. No discernable longer-term trends are apparent in any of the burns, with the 1998 and 1999 densities for all burns and fish ages falling well within the previously recorded limits.

5. Discussion

With the monitoring of the Loch Laidon burns now in its ninth year, there is still no evidence that grazing has had any chemical or biological effect on the experimental burn Although the testing of any grazing effect hypothesis has been hampered by the fact that chemical monitoring of the Experimental burn did not begin before cattle were introduced to the catchment, comparisons with data from the Control site suggest there has been no stream response to the change in management. This conclusion is corroborated by the most recent statistics performed on biological data from the Experimental burn. These show no evidence of time trends or any other temporal pattern in indices.

The data continue to show that the Allt Riabhach na Bioraich Burn is better matched to the Control burn than the current Experimental Burn and this re-emphasises the point made in the previous report, that the Allt Riabhach na Bioraich Burn is better suited than the latter as the experimental pair for the Control. Physically, the two burn's sampling stretches have relatively similar channel and catchment characteristics. Hydrologically, neither would appear subject to the summer base flow conditions found in the current Experimental burn. Unsurprisingly therefore, the two are chemically well matched, both with respect to seasonality and in the amplitudes of measured determinands. These two streams are also more comparable biologically, especially as regards aquatic macroinvertebrates and aquatic macrophytes.

It is intended that the fencing on the eastern edge of the experimental enclosure will be moved further east, to enclose the lower reaches of the Allt Riabhach na Bioraich Burn, in a few months time. Part of the Allt Riabhach na Bioraich catchment will therefore fall under the grazing regime to become a second experimental burn. With closer physical characteristics to the Control, impacts of trampling and manuring may be more evident. However, as topographic constraints will prevent enclosure of the entire Allt Riabhach na Bioraich catchment it is less likely that the chemistry of this new site will be any more sensitive to cattle induced effects on soil condition. In addition to chemical and biological monitoring of the Allt Riabhach na Bioraich we have also instigated a monitoring programme for aquatic macrophytes and littoral zooplankton within the shallow bay where the burn enters Loch Laidon. Baseline biological data were gathered during 2000. Aquatic macrophyte transects have been established and zooplankton samples have been collected by the Freshwater Fisheries Laboratory. Zooplankton samples are as yet unanalysed and await the continuation of further research.

The nine years of chemical and biological data accumulated so far on the Loch Laidon Project provide an important and unique freshwater record for an area of Scotland that has been under-represented by monitoring programmes over the last few years. Our analysis provides a very clear indication that the cattle grazing regime has had no significant effect on the chemistry and biology of the Experimental Burn. Doubts remain however over the sensitivity of this burn to grazing impacts and it is to this end that the project is to incorporate a second, physically more appropriate catchment. Meanwhile, the chemical datasets from the individual burns provide an intriguing record of spatial consistency but also demonstrate the importance of catchment specific hydrological factors in determining differences in seasonal behaviour. The biological datasets indicate strong persistence between years in the flora and fauna of the sites, while synchronous between year variation in several of the applied biological indices demonstrates that the biota of all sites are sensitive to common (possibly climatic) influences. It is a particular strength of the Laidon stream data-set that sampling protocols are consistent with those of the UK government funded Acid Waters Monitoring Network (UKAWMN, see Monteith *et al*, 2000, http://www.geog.ucl.ac.uk/ukawmn) which has been in operation since 1988. Increasingly, it should be possible to compare chemical and biological changes in the grazed catchments not only with the Control site but also with other Scottish stream sites from the UKAWMN, enhancing the sensitivity of our investigation. Conversely, data from the Control site would be of great value in improving the regional coverage of remote freshwater chemistry and biology in the UKAWMN.

6. Acknowledgements

This work is funded by the Rannoch Trust and Scottish Natural Heritage. Special thanks must go to Nicholas Thexton for the collection of water samples and Gavin Simpson for statistical assistance.

7. References

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Figure I: The Loch Laidon catchment indicating the boundaries of Rannoch Moor NNR and SSSI

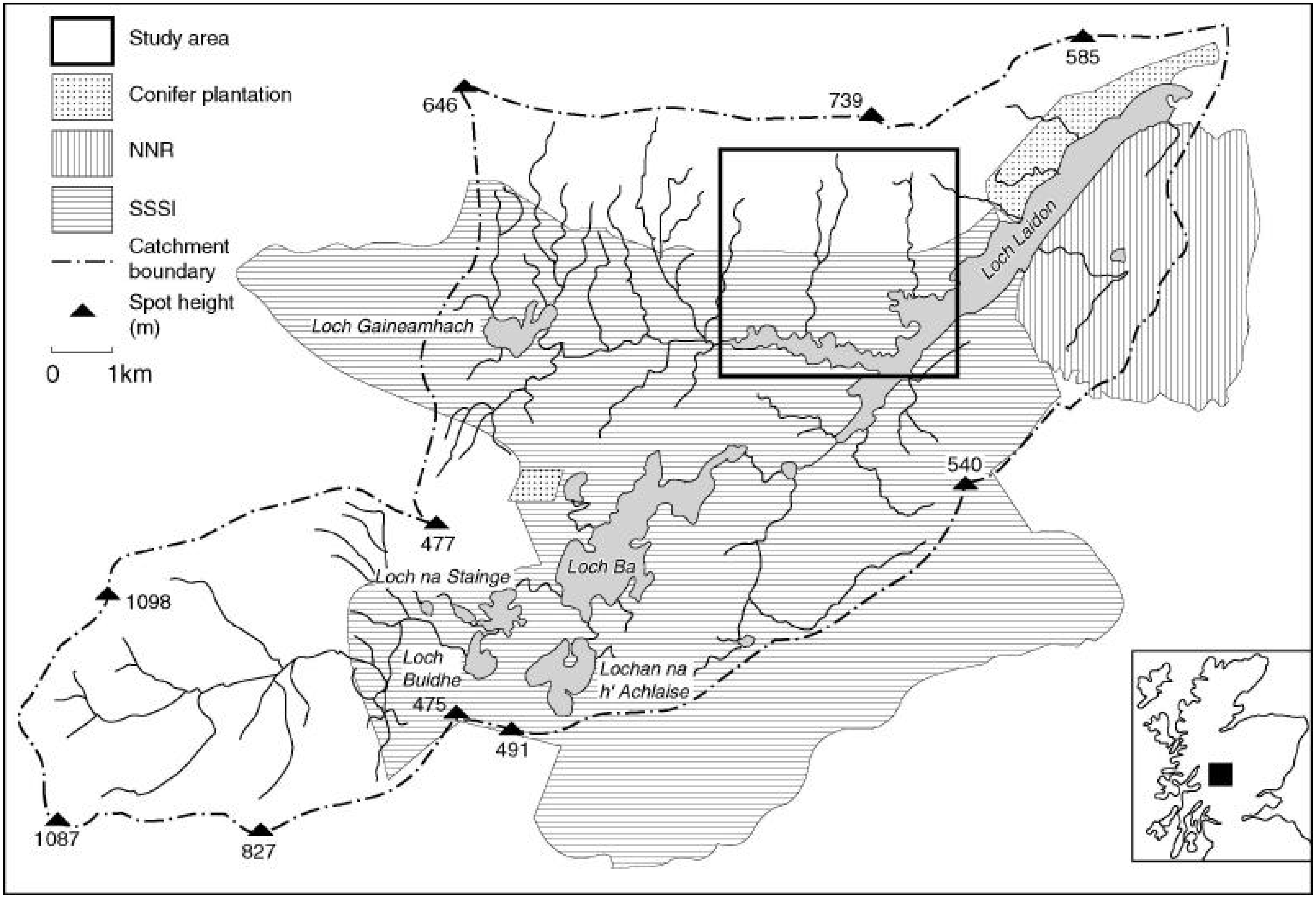

Figure 2: Loch Laidon study area

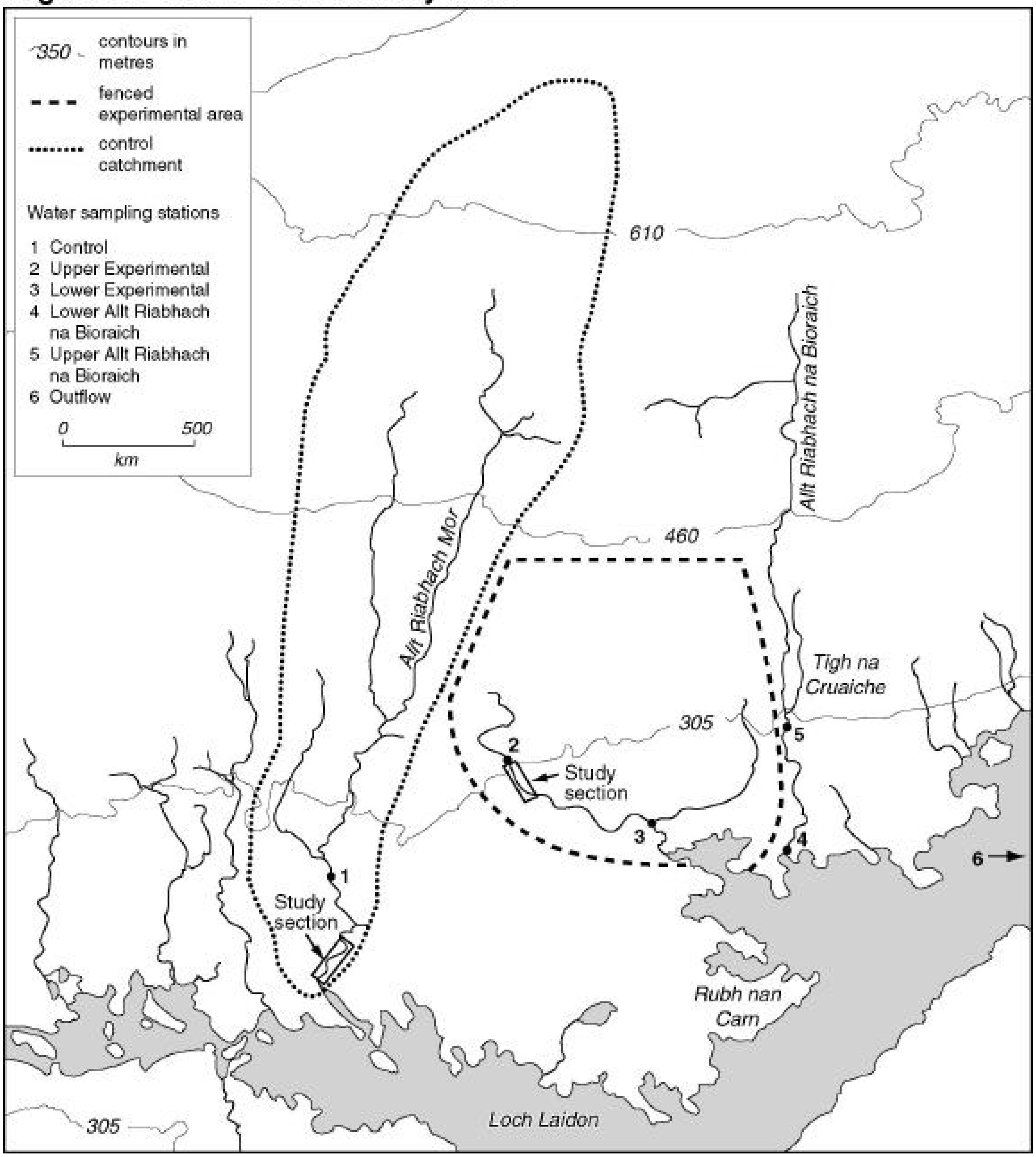

Figure 3.1 The ratio of alkalinity and its temporal variability in spot samples from the Experimental and Control burns, August 1992 – October 2000.

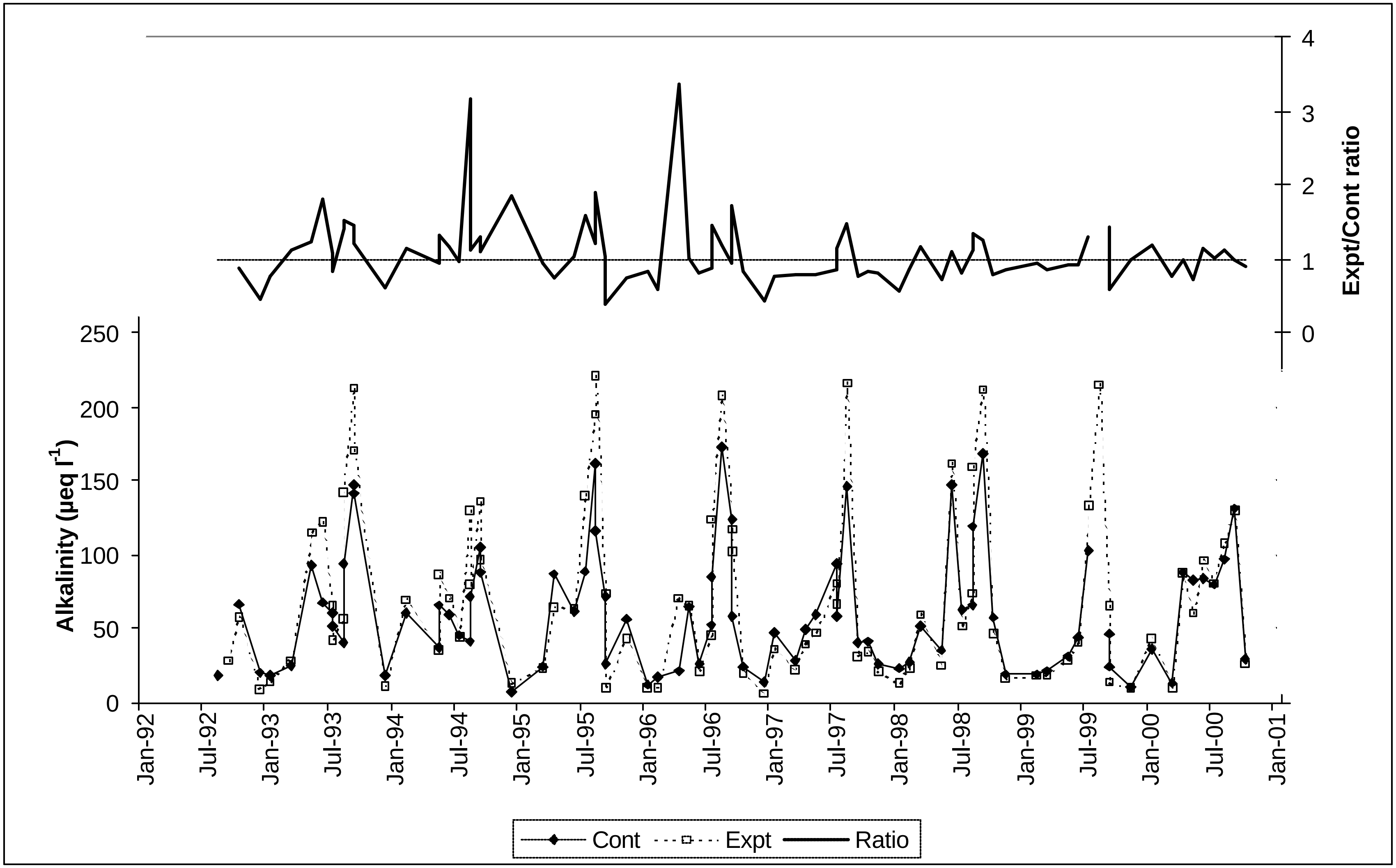

Figure 3.2 The ratio of conductivity and its temporal variability in spot samples from the Experimental and Control burns, August 1992 – October 2000.

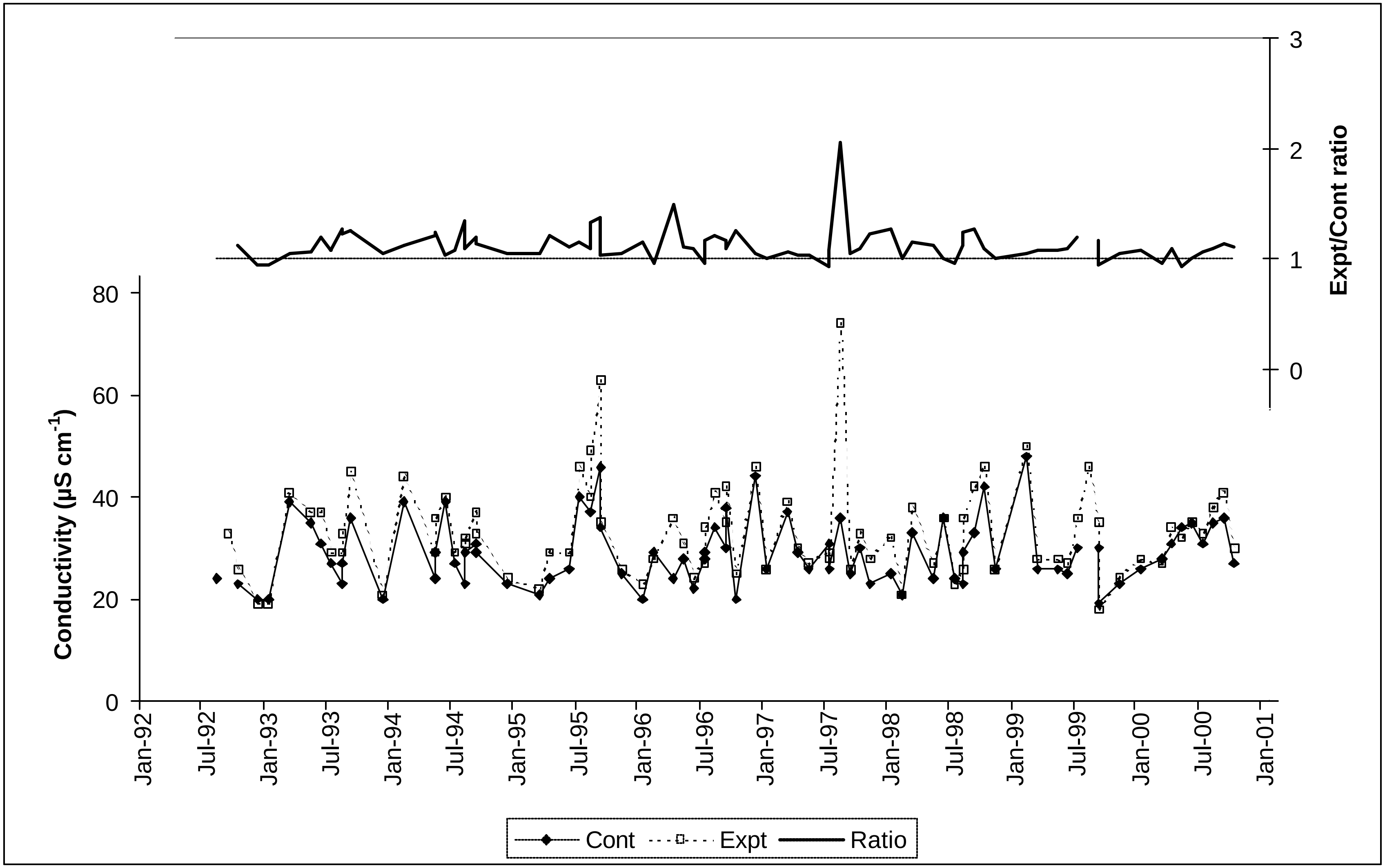

Figure 3.3 Temporal variability of nitrate in spot samples from the Experimental and Control Burns, August 1992- October 2000

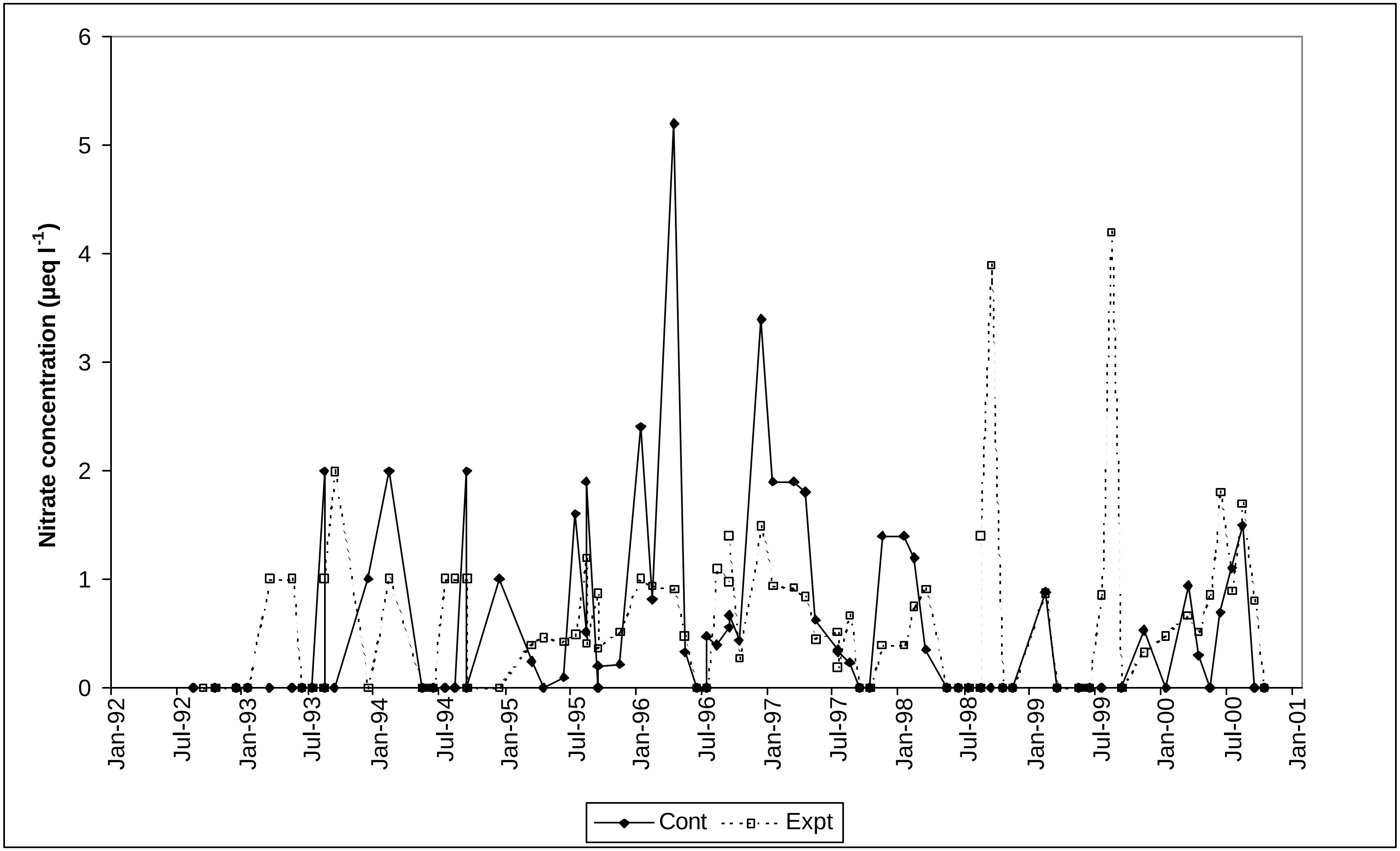

Figure 3.4 The relationship between the ratio of alkalinity in spot samples from the Experimental and Control burns and the stage board height of the Control burn over the period August 1992 – October 2000.

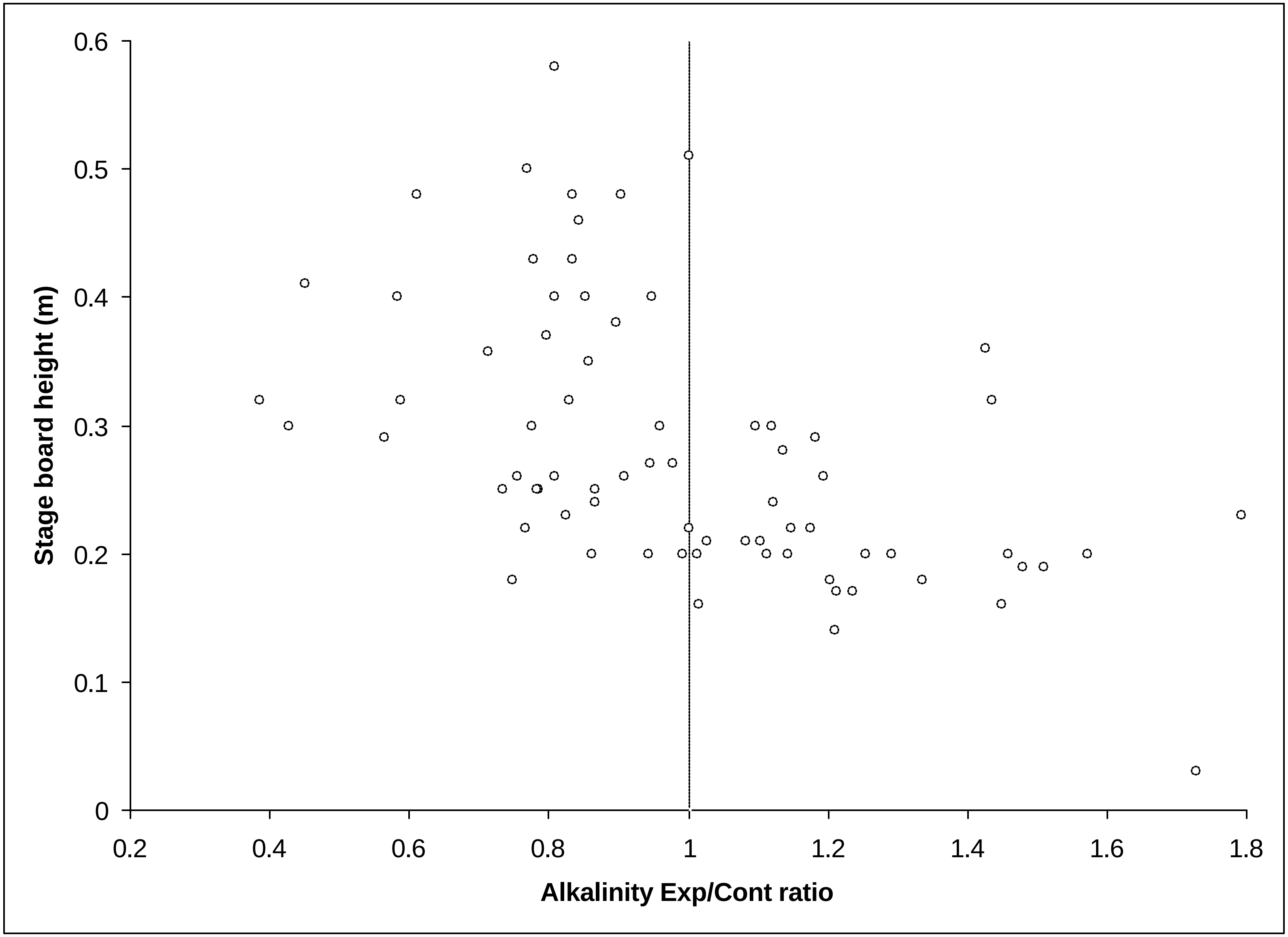

Figure 3.5 Comparison of the nitrate concentration of the Control and Experimental Burn (Lower site) June 1995 – October 2000.

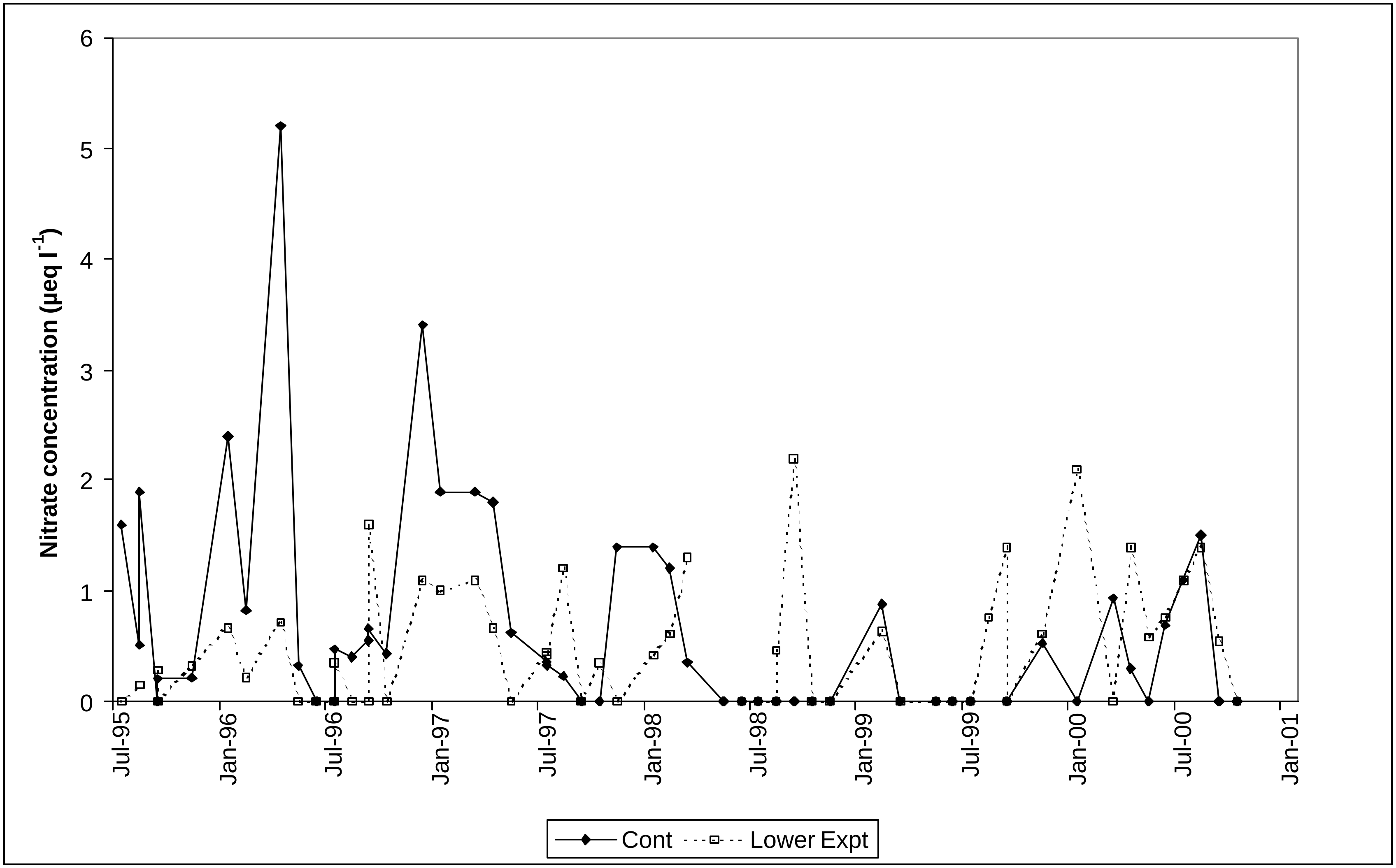

Figure 3.6 The ratio of alkalinity and its temporal variability in spot samples from the Control and Experimental Burn (Lower site) June 1995 – October 2000.

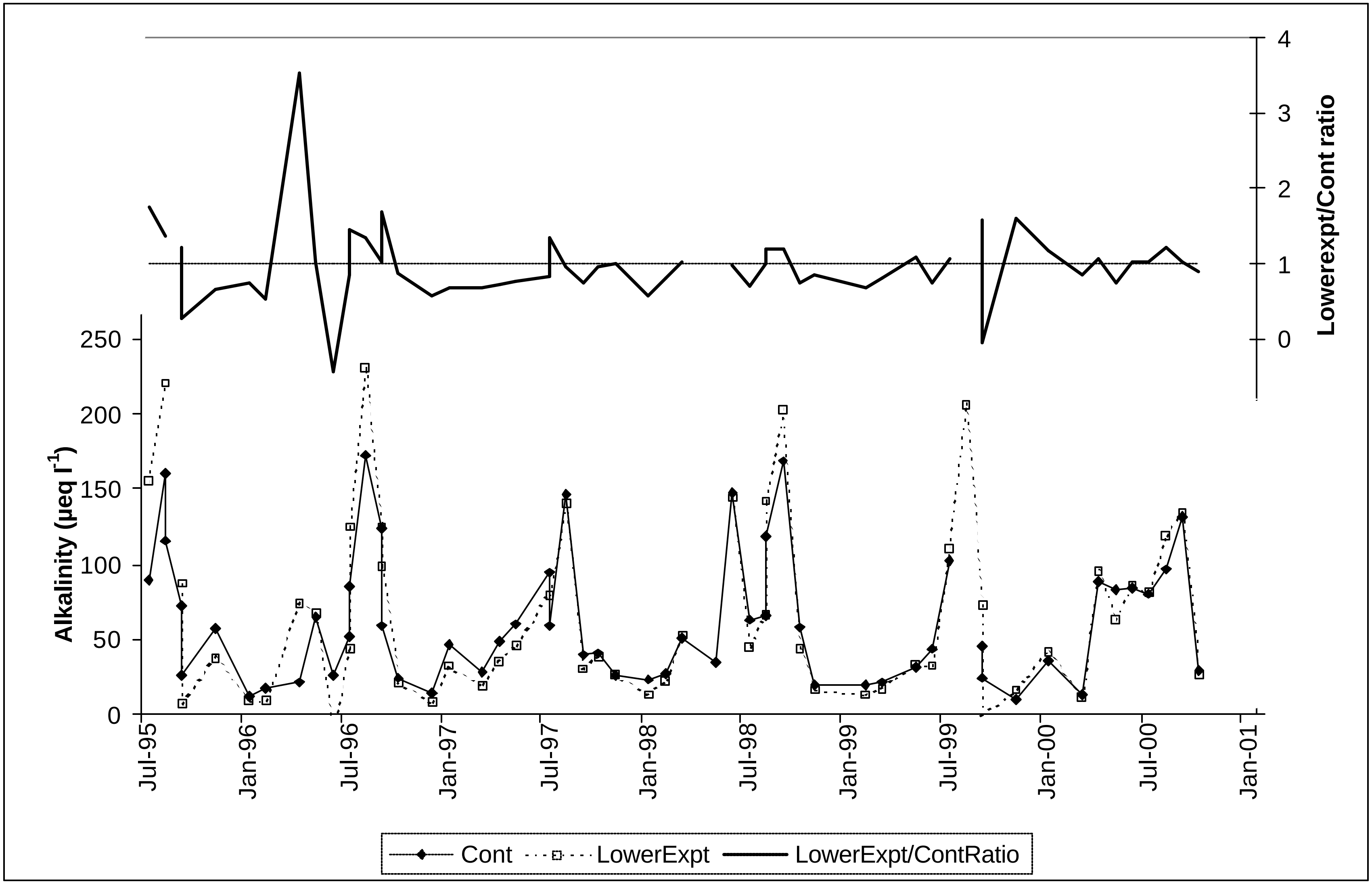

Figure 3.7 The ratio of conductivity and its temporal variability in spot samples from the Control and Experimental burn (Lower site) June 1995 – October 2000.

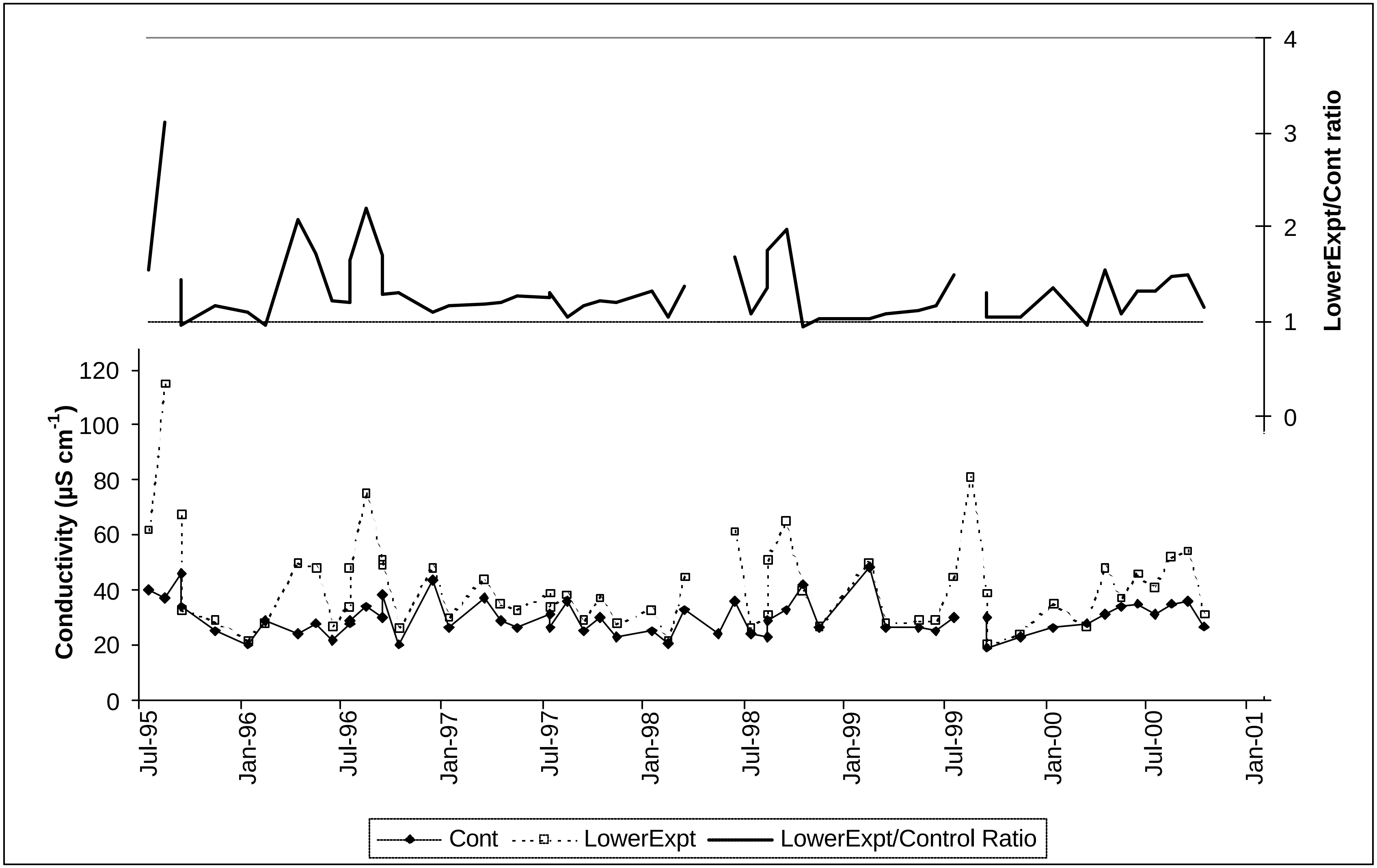

Figure 3.8 A comparison of alkalinity in spot samples from the Control burn, Experimental burn (Lower site) and the Allt Riabhach na Bioraich, June 1995 – October 2000.

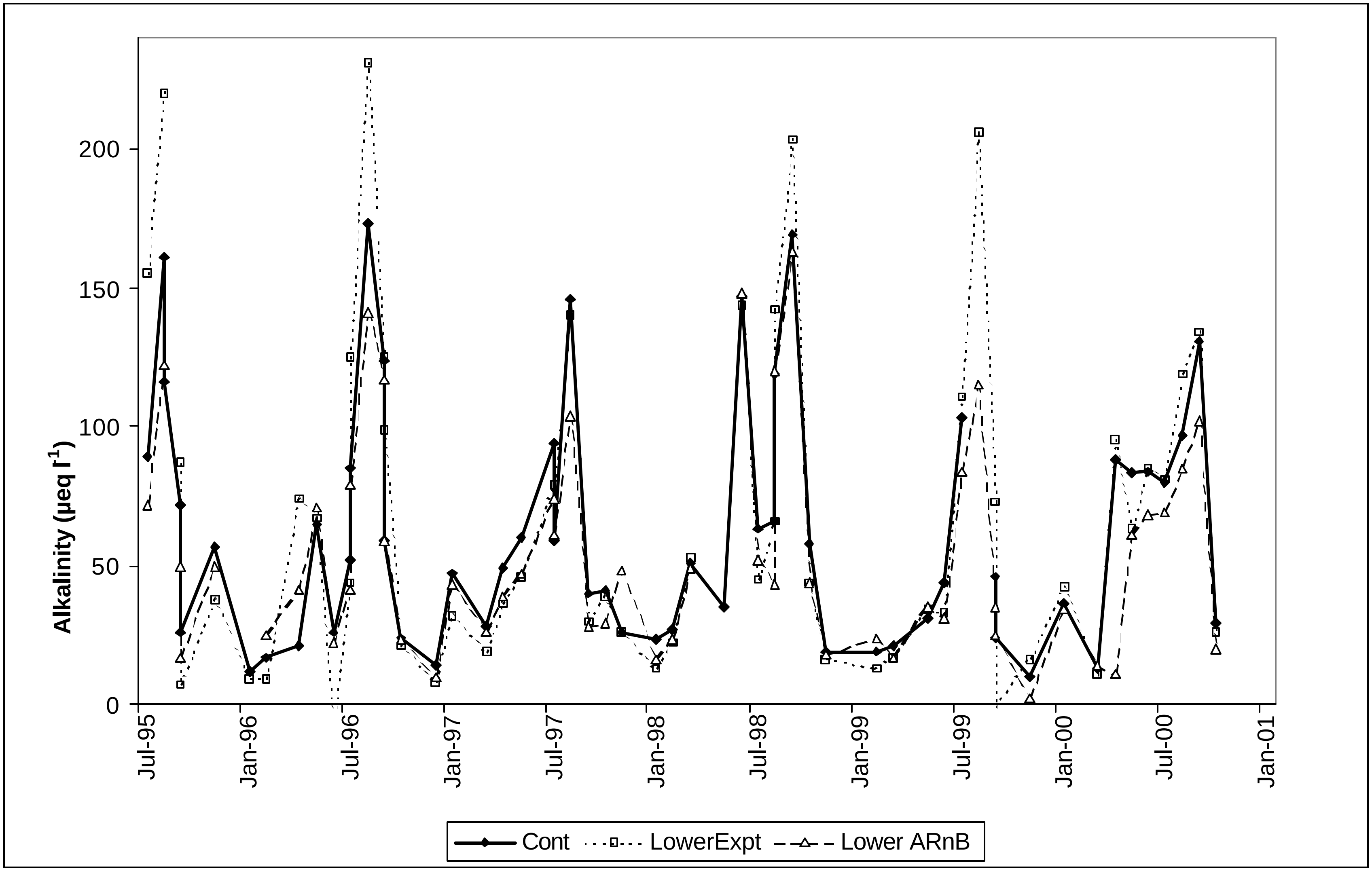

Figure 3.9 A comparison of conductivity of spot samples from the Control burn, Experimental burn (Lower site) and the Allt Riabhach na Bioraich, June 1995 – October 2000.

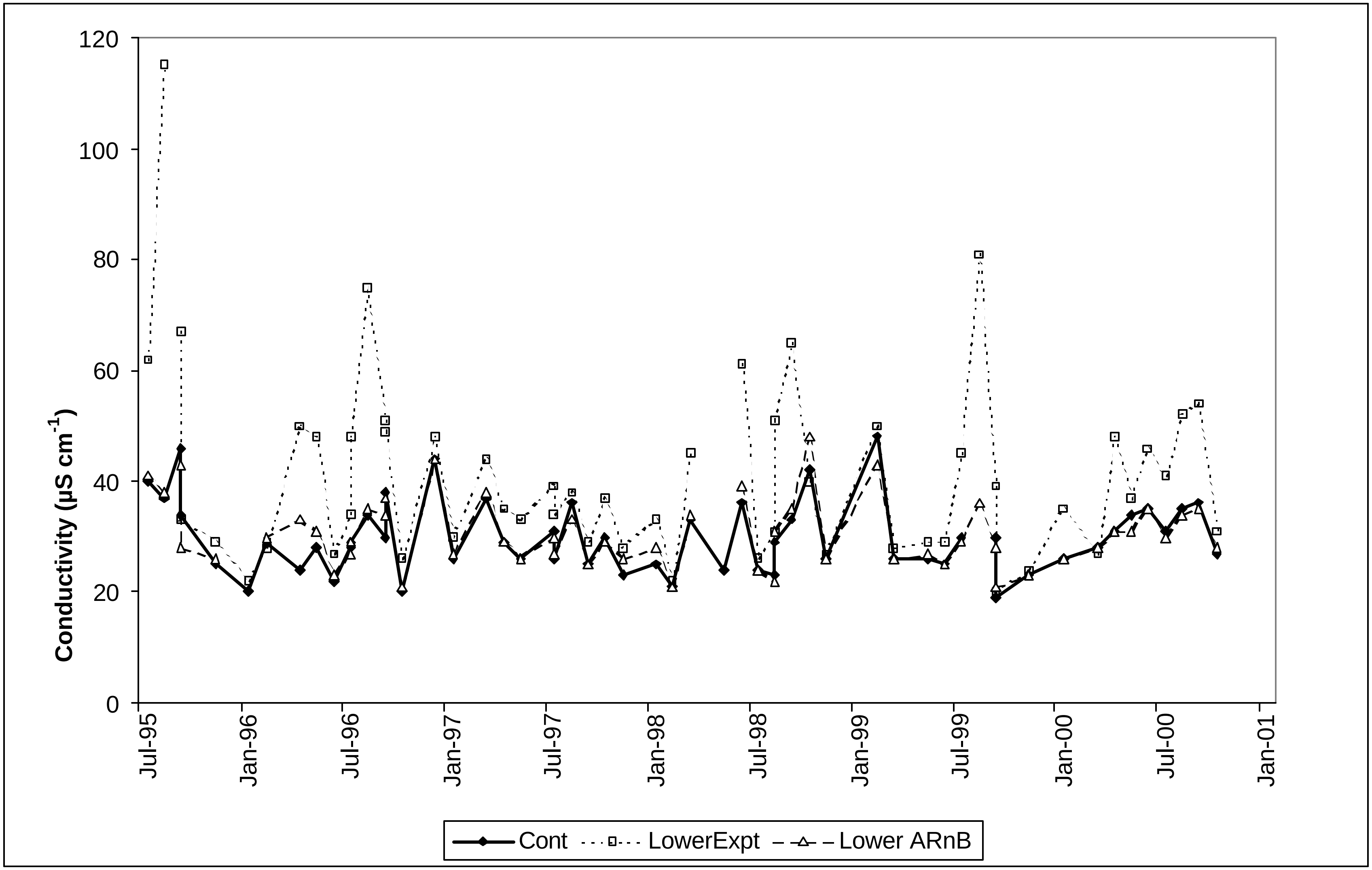

Figure 3.10 A comparison of nitrate concentrations of spot samples from the Control burn, Experimental burn (Lower site) and the Allt Riabhach na Bioraich, June 1995 – October 2000.

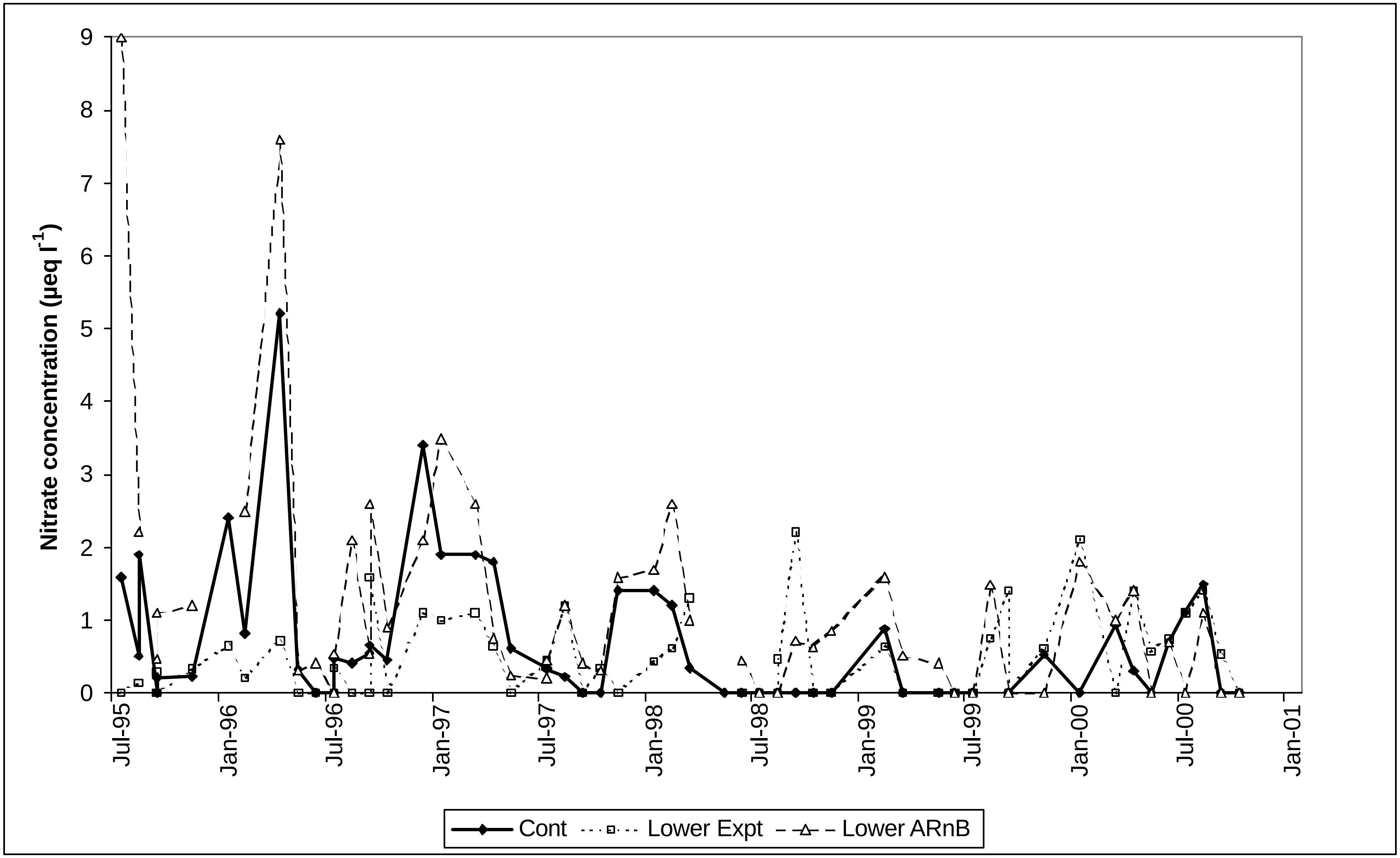

Figure 3.11 A comparison of Total Organic Carbon concentrations of spot samples from the Control burn, Experimental burn (Lower site) and the Allt Riabhach na Bioraich, June 1995 – October 2000.

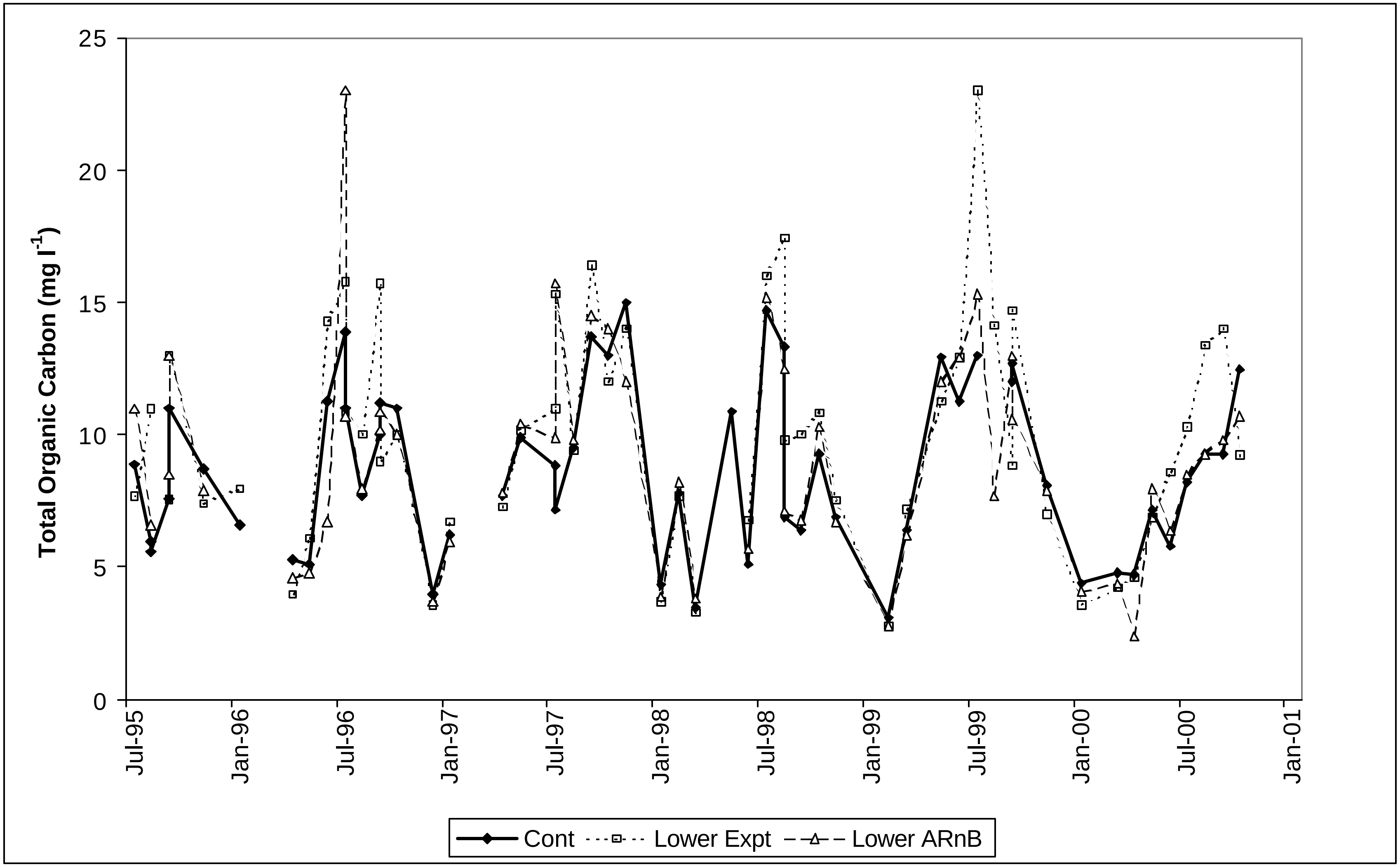

Table 3 Summary statistics of selected chemical determinands for individual years at the Control, Experimental (Upper and Lower) and Allt Riabhach na Bioraich (ARnB Upper and Lower)

Site Name	Year	pH			Alkalinity (µeq l^{-1})			Conductivity (µS cm^{-1})			Nitrate (µeq l^{-1})			Sulphate (µeq l^{-1})			Total phosphorous (µg l^{-1})			Labile Aluminium (µeq l^{-1})		
		mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max
CONTROL	1992	5.87	5.44	6.46	35.0	18.0	67.0	22.3	20.0	24.0	0.0	0.0	0.0	26.3	25.0	28.0				8.0	2.0	18.0
CONTROL	1993	6.23	5.59	6.91	68.7	18.0	147.0	29.2	20.0	39.0	0.3	0.0	2.0	28.1	11.0	44.0	22.5	19.0	26.0	6.3	0.0	29.0
CONTROL	1994	6.22	5.18	6.68	58.2	7.0	105.0	29.3	23.0	39.0	0.5	0.0	2.0	33.9	23.0	85.0	18.9	2.5	58.0	4.4	0.0	17.0
CONTROL	1995	6.42	5.72	7.02	77.1	24.0	161.0	32.2	21.0	46.0	0.5	0.0	1.9	62.0	18.0	175.0	3.1	2.5	6.0	4.6	0.0	28.0
CONTROL	1996	6.03	5.39	6.9	56.0	12.0	173.0	28.8	20.0	44.0	1.2	0.0	5.2	40.5	18.0	62.0	3.3	2.5	10.0	3.8	0.0	10.0
CONTROL	1997	6.32	5.65	6.94	59.0	26.0	146.0	28.9	23.0	37.0	0.9	0.0	1.9	25.9	13.0	43.0	2.9	2.5	6.0	5.3	0.0	10.0
CONTROL	1998	6.19	5.61	6.82	68.0	19.0	169.0	26.8	21.0	36.0	0.3	0.0	1.4	22.3	13.0	35.0	3.3	2.5	11.0	4.9	0.0	16.0
CONTROL	1999	5.86	5.29	6.53	37.3	10.0	103.0	28.4	19.0	48.0	0.2	0.0	0.9	25.4	10.0	54.0	5.0	2.5	6.0	4.0	2.0	7.0
CONTROL	2000	6.34	5.46	6.75	71.2	13.0	131.0	31.4	26.0	36.0	0.5	0.0	1.5	29.1	16.0	59.0	2.9	2.5	6.0	5.6	0.0	13.0
UPPEREXPT	1992	5.71	5.23	6.19	31.7	9.0	58.0	26.0	19.0	33.0	0.0	0.0	0.0	43.7	23.0	82.0				0.3	0.0	1.0
UPPEREXPT	1993	6.04	5.29	6.6	89.2	11.0	213.0	33.2	19.0	45.0	0.6	0.0	2.0	24.2	8.0	45.0	20.5	19.0	22.0	2.7	0.0	9.0
UPPEREXPT	1994	6.19	5.47	6.78	76.3	13.0	136.0	33.5	24.0	44.0	0.5	0.0	1.0	26.8	13.0	51.0	18.9	0.0	60.0	2.9	0.0	7.0
UPPEREXPT	1995	6.14	5.21	6.81	92.8	10.0	221.0	37.7	22.0	63.0	0.6	0.4	1.2	74.2	13.0	302.0	3.0	2.5	6.0	2.6	0.0	7.0
UPPEREXPT	1996	5.86	5.16	6.75	66.7	6.0	208.0	32.7	23.0	46.0	0.7	0.0	1.5	37.4	16.0	75.0	2.6	2.5	3.0	4.0	0.0	13.0
UPPEREXPT	1997	5.90	5.46	6.5	59.4	21.0	216.0	34.0	26.0	74.0	0.5	0.0	0.9	42.0	9.0	233.0	2.5	2.5	2.5	2.3	0.0	10.0
UPPEREXPT	1998	5.92	5.44	6.46	74.3	13.0	212.0	30.0	21.0	42.0	0.7	0.0	3.9	18.6	9.0	29.0	2.8	2.5	6.0	1.9	0.0	5.0
UPPEREXPT	1999	5.79	5.29	6.49	60.2	10.0	215.0	32.4	18.0	50.0	0.7	0.0	4.2	21.1	7.0	46.0	4.7	2.5	6.0	3.1	0.0	10.0
UPPEREXPT	2000	6.10	5.33	6.43	71.4	10.0	130.0	33.1	27.0	41.0	0.9	0.0	1.8	21.3	10.0	32.0	4.1	2.5	6.0	4.9	0.0	9.0
LOWEREXPT	1995	6.13	5.13	6.77	101.4	7.0	220.0	61.2	29.0	115.0	0.2	0.0	0.3	291.2	55.0	749.0	5.3	2.5	11.0	1.8	0.0	4.0
LOWEREXPT	1996	5.82	4.98	6.67	66.8	-11.0	231.0	42.2	22.0	75.0	0.4	0.0	1.6	105.1	21.0	278.0	3.1	2.5	6.0	4.6	0.0	12.0
LOWEREXPT	1997	5.91	5.54	6.67	52.6	19.0	140.0	34.7	28.0	44.0	0.5	0.0	1.2	51.8	28.0	80.0	5.6	2.5	17.0	2.4	0.0	7.0
LOWEREXPT	1998	5.85	5.44	6.34	72.6	13.0	203.0	38.1	20.0	65.0	0.5	0.0	2.2	88.4	20.0	232.0	3.2	2.5	6.0	7.5	0.0	42.0
LOWEREXPT	1999	5.70	4.97	6.29	55.8	-1.0	206.0	38.3	20.0	81.0	0.4	0.0	1.4	67.0	10.0	312.0	5.4	2.5	8.0	4.2	0.0	9.0
LOWEREXPT	2000	6.17	5.63	6.39	72.9	11.0	134.0	41.2	27.0	54.0	0.9	0.0	2.1	82.3	18.0	128.0	4.1	2.5	6.0	4.1	0.0	13.0
LOWERARnB	1995	6.16	5.41	6.8	59.8	17.0	122.0	33.5	25.0	43.0	2.4	0.5	9.0	84.2	26.0	156.0	3.4	2.5	6.0	3.2	0.0	8.0
LOWERARnB	1996	5.97	5.26	6.69	57.2	10.0	141.0	31.3	21.0	44.0	1.8	0.0	7.6	46.8	22.0	88.0	2.7	2.5	4.0	7.4	1.0	29.0
LOWERARnB	1997	6.02	5.64	6.63	49.9	26.0	104.0	29.0	25.0	38.0	1.1	0.2	3.5	30.5	20.0	49.0	2.9	2.5	6.0	4.0	0.0	10.0
LOWERARnB	1998	5.95	5.46	6.52	65.4	16.0	163.0	28.4	21.0	39.0	0.8	0.0	2.6	33.2	18.0	62.0	2.5	2.5	2.5	3.2	0.0	12.0
LOWERARnB	1999	5.79	5.02	6.56	40.9	2.0	115.0	28.7	21.0	43.0	0.4	0.0	1.6	29.3	14.0	51.0	3.8	2.5	6.0	4.3	0.0	20.0
LOWERARnB	2000	6.03	5.47	6.59	51.6	11.0	102.0	30.9	26.0	35.0	0.7	0.0	1.8	33.2	20.0	47.0	4.1	2.5	6.0	6.1	2.0	15.0
UPPERARnB	1995	6.19	5.56	6.59	50.0	19.0	86.0	30.8	23.0	41.0	2.7	0.0	7.7	76.8	20.0	158.0	3.4	2.5	6.0	2.3	0.0	8.0
UPPERARnB	1996	5.94	5.28	6.67	44.3	9.0	114.0	28.4	20.0	43.0	1.7	0.0	7.4	42.6	21.0	82.0	2.8	2.5	4.0	5.0	1.0	11.0
UPPERARnB	1997	6.05	5.63	6.51	55.0	17.0	202.0	29.4	24.0	46.0	1.2	0.0	3.8	25.6	17.0	44.0	2.9	2.5	6.0	7.3	0.0	28.0
UPPERARnB	1998	6.02	5.54	6.68	50.5	16.0	130.0	25.3	20.0	32.0	0.6	0.0	2.4	23.0	14.0	33.0	3.1	2.5	6.0	6.8	0.0	27.0
UPPERARnB	1999	5.82	5.22	6.46	34.4	8.0	90.0	27.9	19.0	45.0	0.4	0.0	1.6	24.8	15.0	39.0	4.1	1.0	10.0	3.7	0.0	13.0
UPPERARnB	2000	6.15	5.54	6.51	47.8	14.0	85.0	29.0	25.0	32.0	0.7	0.0	1.8	27.4	17.0	46.0	4.1	2.5	6.0	2.4	0.0	6.0

Figure 4.1 Control Burn Diatom Abundances

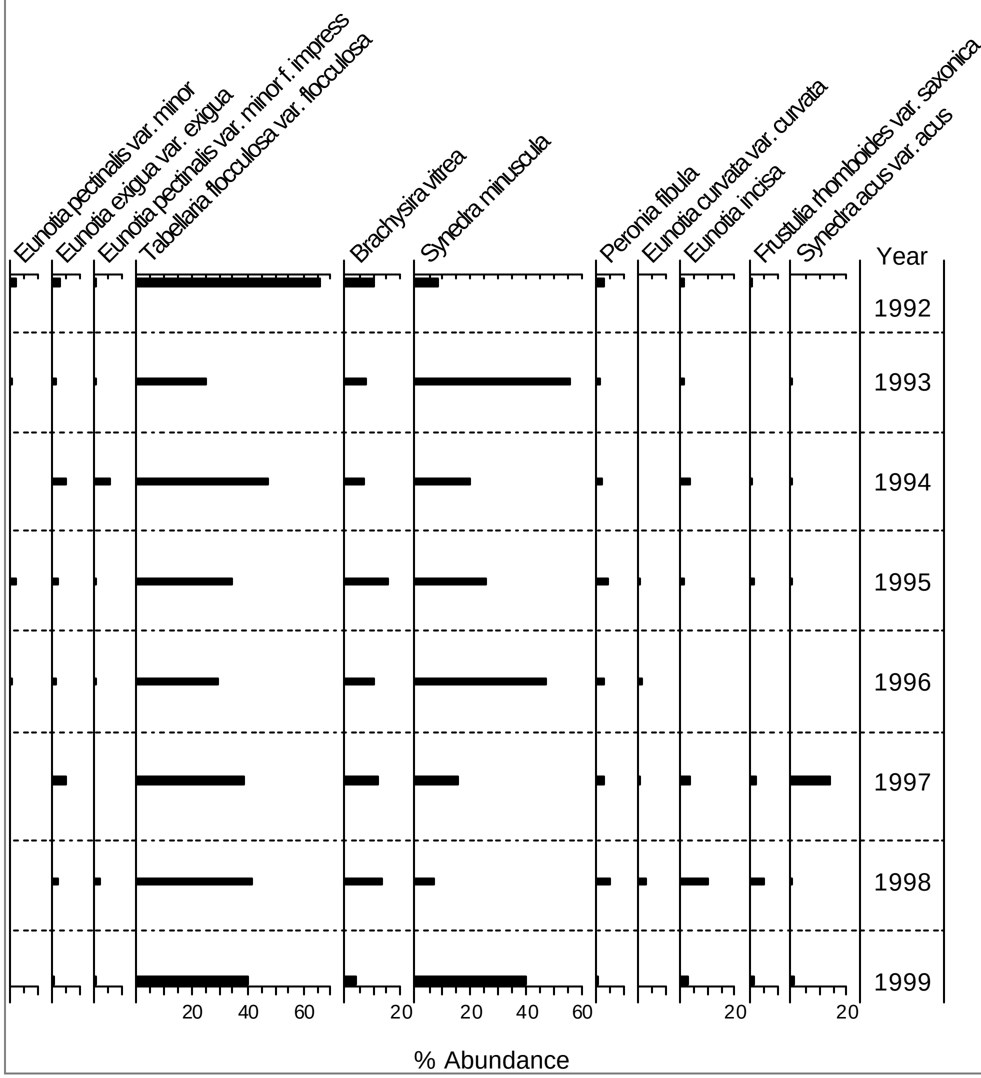

Figure 4.2 Experimental Burn Diatom Abundances

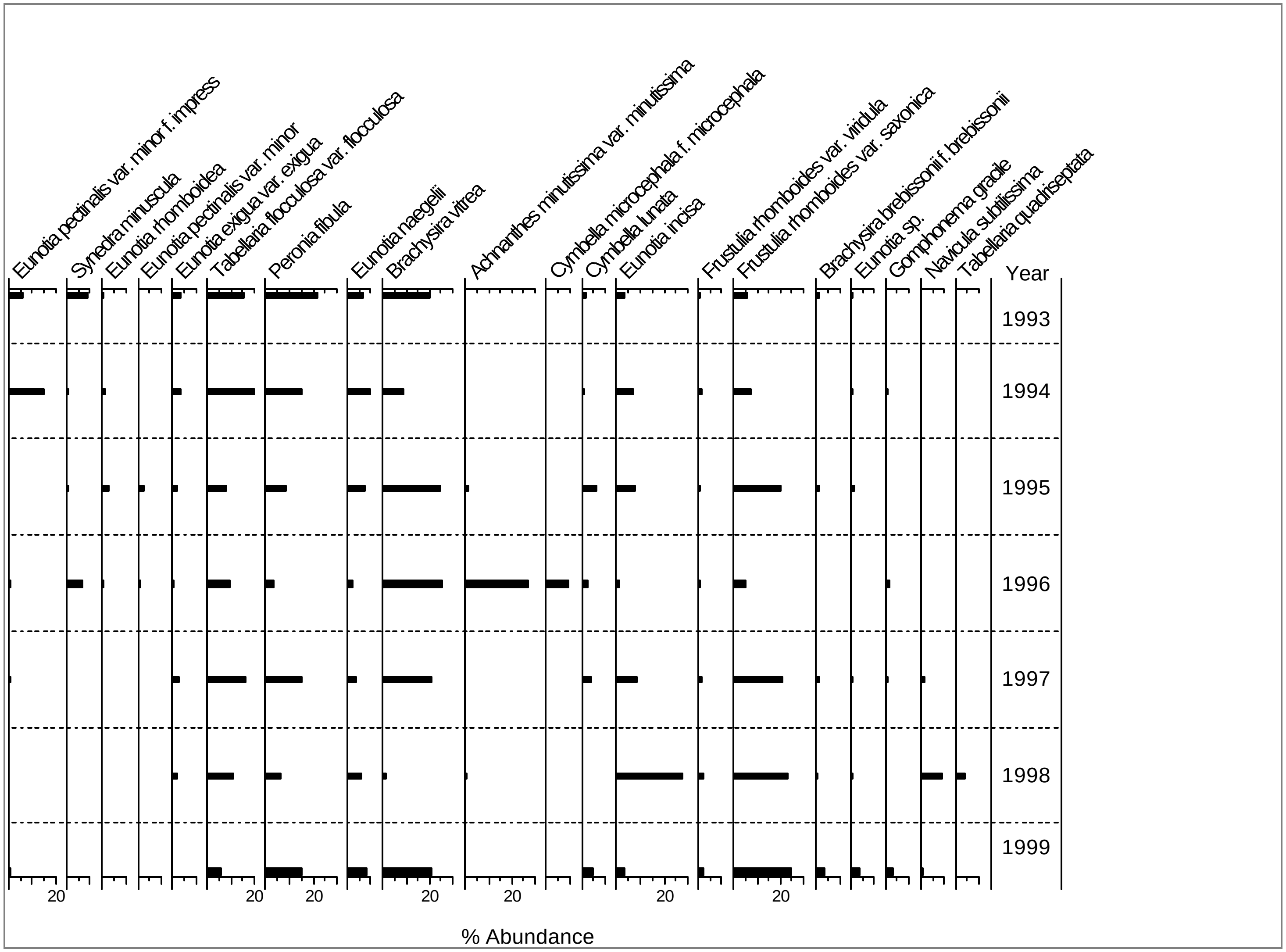

Figure 4.3 Allt Riabhach na Bioraich Diatom Abundances

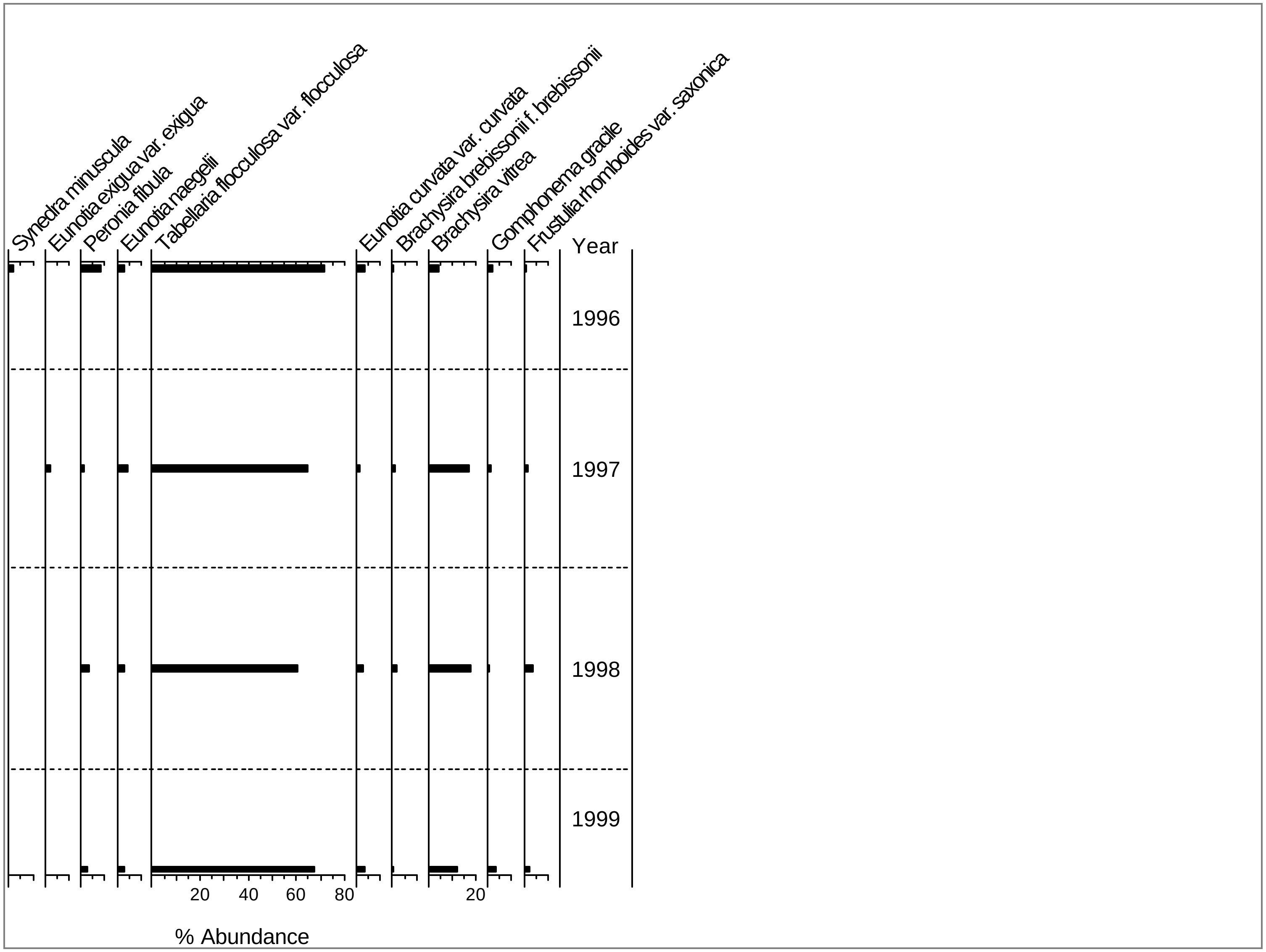

Figure 5.1 Control Burn Macroinvertebrate Abundances

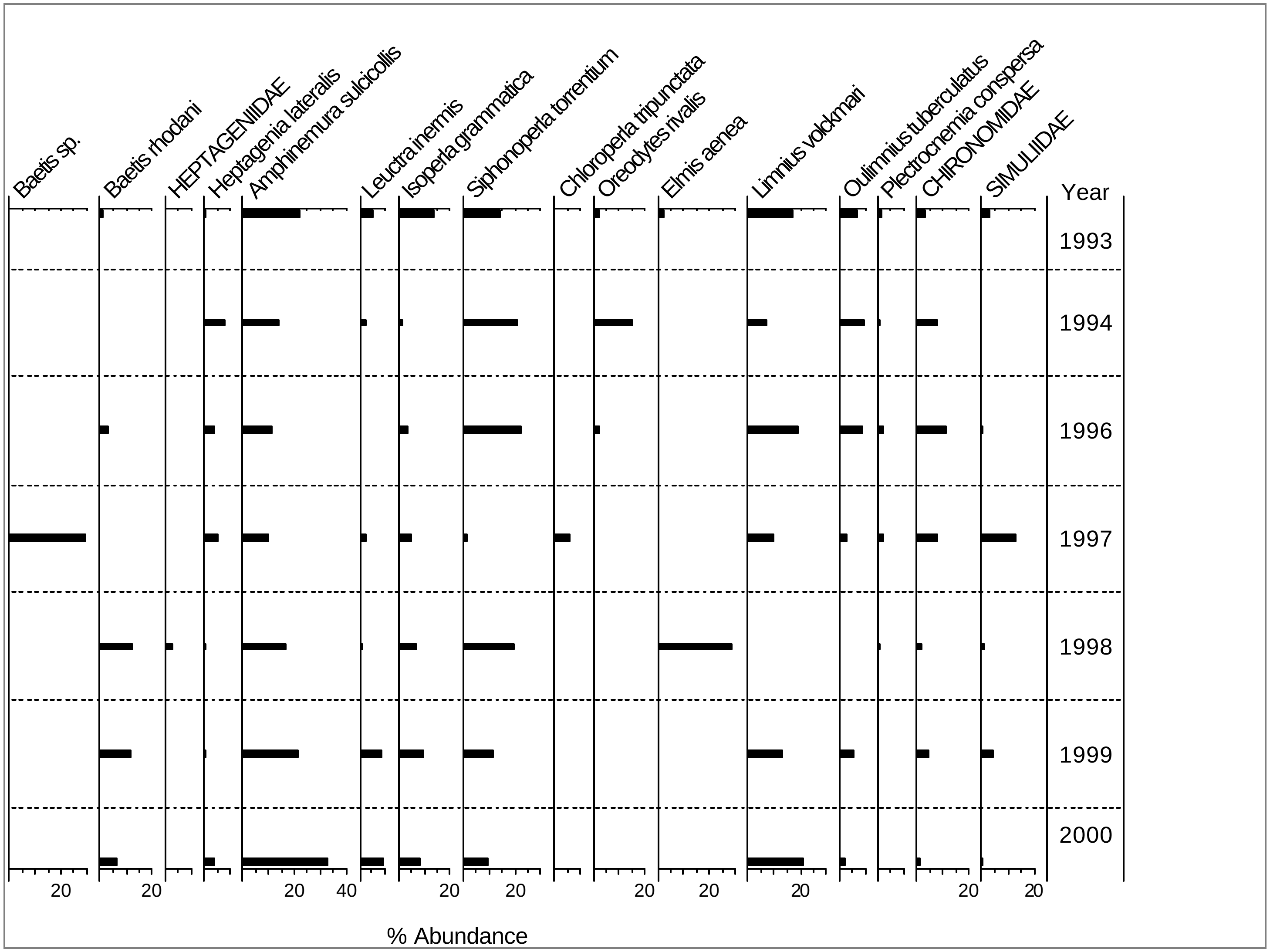

Figure 5.2 Experimental Burn Macroinvertebrate Abundances

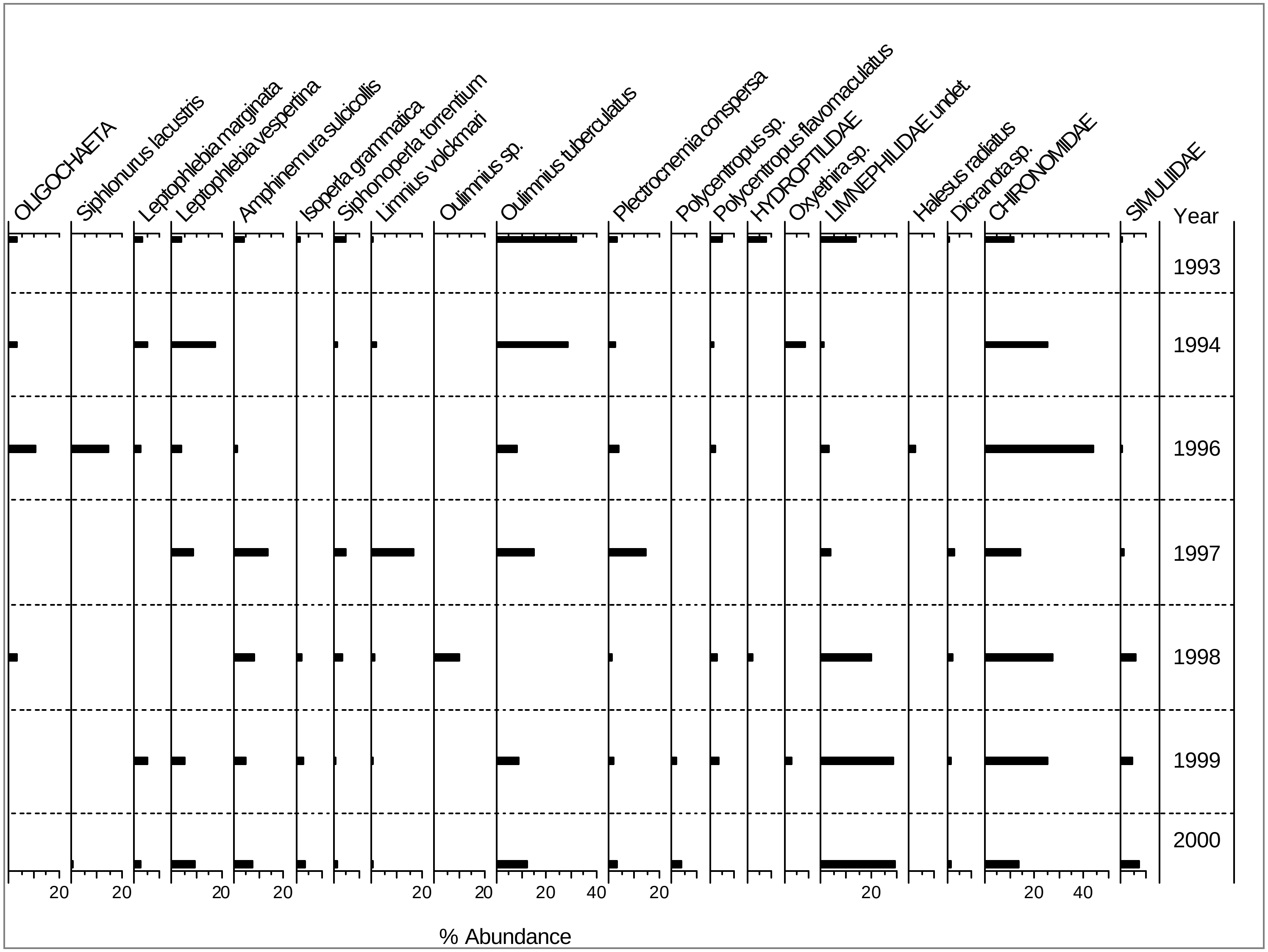

Figure 5.3 Allt Riabhach na Bioraich Burn Macroinvertebrate Abundances

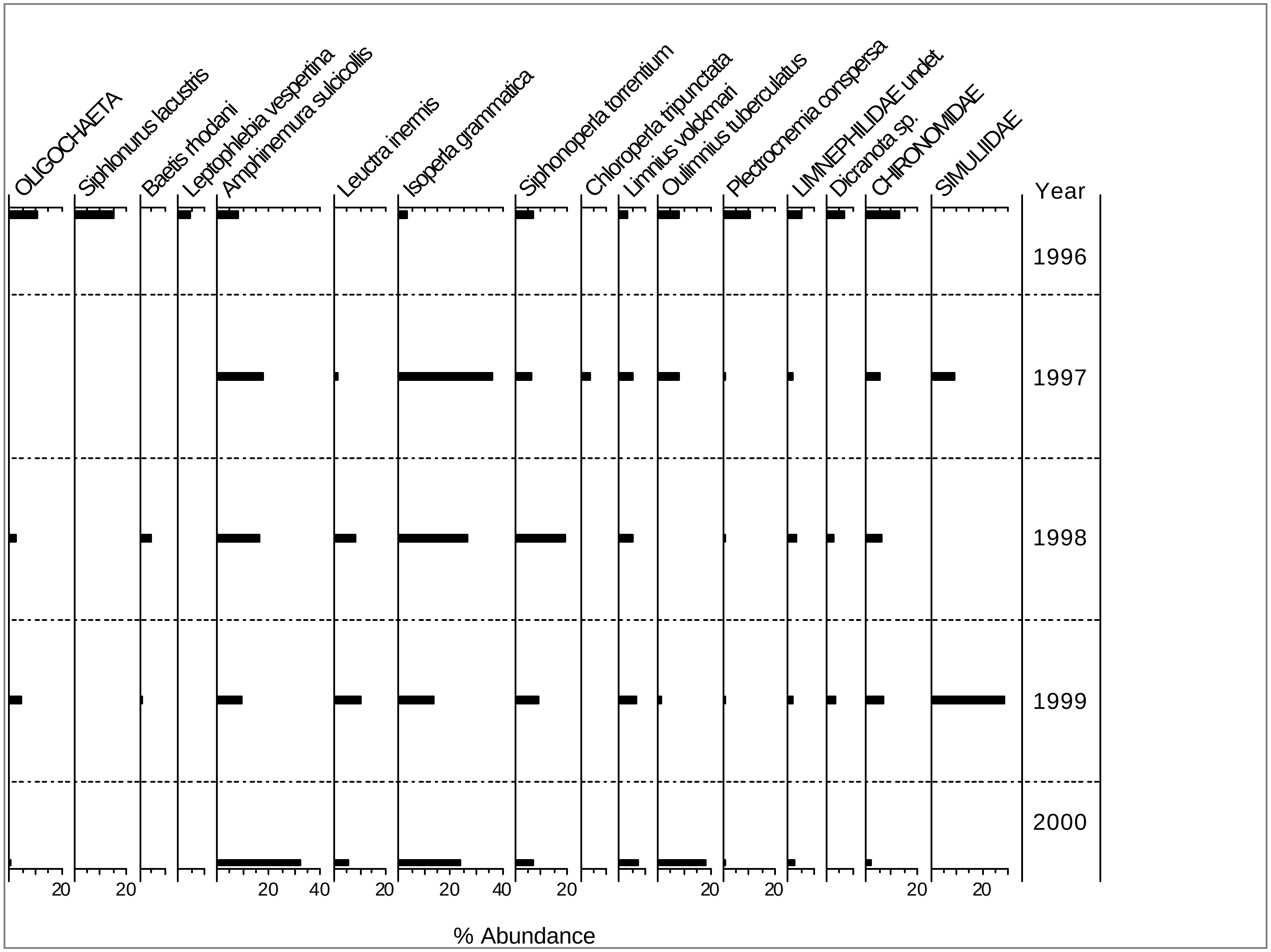

Table 4 Macroinvertebrate taxon list and total abundances.

TAXON	CONTROL BURN 1993	1994	1996	1997	1998	1999	2000	EXPERIMENTAL BURN 1993	1994	1996	1997	1998	1999	2000	ARnB BURN 1996	1997	1998	1999	2000
NEMATODA			1					2		1	1				1				
Pisidium sp.									1										
OLIGOCHAETA	22	6	8	3	5	2	1	14	10	26		3			12		5	12	1
HYDRACARINA						1						1							
COLLEMBOLA												1							
Siphlonurus lacustris										35				1	17				
Ameletus inopinatus	11	4			1	1	3												
Baetis sp.				52					1										
Baetis rhodani	5		7		39	30	20				1	1	1				8	4	
Baetis muticus	3	2	3				1	9		3									
HEPTAGENIIDAE					9														
Heptagenia lateralis	3	18	11	9	2	3	13								2	1	2	1	2
Ecdyonurus sp.					1														
Ecdyonurus dispar				1															
Leptophlebia marginata			1			1		16	19	6			7	5					
Leptophlebia vespertina								20	61	9	9		7	15	5				
Brachyptera risi																		1	
Protonemura praecox							1												
Protonemura meyeri								1											
Amphinemura sulcicollis	168	32	27	17	52	54	103	20	1	2	14	7	7	12	9	23	28	25	99
Nemurella picteti				1							1								
Nemoura sp.														1		2			
Nemoura avicularis									2				1						
Nemoura cambrica								2		1			1					1	
LEUCTRIDAE					1														
Leuctra inermis	41	6	1	5	3	22	30	1								2	14	27	17
Leuctra hippopus		1										1		1					
Leuctra nigra								1											

TAXON	CONTROL BURN							EXPERIMENTAL BURN							ARnB BURN				
	1993	1994	1996	1997	1998	1999	2000	1993	1994	1996	1997	1998	1999	2000	1996	1997	1998	1999	2000
Perlodes microcephala	2					1													
Isoperla grammatica	106	4	8	9	20	25	25	7				2	4	6	3	46	45	36	74
Siphonoperla torrentium	109	48	54	2	61	29	30	23	5		5	3	1	2	7	8	33	24	20
Chloroperla tripunctata				11												5			
Pyrrhosoma nymphula								1	1				1						
Cordulegaster boltonii								1											
Dytiscidae undet. (larvae)									1		1				1				
Oreodytes rivalis	18	36	7	1											1				
Oreodytes sanmarkii																		1	
Agabus guttatus								1											
Platambus maculatus		1																	
Anacaena globulus										1									
HELODIDAE	1																		
Elmis aenea	17		1		88	2	1												
Limnius volckmari	129	16	46	17		34	65	2	5		17	1	1	1	3	7	9	18	22
Oulimnius sp.					3							9					1		
Oulimnius tuberculatus	55	22	21	5		14	8	151	98	19	15		12	20	9	10		4	56
Rhyacophila dorsalis	1		1	2		4	2											1	
Plectrocnemia conspersa	6	1	5	3	2			13	9	9	15	1	2	5	11	1	1	1	2
Plectrocnemia geniculata		2							1										
Polycentropus sp.						2							2	6					
Polycentropus flavomaculatus		2	3		4			23	6	6		3	5		1			3	
Hydropsyche siltalai	1				1														
HYDROPTILIDAE								38				2							
Hydroptila sp.		2								1									
Oxyethira sp.		1							29				4						
LIMNEPHILIDAE undet.	10	7	6		3	3	4	66	2	7	4	17	41	47	6	3	6	5	8
Ecclisopteryx guttulata																	1		

TAXON	CONTROL BURN							EXPERIMENTAL BURN							ARnB BURN				
	1993	1994	1996	1997	1998	1999	2000	1993	1994	1996	1997	1998	1999	2000	1996	1997	1998	1999	2000
Potamophylax rotundipennis												1							
Halesus sp.														1					
Halesus radiatus										6									
DIPTERA					2							2					1	1	
TIPULIDAE	2	1						1			1								
Dicranota sp.	8	2	3	3	1	5	1	6	2	1	3	2	2	3	7		5	9	
Psychodidae	1																		
CHIRONOMIDAE	26	17	28	13	6	11	4	56	86	104	15	24	36	22	14	7	10	18	6
SIMULIIDAE	23		1	23	3	11	1	2		1	1	5	6	11		12	1	76	1
Simulium latipes									3										
EMPIDIDAE						2						2	1						
Clinocera sp.														1					

Figure 5.4 Selected Control Burn Macroinvertebrate Summary Statistics

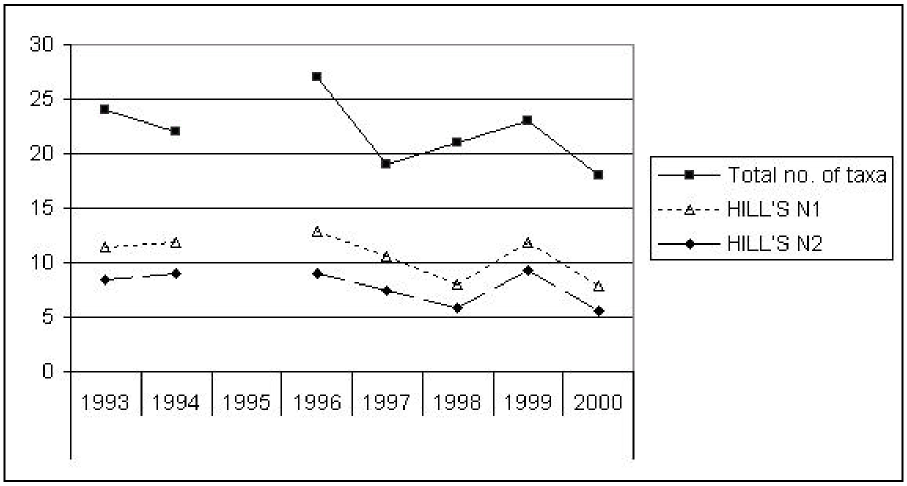

Figure 5.5 Selected Experimental Burn Macroinvertebrate Summary Statistics

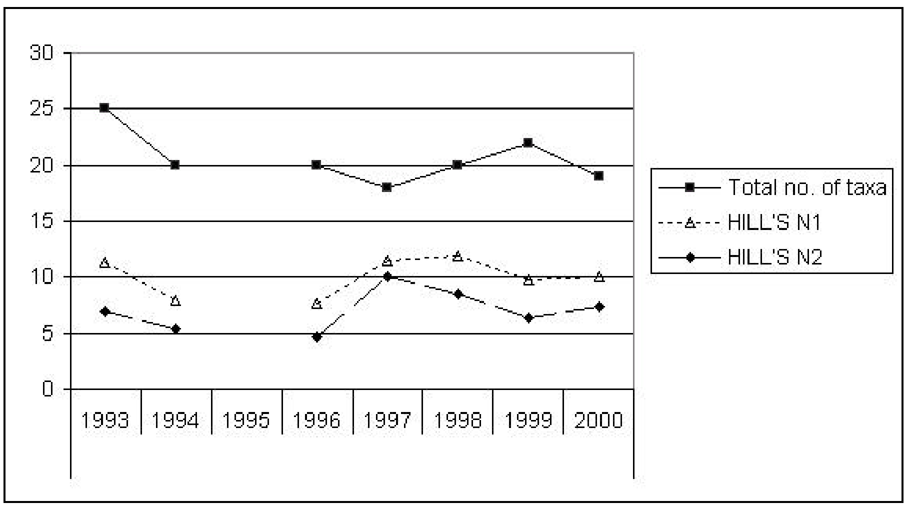

Figure 5.6 Selected Allt Riabhach na Bioraich Macroinvertebrate Summary Statistics

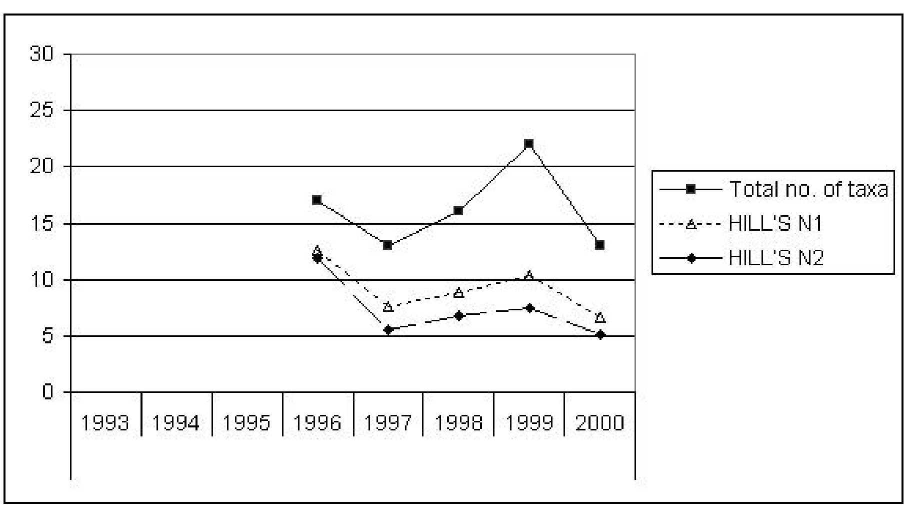

Table 5 Macroinvertebrate Summary Statistics

	CONTROL BURN							**EXPERIMENTAL BURN**							**ARnB BURN**				
	1993	**1994**	**1996**	**1997**	**1998**	**1999**	**2000**	**1993**	**1994**	**1996**	**1997**	**1998**	**1999**	**2000**	**1996**	**1997**	**1998**	**1999**	**2000**
Total Count	768	231	256	178	307	257	314	477	231	247	110	96	142	162	109	128	171	268	315
Total no. of taxa	24	22	27	19	21	23	18	25	20	20	18	20	22	19	17	13	16	22	13
RICHNESS (rareftn 100)	17	17	18	15	12	17	13	18	14	14	16	19	19	16	17	12	13	16	10
HILL'S N1	11.5	11.9	12.8	10.6	8.01	11.8	7.8	11.3	7.9	7.7	11.4	11.90	9.8	10.11	12.6	7.6	8.79	10.3	6.57
HILL'S N2	8.4	9.0	9.0	7.5	5.87	9.3	5.57	6.9	5.4	4.6	10.0	8.5	6.4	7.31	11.9	5.5	6.79	7.5	5.09
EVENNESS (E5)	0.71	0.73	0.68	0.68	0.69	0.76	0.67	0.57	0.64	0.54	0.87	0.69	0.61	0.69	0.94	0.67	0.74	0.69	0.73
BMWP	110	99	125	88	88	118	93	108	83	82	67	94	84	93	89	78	83	105	75
ASPT	6.4	6.6	6.6	6.3	6.3	6.6	6.06	6.4	5.5	5.9	6.1	6.3	6.5	7.01	6.9	7.1	6.4	6.6	6.06

Table 6 Aquatic Macrophyte Cover

	CONTROL BURN								EXPERIMENTAL BURN							ARnB BURN			
	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**1996**	**1997**	**1998**	**1999**
Batrachospermum sp.	+	0.7	+		+				33.3	12.7	54.2	32.8	35.0	28.8	17.8		1.6	0.3	0.3
Marsupella emarginata var *aquatica*	4.4	4.0	4.9	0.4	1.5	0.2	1.9	1.2	38.0	37.3	9.4	27.4	23.2	25.7	26.7	+			
Scapania undulata	2.8	3.7	1.7	0.9	2.0	1.9	3.7	3.3		5.0	21.7	12.0	11.8	15.2	22.1	0.4	0.2	0.7	0.5
Racomitrium aciculare	0.3	+	2.1	0.4	+	+		0.7										0.2	0.2
Juncus bulbosus var *fluitans*	0.1	+							2.6	9.0	2.7	6.6		3.3	0.2				
TOTAL COVER (excluding filamentous green algae)	7.6	8.4	8.7	1.7	3.5	2.2	5.6	5.2	73.9	64.0	88.0	78.8	70.0	73	66.8	0.4	1.8	1.2	1.0
Filamentous green algae	+	10.7	+	0.1	+	+	+	1.3	68.0	+						0.4		+	+

Control burn and Allt Riabhach na Bioraich burn sampling stretches are 50m long
Experimental burn sampling stretch is 20m long.

Figure 6.1 Control Burn Fish Densities

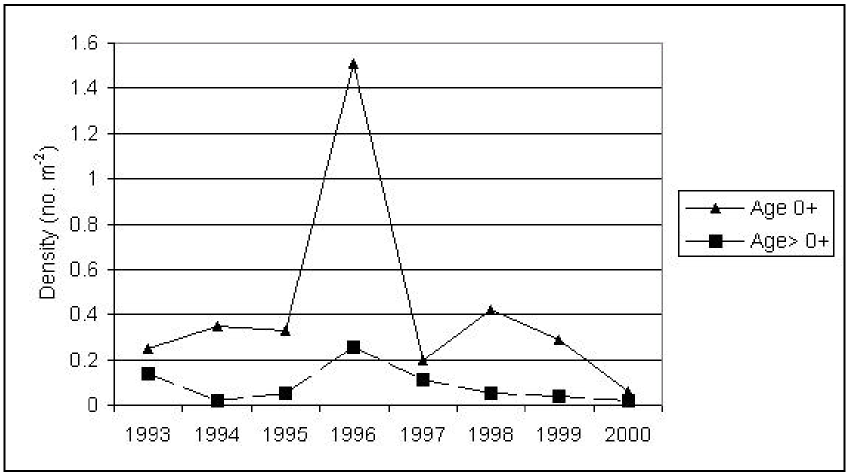

Figure 6.2 Experimental Burn Fish Densities

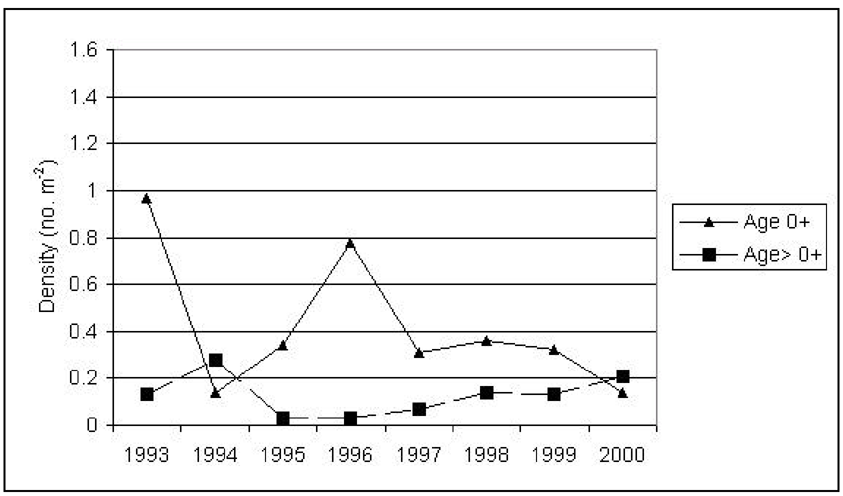

Figure 6.3 Allt Riabhach na Bioraich Fish Densities

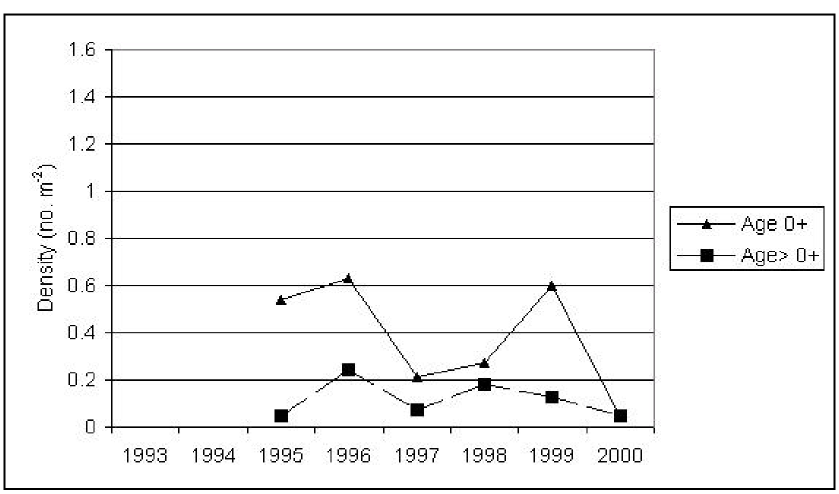

Table 7 Fish Population Data

Site	Year	Area Fished (m^2)	Density (no. m^{-2})	
			Age 0+	**Age> 0+**
Control Burn	1993	115	0.25	0.14
Control Burn	1994	115	0.35	0.02
Control Burn	1995	118	0.33	0.05
Control Burn	1996	87	1.51	0.26
Control Burn	1997	109	0.20	0.11
Control Burn	1998	101	0.42	0.05
Control Burn	1999	117.5	0.29	0.04
Control Burn	2000	114	0.06	0.02
Experimental Burn	1993	32	0.97	0.13
Experimental Burn	1994	32	0.14	0.28
Experimental Burn	1995	36	0.34	0.03
Experimental Burn	1996	38	0.78	0.03
Experimental Burn	1997	45	0.31	0.07
Experimental Burn	1998	44	0.36	0.14
Experimental Burn	1999	31.2	0.32	0.13
Experimental Burn	2000	42	0.14	0.21
ARnB Burn	1995	79	0.54	0.05
ARnB Burn	1996	57	0.63	0.24
ARnB Burn	1997	73	0.21	0.07
ARnB Burn	1998	71	0.27	0.18
ARnB Burn	1999	63	0.60	0.13
ARnB Burn	2000	75	0.04	0.05

Appendix 1 Water Chemistry for the Control Burn August 1992 – October 2000

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH_4
12-Aug-92	5.44	18	24	106	3	34	68	94	0.00	26	1		70	18	0.740		
30-Oct-92	6.46	67	23	112	4	32	68	99	0.00	28	0		29	4	0.320	5.0	
06-Dec-92	5.70	20	20	104	3	17	43	103	0.00	25	1		33	2	0.250	3.5	
04-Jan-93	5.63	18	20	105	4	25	41	101	0.00	44	0		21	3	0.270	3.8	
30-Mar-93	5.91	25	39	203	5	44	67	278	0.00	41	1		20	3	0.170	3.1	
03-May-93	6.57	93	35	177	6	42	97	186	0.00	35	0		9	5	0.170	3.3	
18-Jun-93	6.38	68	31	145	4	39	88	130	0.00	30	1	19.0	15	29	0.550	9.4	
10-Jul-93	6.31	61	27	141	4	33	77	129	0.00	19	2	26.0	71	1	0.610	9.1	
25-Jul-93	6.06	51	27	134	3	38	92	117	0.00	16	2		72	0	0.780	11.0	
09-Aug-93	5.91	40	23	114	3	33	72	98	2.00	11	4		92	13	0.880		
22-Aug-93	6.54	94	27	148	4	42	91	141	0.00	18	2		39	4	0.480		
04-Sep-93	6.76	147	36	168	7	46	111	151	0.00	26	0		17	1	0.290		
29-Sep-93	6.91	141	36	161	6	47	114	155	0.00	31	0		26	5			
06-Dec-93	5.59	18	20	99	4	25	32	86	1.00	38	1		37	5	0.459	6.7	
18-Feb-94	6.34	61	39	210	6	66	101	211	2.00	41	0	5.0	14	0	0.132		0
01-May-94	6.03	37	24	141	9	34	56	123	0.00	25	0	10.0	36	8	0.309	4.4	0
12-May-94	6.48	66	29	161	6	48	82	143	0.00	30	0		22	5	0.213	3.2	0
10-Jun-94	6.39	60	39	201	9	68	110	174	0.00	85	1		30	4	0.283		0
08-Jul-94	5.98	45	27	151	6	52	83	111	0.00	35	1		80	0	0.632		0
07-Aug-94	6.12	41	23	140	5	46	71	109	0.00	26	4	58.0	60	2			0
25-Aug-94	6.47	72	29	152	5	61	113	118	0.00	27	1		41	1			0
03-Sep-94	6.68	105	31	163	6	60	110	125	2.00	24	1	2.5	28	7	0.339	5.5	0
22-Sep-94	6.50	88	29	152	6	56	119	123	0.00	23	1		26	17	0.385	7.5	0
29-Dec-94	5.18	7	23	108	4	30	31	126	1.00	23	1		24	0	0.198	4.0	0
27-Mar-95	5.86	24	21	121	6	31	41	122	0.25	22	0	2.5	29	2	0.239	4.8	0
27-Apr-95	6.61	87	24	133	8	43	81	107	0.00	20	0	2.5	16	0	0.204	4.8	0

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH_4
02-Jun-95	6.38	62	26	137	4	41	75	103	0.10	18	3	3.0	29	28	0.490	9.9	0
15-Jul-95	6.65	89	40	178	9	75	128	127	1.60	96	0	2.5	29	1	0.340	8.9	0
06-Aug-95	7.02	161	37	195	11	67	146	143	0.51	44	0		21	0	0.285	6.0	0
25-Aug-95	6.77	116	37	186	10	62	115	144	1.90	37	1	2.5	20	1	0.262	5.6	0
04-Sep-95	6.51	72	46	188	7	90	157	118	0.00	175	0	6.0	34	3	0.313	7.6	0
24-Sep-95	5.72	26	34	156	5	66	99	108	0.20	107	0		62	4	0.469	11.0	0
11-Nov-95	6.27	57	25	124	6	48	85	95	0.22	39	0	2.5	65	2	0.430	8.7	0
10-Jan-96	5.39	12	20	100	6	37	50	78	2.40	59	0	2.5	44	5	0.297	6.6	3
27-Feb-96	5.49	17	29	152	5	55	68	166	0.82	60			28	2	0.238		0
03-Apr-96	5.72	21	24	124	6	39	61	112	5.20	49	1	2.5	28	0	0.243	5.3	3
02-May-96	6.26	65	28	136	5	50	88	113	0.32	49	0	2.5	30	4	0.251	5.1	0
12-Jun-96	5.68	26	22	109	2	38	62	88	0.00	21	3	10.0	70	2	0.586	11.3	0
04-Jul-96	6.21	52	28	131	4	49	83	93	0.00	47	2	2.5	48	10	0.513	13.9	0
27-Jul-96	6.54	85	29	143	5	61	112	102	0.47	31	1	2.5	48	2	0.551	11.0	0
18-Aug-96	6.90	173	34	160	7	69	144	110	0.40	26	0	2.5	24	0	0.386	7.7	0
07-Sep-96	6.61	124	30	159	7	71	131	114	0.56	24	1	2.5	31	5	0.496	10.0	0
28-Sep-96	6.34	59	38	164	9	74	125	163	0.66	62	0	2.5	58	5	0.486	11.2	0
30-Oct-96	5.69	24	20	94	7	37	57	79	0.44	18	4		69	10	0.564	11.0	0
03-Dec-96	5.49	14	44	219	7	67	73	296	3.40	40	0	2.5	38	1	0.165	4.0	3
28-Jan-97	6.25	47	26	128	5	42	72	102	1.90	43	0	2.5	40	0	0.301	6.2	2
10-Mar-97	6.93	28	37	190	7	57	80	228	1.90	41	0						0
30-Apr-97	6.20	49	29	170	5	52	89	162	1.80	25	1	2.5	46	0	0.384	7.7	0
21-May-97	6.35	60	26	142	5	45	79	118	0.62	19	1	2.5	52	4	0.487	9.9	1
05-Jul-97	6.55	94	31	160	7	54	100	121	0.35	29	0	2.5	29	10	0.410	8.8	4
30-Jul-97	6.20	59	26	135	4	54	100	104	0.32	13	2	2.5	86	4	0.870	7.2	0
19-Aug-97	6.94	146	36	169	8	67	135	122	0.23	24	0	2.5	32	9	0.447	9.5	0
07-Sep-97	6.02	40	25	130	4	48	82	106	0.00	17	1	2.5	88	4	0.708	13.7	0
05-Oct-97	6.06	41	30	143	8	55	96	145	0.00	20	0	2.5	58	10	0.607	13.0	0
14-Nov-97	5.65	26	23	119	12	44	65	101	1.40	28	1	6.0	73	7	0.640	15.0	1

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH_4
05-Jan-98	5.91	23	25	139	6	46	60	159	1.40	29	0	2.5	34	2	0.213	4.3	0
05-Feb-98	5.86	27	21	105	4	35	53	94	1.20	27	1	2.5	44	0	0.313	7.8	0
21-Mar-98	6.31	51	33	174	7	52	74	192	0.35	29	0	2.5	20	5	0.161	3.5	0
07-May-98	5.94	35	24	137	5	42	66	115	0.00	15	1	2.5	45	8	0.525	10.9	0
20-Jun-98	6.75	147	36	177	7	60	114	120	0.00	35	2	2.5	1	13	0.204	5.1	0
20-Jul-98	6.24	63	24	125	2	51	87	82	0.00	13	1	2.5	66	1	0.716	14.7	0
09-Aug-98	6.23	66	23	129	3	53	82	79	0.00	13	1	2.5	59	16	0.704	13.3	0
29-Aug-98	6.63	119	29	143	5	54	102	92	0.00	19	9	11.0	29	2	0.365	6.9	0
27-Sep-98	6.82	169	33	151	6	67	132	108	0.00	23	0	2.5	21	2		6.4	0
25-Oct-98	5.82	29	21	101	6	37	61	89	0.00	18	2	2.5	51	3	0.490	9.3	0
25-Nov-98	5.61	19	26	129	3	40	57	146	0.00	24	2	2.5	34	2	0.327	6.9	0
12-Feb-99	5.76	19	48	258	9	73	92	337	0.88	37	1	6.0	15	2	0.112	3.1	0
25-Mar-99	5.74	21	26	147	5	35	45	161	0.00	20	1	2.5	28	4	0.289	6.4	1
10-May-99	5.81	31	26	149	6	43	64	133	0.00	27	3	6.0	53	4	0.580	12.9	0
17-Jun-99	6.09	44	25	146	4	44	73	134	0.00	10	2	6.0	63	4	0.552	11.3	0
12-Jul-99	6.53	103	30	168	8	62	118	127	0.00	18	0		57	2	0.617	13.0	0
1-Sep-99	6.04	46	30	146	4	62	106	120	0.00	54	3	6.0	59	7	0.581	12.0	0
26-Sep-99	5.62	24	19	104	5	37	54	81	0.00	16	4	6.0	50	3	0.612	12.7	0
6-Nov-99	5.29	10	23	115	7	33	42	126	0.53	21	0	2.5	30	6	0.357	8.1	0
20-Jan-00	6.11	36	26	141	3	41	63	145	0.00	26	2	2.5	33	0	0.197	4.4	0
5-Mar-00	5.46	13	28	168	3	39	48	185	0.94	27	1	2.5	26	1	0.192	4.8	0
14-Apr-00	6.59	88	31	166	6	52	106	158	0.30	21	0	2.5	16	7	0.209	4.7	0
31-May-00	6.53	83	34	188	5	64	108	149	0.00	59	0	2.5	26	13	0.336	7.2	0
17-Jun-00	6.56	84	35	190	5	67	114	181	0.69	31	0	2.5	32	0	0.250	5.8	0
12-Jul-00	6.70	80	31	169	4	62	110	147	1.10	26	0	2.5	25	11	0.354	8.2	0
5-Aug-00	6.60	97	35	175	5	62	108	146	1.50	38	0	2.5	30	3	0.391	9.3	2
4-Sep-00	6.75	131	36	170	5	67	128	154	0.00	18	0	6.0	20	6	0.425	9.3	0
8-Oct-00	5.75	29	27	142	5	46	68	144	0.00	16	0	2.5	67	9	0.613	12.5	0

Appendix 2 Water chemistry for the Experimental Burn (Upper site) September 1992- October 2000

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4-P	Tot-P	Al-NL	Al-L	Abs-250	TOC	NH_4
18-Sep-92	5.71	28	33	136	3	36	113	152	0.00	82	0		21	1	0.410		
30-Oct-92	6.19	58	26	130	3	32	61	128	0.00	26	0		15	0	0.270	4.4	
06-Dec-92	5.23	9	19	93	2	14	27	88	0.00	23	0		27	0	0.260	3.4	
04-Jan-93	5.43	14	19	98	2	21	31	86	0.00	35	0		12	0	0.270	3.8	
30-Mar-93	5.86	28	41	230	5	44	64	296	1.00	45	2		9	3	0.170	2.9	
03-May-93	6.42	115	37	204	7	44	95	192	1.00	29	0		5	2	0.260	4.2	
18-Jun-93	6.33	122	37	202	4	44	100	156	0.00	16	0	19.0	19	9	0.510	8.2	
10-Jul-93	6.05	66	29	164	4	35	76	139	0.00	18	3	22.0	46	1	0.700	9.5	
25-Jul-93	5.71	42	29	156	2	42	73	130	0.00	12	3		48	9	0.860	13.0	
09-Aug-93	5.93	57	29	151	4	42	76	131	0.00	8	5		54	0	0.880		
22-Aug-93	6.36	142	33	186	6	60	108	159	1.00	14	3		28	2	0.650		
04-Sep-93	6.47	213	45	210	7	68	159	171	2.00	22	1		10	2	0.410		
29-Sep-93	6.60	171	45	209	15	64	135	207	2.00	28	0		20	0			
06-Dec-93	5.29	11	21	105	3	24	26	87	0.00	39	6		24	2	0.492	6.8	
18-Feb-94	6.30	70	44	243	6	75	109	246	1.00	49	1	0.0	5	0	0.096		0
01-May-94	5.88	35	29	183	4	44	58	159	0.00	28	1	13.0	26	7	0.414	5.4	0
12-May-94	6.36	87	36	202	7	58	90	176	0.00	26	0		19	4	0.279	5.0	7
10-Jun-94	6.25	71	40	224	5	62	100	200	0.00	51	0		22	2	0.292		0
08-Jul-94	5.75	44	29	178	3	53	75	122	1.00	24	2		45	1	0.836		0
07-Aug-94	6.78	130	31	181	13	78	137	141	1.00	19	4	60.0	17	6			0
25-Aug-94	6.29	80	32	177	7	71	111	141	1.00	18	2		28	3			0
03-Sep-94	6.51	136	37	200	12	81	136	153	1.00	16	5	2.5	18	3	0.488	7.6	0
22-Sep-94	6.27	97	33	186	7	66	123	160	0.00	13	2		21	0		7.3	0
29-Dec-94	5.47	13	24	125	6	39	36	139	0.00	24	1		35	3	0.238	4.6	0
27-Mar-95	5.74	23	22	129	5	32	40	121	0.40	21	2	2.5	18	1	0.260	5.3	0
27-Apr-95	6.10	65	29	168	15	48	80	158	0.46	24	1	2.5	30	1	0.284	6.6	0
02-Jun-95	6.26	64	29	169	5	47	68	129	0.42	13	1	2.5	35	7	0.548	11.0	0

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4-P	Tot-P	Al-NL	Al-L	Abs-250	TOC	NH_4
15-Jul-95	6.46	140	46	202	6	86	154	138	0.49	94	1	2.5	12	2	0.343	8.5	0
06-Aug-95	6.51	195	40	219	8	86	164	155	1.20	30	1		15	1	0.417	8.6	0
25-Aug-95	6.81	221	49	225	7	99	176	171	0.41	35	1	2.5	9	0	0.266	6.1	0
04-Sep-95	6.22	74	63	239	8	134	208	125	0.87	302	0	6.0	14	0	0.239	6.8	0
24-Sep-95	5.21	10	35	167	5	66	84	115	0.37	112	0		37	5	0.494	12.0	0
11-Nov-95	5.91	43	26	139	4	47	72	98	0.52	37	0	2.5	32	6	0.473	8.7	0
10-Jan-96	5.31	10	23	126	6	42	47	96	1.00	68	0	2.5	35	5	0.305	6.6	2
27-Feb-96	5.28	10	28	152	4	51	55	166	0.94	56			19	8	0.237		0
03-Apr-96	6.29	71	36	189	12	62	105	172	0.91	75	1	2.5	15	0	0.170	4.7	4
02-May-96	6.06	66	31	159	6	51	83	132	0.48	44	0	2.5	21	3	0.311	6.5	2
12-Jun-96	5.41	21	24	127	2	36	47	103	0.00	17	3	3.0	41	2	0.627	12.6	0
04-Jul-96	5.83	45	27	144	3	51	77	104	0.00	32	1	2.5	23	13	0.586	19.8	0
27-Jul-96	6.24	124	34	168	4	71	128	122	0.00	19	2	2.5	20	2	0.52	12.7	0
18-Aug-96	6.75	208	41	198	7	89	169	140	1.10	20	1	2.5	14	1	0.464	9.7	0
07-Sep-96	6.13	117	35	174	9	78	130	136	0.98	16	2	2.5	27	4	0.677	14.0	0
28-Sep-96	6.31	102	42	194	9	78	128	183	1.40	42	1	2.5	18	1	0.372	9.3	0
30-Oct-96	5.53	20	25	118	10	41	53	112	0.27	20	2		46	8	0.505	10.0	0
03-Dec-96	5.16	6	46	227	7	72	73	305	1.50	40	0	2.5	25	1	0.166	3.9	0
28-Jan-97	5.95	36	26	142	4	39	58	106	0.94	43	0	2.5	26	1	0.371	7.4	2
10-Mar-97	5.68	22	39	204	6	57	70	241	0.92	38	0						0
30-Apr-97	5.88	39	30	178	5	49	72	168	0.84	17	0	2.5	27	0	0.370	7.5	0
21-May-97	5.98	47	27	152	3	43	67	125	0.45	13	2	2.5	33	0	0.550	11.2	0
05-Jul-97	6.12	81	29	166	8	50	87	114	0.51	14	1	2.5	30	10	0.590	12.0	6
30-Jul-97	6.02	67	28	155	4	58	93	112	0.19	9	2	2.5	39	0	0.841	17.7	0
19-Aug-97	6.50	216	74	229	10	95	380	148	0.66	233	1	2.5	25	0	0.638	14.0	0
07-Sep-97	5.69	31	26	140	4	52	73	116	0.00	12	2	2.5	59	6	0.766	15.0	0
05-Oct-97	5.76	34	33	158	9	64	86	183	0.00	14	1	2.5	46	1	0.541	12.0	0
14-Nov-97	5.46	21	28	143	16	51	59	127	0.39	27	1	2.5	50	3	0.697	16.0	0
05-Jan-98	5.44	13	32	167	5	61	62	214	0.39	29	0	2.5	25	0	0.195	4.0	0

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4-P	Tot-P	Al-NL	Al-L	Abs-250	TOC	NH_4
05-Feb-98	5.64	23	21	110	3	35	45	93	0.75	27	1	2.5	26	0	0.361	8.2	0
21-Mar-98	6.19	60	38	185	6	58	80	208	0.91	26	0	2.5	9	5	0.135	3.4	0
07-May-98	5.63	25	27	146	4	43	53	129	0.00	13	1	2.5	30	5	0.507	10.9	0
20-Jun-98	6.46	161	36	194	6	65	119	129	0.00	20	2	2.5	16	0	0.271	6.9	0
20-Jul-98	5.89	51	23	130	1	52	74	77	0.00	9	2	2.5	46	1	0.773	16.3	0
09-Aug-98	6.05	74	26	140	4	62	86	86	0.00	10	2	2.5	43	3	0.751	16.5	0
29-Aug-98	6.33	159	36	172	7	76	129	117	1.40	15	3	6.0	24	0	0.437	9.0	0
27-Sep-98	6.43	212	42	189	8	96	169	145	3.90	17	2	2.5	35	3	0.529	11.0	2
25-Oct-98	5.56	23	23	109	9	43	55	103	0.00	17	2	2.5	38	0	0.522	9.8	0
25-Nov-98	5.46	16	26	136	4	42	52	144	0.00	22	1	2.5	39	4	0.371	7.9	0
12-Feb-99	5.70	18	50	278	7	83	93	363	0.87	36	0	6.0	13	2	0.119	3.7	0
25-Mar-99	5.56	18	28	167	5	37	42	177	0.00	20	1	2.5	29	0	0.358	7.9	2
10-May-99	5.67	28	28	168	6	44	55	153	0.00	18	3	6.0	49	1	0.608	14.3	0
17-Jun-99	5.84	40	27	164	2	46	60	143	0.00	7	3	6.0	47	1	0.613	12.3	0
12-Jul-99	6.21	133	36	196	6	87	129	138	0.86	11	31		50	5	0.930	19.3	0
3-Aug-99	6.49	215	46	222	10	100	167	158	4.20	20	1	6.0	34	10	0.639	13.3	0
1-Sep-99	6.07	66	35	173	5	70	109	157	0.00	46	0	2.5	18	2	0.431	9.7	0
26-Sep-99	5.32	14	18	92	9	33	41	75	0.00	10	4	6.0	30	6	0.624	13.7	0
6-Nov-99	5.29	10	24	129	10	36	45	134	0.33	22	0	2.5	22	1	0.354	5.9	0
20-Jan-00	6.01	43	28	167	3	47	70	167	0.47	32	6	6.0	13	0	0.171	3.9	0
5-Mar-00	5.33	10	27	161	5	35	40	171	0.66	25	1	2.5	19	0	0.190	4.5	0
14-Apr-00	6.31	88	34	191	6	54	104	182	0.51	19	0	2.5	7	3	0.186	4.7	0
31-May-00	6.16	61	32	193	3	56	84	155	0.85	30	0	2.5	24	9	0.444	9.6	0
17-Jun-00	6.43	96	35	207	5	68	100	177	1.80	18	0	2.5	15	9	0.347	8.1	0
12-Jul-00	6.36	81	33	189	4	67	104	158	0.89	19	2	6.0	23	6	0.503	12.0	0
5-Aug-00	6.30	108	38	194	5	73	110	154	1.70	26	4	6.0	23	1	0.546	13.6	2
4-Sep-00	6.34	130	41	200	7	83	129	182	0.80	10	0	6.0	22	9	0.624	13.0	0
8-Oct-00	5.62	26	30	160	13	54	64	171	0.00	13	1	2.5	37	7	0.628	11.9	0

Appendix 3 Water chemistry for the Experimental Burn (Lower site) July 1995 - October 2000

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH_4
15-Jul-95	6.63	155	62	210	6	73	276	148	0.00	206	1	2.5	12	0	0.348	7.7	0
06-Aug-95	6.77	220	115	287	11	99	868	154	0.15	749	2		18	2	0.524	11.0	0
04-Sep-95	6.36	87	67	245	8	110	275	144	0.28	337	0	11.0	16	0	0.280	7.6	0
24-Sep-95	5.13	7	33	165	7	64	86	120	0.00	109	0		33	4	0.514	13.0	0
11-Nov-95	5.76	38	29	139	9	44	82	113	0.32	55	0	2.5	51	3	0.384	7.4	0
10-Jan-96	5.26	9	22	119	3	39	43	82	0.66	69	0	2.5	40	2	0.369	8.0	2
27-Feb-96	5.28	9	28	148	7	48	46	165	0.21	51			19	12	0.167		0
03-Apr-96	6.31	74	50	185	8	59	211	168	0.72	188	1	2.5	11	0	0.149	4.0	0
02-May-96	6.03	67	48	167	6	50	195	134	0.00	175	0	2.5	18	3	0.299	6.1	0
12-Jun-96	4.98	-11	27	128	3	34	41	109	0.00	21	3	4.0	36	2	0.700	14.3	0
04-Jul-96	5.89	44	34	151	3	50	113	111	0.00	79	0	2.5	26	6	0.538	15.8	0
27-Jul-96	6.15	125	48	184	7	67	209	140	0.35	111	2	6.0	18	6	0.488	10.9	3
18-Aug-96	6.67	231	75	227	9	90	430	148	0.00	278	1	2.5	14	1	0.477	10.0	0
07-Sep-96	6.02	125	51	193	12	81	228	147	0.00	118	3	3.5	41	2	0.750	15.7	0
28-Sep-96	6.30	99	49	206	13	75	172	199	1.60	94	1	2.5	12	1	0.350	9.0	0
30-Oct-96	5.49	21	26	122	15	42	57	113	0.00	27	0		49	10	0.479	10.0	0
03-Dec-96	5.41	8	48	230	10	73	77	309	1.10	50	1	2.5	22	10	0.155	3.6	3
28-Jan-97	5.87	32	30	145	5	40	83	114	1.00	75	0	2.5	24	1	0.328	6.7	2
10-Mar-97	5.54	19	44	207	8	59	101	243	1.10	77	0						0
30-Apr-97	5.77	36	35	179	6	48	96	174	0.66	48	0	2.5	25	1	0.344	7.3	2
21-May-97	6.11	46	33	154	3	40	107	128	0.00	65	1	2.5	31	0	0.474	10.2	0
05-Jul-97	6.08	79	39	176	8	49	143	127	0.42	80	1	2.5	21	7	0.502	11.0	3
30-Jul-97	6.02	79	34	169	7	57	124	135	0.45	38	2	16.0	29	3	0.731	15.3	3
19-Aug-97	6.67	140	38	173	9	67	142	124	1.20	39	1	2.5	29	0	0.445	9.4	3

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH_4
07-Sep-97	5.72	30	29	149	6	52	81	125	0.00	28	1	2.5	64	4	0.766	16.4	3
05-Oct-97	5.74	39	37	171	12	65	115	194	0.35	39	0	2.5	36	2	0.519	12.0	0
14-Nov-97	5.55	26	28	144	17	49	63	134	0.00	29	1	17.0	43	4	0.613	14.0	0
05-Jan-98	5.44	13	33	170	7	59	67	215	0.42	36	0	2.5	20	0	0.176	3.7	0
05-Feb-98	5.64	22	22	115	5	35	48	100	0.61	32	1	2.5	28	2	0.323	7.7	0
21-Mar-98	6.00	53	45	210	9	64	142	241	1.30	95	0	2.5	13	4	0.131	3.3	2
20-Jun-98	6.26	144	61	209	6	70	291	132	0.00	232	1	2.5	4	13	0.270	6.8	0
20-Jul-98	5.75	45	26	137	3	50	91	86	0.00	29	5	6.0	42	42	0.759	16.0	0
09-Aug-98	5.85	66	31	143	5	63	124	85	0.00	51	2	2.5	50	2	0.808	17.4	0
29-Aug-98	6.21	142	51	178	5	75	235	118	0.46	145	3	6.0	31	0	0.470	9.8	0
27-Sep-98	6.34	203	65	207	10	99	351	149	2.20	218	1	2.5	32	2	0.482	10.0	3
25-Oct-98	5.58	22	20	100	5	35	51	89	0.00	20	2	2.5	57	6	0.496	10.8	0
25-Oct-98	5.58	22	20	100	5	35	51	89	0.00	20	2						0
25-Nov-98	5.44	16	27	143	6	42	54	151	0.00	26	1	2.5	31	4	0.351	7.5	0
12-Feb-99	5.47	13	50	255	12	77	84	336	0.63	36	0	6.0	15	1	0.082	2.8	0
25-Mar-99	5.51	17	28	163	7	36	44	174	0.00	24	1	2.5	28	4	0.320	7.2	1
10-May-99	5.75	34	29	168	7	43	63	161	0.00	30	2	6.0	40	1	0.474	11.3	0
17-Jun-99	5.71	33	29	169	3	46	72	155	0.00	26	4	6.0	31	9	0.607	12.9	0
12-Jul-99	5.87	111	45	207	9	92	195	150	0.00	75	3		109	7	1.195	23.0	0
03-Aug-99	6.25	206	81	246	12	111	432	156	0.76	312	0	2.5	31	3	0.684	14.1	0
01-Sep-99	6.29	73	39	175	7	65	133	164	1.40	67	3	6.0	19	0	0.380	8.8	0
26-Sep-99	4.97	-1	20	88	11	29	32	74	0.00	10	6	8.0	30	8	0.691	14.7	0
06-Nov-99	5.46	16	24	131	12	38	47	137	0.61	23	0	6.0	34	5	0.352	7.0	0
20-Jan-00	5.99	42	35	168	4	48	110	171	2.10	71	1	6.0	11	2	0.149	3.6	0
05-Mar-00	6.39	11	27	158	6	34	40	171	0.00	27	0	2.5	22	0	0.161	4.2	0
14-Apr-00	6.38	95	48	200	6	55	205	184	1.40	128	0	2.5	7	3	0.191	4.6	0

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH_4
31-May-00	6.11	63	37	200	4	58	127	165	0.58	78	0	2.5	22	13	0.310	6.9	0
17-Jun-00	6.20	85	46	217	6	70	185	186	0.76	105	1	2.5	31	1	0.356	8.6	0
12-Jul-00	6.37	81	41	200	6	69	170	169	1.10	86	0	6.0	15	9	0.468	10.3	0
05-Aug-00	6.23	119	52	215	8	75	201	178	1.40	114	1	6.0	24	6	0.535	13.4	2
04-Sep-00	6.27	134	54	217	9	83	228	189	0.54	114	0	6.0	31	2	0.640	14.0	2
08-Oct-00	5.63	26	31	161	17	52	63	170	0.00	18	1	2.5	52	1	0.580	9.2	0

Appendix 4 Water chemistry for the Allt Riabhach na Bioraich (Lower site) June 1995 - October 2000

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH_4
02-Jun-95	6.15	48	25	137	5	41	68	109	0.51	26	0	2.5	53	0	0.431	8.8	0
15-Jul-95	6.35	72	41	175	9	76	128	121	9.00	104	0	2.5	30	8	0.436	11.0	0
06-Aug-95	6.80	122	38	207	13	65	142	148	2.20	80	1		15	3	0.287	6.6	0
04-Sep-95	6.19	50	43	182	9	84	132	118	0.47	156	0	6.0	39	0	0.347	8.5	0
24-Sep-95	5.41	17	28	150	6	63	85	107	1.10	96	0		66	8	0.517	13.0	0
11-Nov-95	6.03	50	26	130	6	47	81	94	1.20	43	1	2.5	65	0	0.411	7.9	0
27-Feb-96	5.68	25	30	155	5	55	74	166	2.50	64			29	1	0.213		1
03-Apr-96	6.07	41	33	153	12	59	100	135	7.60	88	0	2.5	29	2	0.194	4.6	6
02-May-96	5.98	71	31	139	6	48	98	115	0.30	60	0	2.5	32	2	0.241	4.8	0
12-Jun-96	5.52	22	23	115	3	37	51	91	0.40	23	3	4.0	40	29	0.563	6.7	0
04-Jul-96	5.92	41	27	130	4	49	85	96	0.00	46	0	2.5	47	14	0.553	23.0	0
27-Jul-96	6.36	79	29	140	5	57	117	100	0.54	34	1	2.5	42	4	0.532	10.7	0
18-Aug-96	6.69	141	35	158	7	62	144	108	2.10	39	2	2.5	24	2	0.398	8.0	0
07-Sep-96	6.34	117	34	162	11	65	137	117	0.54	40	2	2.5	35	4	0.485	10.2	0
28-Sep-96	6.21	59	37	169	10	74	120	174	2.60	57	1	2.5	46	9	0.484	10.9	0
30-Oct-96	5.61	23	21	97	7	36	53	80	0.89	22	1		90	7	0.525	10.0	0
03-Dec-96	5.26	10	44	218	8	71	75	293	2.10	42	0	2.5	35	7	0.160	3.7	0
28-Jan-97	6.09	43	27	129	6	41	73	104	3.50	49	4	6.0	45	0	0.305	6.0	2
10-Mar-97	5.64	26	38	184	9	56	77	218	2.60	46	1						0
30-Apr-97	5.92	39	29	154	5	48	79	149	0.76	27	0	2.5	43	1	0.382	7.8	0
21-May-97	6.09	47	26	144	5	45	76	120	0.24	25	1	2.5	52	7	0.501	10.4	4
05-Jul-97	6.23	74	30	148	7	51	97	108	0.20	35	1	2.5	55	0	0.480	9.9	3
30-Jul-97	6.18	61	27	136	5	54	97	104	0.44	27	1	2.5	70	8	0.769	15.7	0
19-Aug-97	6.63	104	33	163	8	60	112	120	1.20	22	1	2.5	32	0	0.478	9.8	0

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH_4
07-Sep-97	5.68	28	25	125	4	47	71	103	0.40	20	2	2.5	89	10	0.740	14.5	0
05-Oct-97	5.75	29	29	143	7	57	84	145	0.31	24	0	2.5	82	5	0.644	14.0	0
14-Nov-97	6.02	48	26	139	8	50	76	114	1.60	30	1	2.5	57	5	0.561	12.0	0
05-Jan-98	5.46	16	28	146	6	49	55	168	1.70	31	0	2.5	31	0	0.209	3.9	1
05-Feb-98	5.72	23	21	115	7	36	53	102	2.60	30	1	2.5	47	1	0.346	8.2	3
21-Mar-98	6.05	49	34	171	8	50	77	183	1.00	40	0	2.5	24	2	0.149	3.8	2
20-Jun-98	6.48	148	39	180	9	60	138	120	0.45	62	1	2.5	23	0	0.228	5.7	0
20-Jul-98	5.94	52	24	129	4	48	77	81	0.00	18	1	2.5	85	3	0.735	15.2	0
09-Aug-98	5.89	43	22	123	4	44	71	82	0.00	20	1	2.5	55	9	0.634	12.5	0
29-Aug-98	6.36	120	31	156	8	51	106	101	0.00	34	1	2.5	27	1	0.350	7.1	0
27-Sep-98	6.52	163	35	159	8	66	159	109	0.72	51	1	2.5	21	0	0.312	6.8	0
25-Oct-98	5.49	22	24	109	12	43	51	107	0.32	20	2	2.5	49	12	0.513	10.3	0
25-Nov-98	5.56	18	26	134	5	40	55	145	0.85	26	1	2.5	45	4	0.318	6.7	0
12-Feb-99	5.80	24	43	238	8	69	89	299	1.60	38	1	2.5	16	0	0.098	2.8	0
25-Mar-99	5.56	17	26	142	6	35	42	158	0.52	23	1	2.5	39	0	0.274	6.2	0
10-May-99	5.89	35	27	149	9	45	68	139	0.40	28	3	6.0	51	0	0.558	12.0	0
17-Jun-99	5.74	31	25	142	2	42	61	129	0.00	14	2	2.5	52	20	0.617	12.9	0
12-Jul-99	6.20	84	29	168	7	57	105	124	0.00	27	0		82	2	0.752	15.3	0
03-Aug-99	6.56	115	36	179	9	59	138	145	1.50	51	0	6.0	24	0	0.372	7.7	0
01-Sep-99	5.83	35	28	136	5	54	78	110	0.00	40	2	2.5	61	10	0.647	13.0	0
26-Sep-99	5.50	25	21	108	5	36	52	88	0.00	21	3	6.0	68	5	0.563	10.6	0
06-Nov-99	5.02	2	23	110	6	35	31	119	0.00	22	1	2.5	18	2	0.303	7.9	0
20-Jan-00	5.86	34	26	140	4	40	71	140	1.80	33	1	2.5	31	2	0.190	4.1	0
05-Mar-00	5.47	14	28	163	4	39	52	182	1.00	29	0	2.5	24	2	0.188	4.4	0
14-Apr-00	5.47	11	31	188	3	43	57	215	1.40	27	0	2.5	10	5	0.108	2.4	0
31-May-00	6.31	61	31	174	5	57	95	145	0.00	47	0	2.5	34	15	0.364	8.0	0

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH_4
17-Jun-00	6.27	68	35	187	6	61	100	179	0.69	40	0	2.5	34	3	0.269	6.4	0
12-Jul-00	6.33	69	30	163	5	59	109	139	0.00	31	0	6.0	29	12	0.397	8.5	0
05-Aug-00	6.48	85	34	174	6	58	104	143	1.10	45	0	6.0	26	3	0.389	9.3	3
04-Sep-00	6.59	102	35	169	6	62	118	152	0.00	27	0	6.0	24	4	0.439	9.8	0
08-Oct-00	5.47	20	28	144	6	46	62	146	0.00	20	2	6.0	83	9	0.636	10.7	0

Appendix 5 Biology Sampling Dates

Sampling Year	Fish	Macroinvertebrates	Epilithic Diatoms	Aquatic Macrophytes
1992 *			15 Aug	15 Aug
1993	29 Sept	3 May	29 Sept	29 Sept
1994	27 Sept	12 may	25 Aug	25 Aug
1995	27 Sept	No sample	25 Aug	25 Aug
1996	24 Sept	15 May	28 Aug	28 Aug
1997	17 Sept	21 May	23 July	23 July
1998	1 Oct		1 Aug	1 Aug
1999	6 Oct			
2000	20 Nov			

* only control burn sampled in 1992