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Land-Use Experiments in the Loch Laidon Catchment:
Seventh Report on Stream Water Quality to the Rannoch Trust

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2 INTRODUCTION

This report presents and summarises data from the Stream Water Quality project instigated by the Rannoch Trust in 1992. The project comprises the aquatic part of the Loch Laidon Catchment land-use experiment, which is investigating the effects of summer cattle grazing 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 biological and chemical datasets.

3 METHODOLOGY

Sampling methodologies follow those of Allott *et al* (1994). Annual biological surveys of fish, aquatic macroinvertebrates, epilithic diatoms and aquatic macrophytes continue to be undertaken. Aquatic macroinvertebrates were not surveyed in 1995 nor aquatic macrophytes in 2000. Biological sampling dates are provided 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:

1. A lower station on the Experimental Burn
2. An upper station on the Allt Riabhach na Bioraich Burn
3. A lower station on the Allt Riabhach na Bioraich Burn
4. The Loch Laidon Outflow

One further spot water chemistry sampling point was added in September 2000 in a burn downstream from a recently planted area of forest, approximately 1.5 km North East of the Allt Riabhach na Bioraich.

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.

It is envisaged that by the time this report is published the experimentally fenced area will have been enlarged to include the Allt Riabhach na Bioraich Burn.

The area of study is shown in Figure 1. Sampling locations are presented in Figure 2.

4 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.

Diatom and aquatic macroinvertebrate diagrams show percentage abundances of taxa. All macroinvertebrate species are included in the figures whereas only diatom species occurring with a minimum abundance of at least 1% are shown.

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).

5 RESULTS

5.1 CHEMISTRY

5.1.1 COMPARISON OF THE CONTROL AND UPPER EXPERIMENTAL BURN

The relationship between Control and Upper Experimental burn concentrations of key chemical determinands are provided in Figures 6 to 9. In the last two years differences in concentration between the two sampling sites have been slightly less marked than previously. However flow related seasonality in ratios of alkalinity and conductivity between the two sites is still apparent (see Shilland *et al,* 2001).

Nitrate values at both sampling locations have persisted within levels encountered during previous monitoring, with the exception of a large peak in the Control Burn in early 2001. This was slightly larger than the previous maximum recorded at the beginning of 1996. Both these peaks coincide with cold winters and may be due to low temperatures limiting catchment nitrate uptake (Monteith *et al*, 2000)

5.1.2 COMPARISON OF THE CONTROL AND LOWER EXPERIMENTAL BURN

Figures 10 to 15 illustrate the relationships of selected chemical determinands between the Control Burn and the Lower Experimental Burn. The ratio of alkalinity between the two burns appears to show a slight upward trend since the beginning of 1997, suggesting that alkalinity in the Experimental Burn may be increasing relative to the Control Burn. This upwards trend also seems to occur, though less markedly, in calcium, magnesium and potassium. A significant proportion of the variance in the ratio of these determinands can be explained by hydrology (i.e. “experimental burn stage board height”). This influence was therefore controlled for using linear regression, and the residuals of the chemistry-board height relationships are provided in Figures 16 to 19. Although visual inspection of these plots still gives some indication of an upward trend (at least for alkalinity ratio residuals) time trends are not significant according to linear regression. The conductivity of the Lower Experimental Burn in 2001 persisted in being higher than that of the Control Burn, similar to previous years.

5.1.3 COMPARISON OF THE ALLT RIABHACH NA BIORAICH WITH THE CONTROL AND LOWER EXPERIMENTAL BURN

Graphs of alkalinity, conductivity, total organic carbon and nitrate comparing the Allt Riabhach na Bioraich, the Control and the Lower Experimental burns are given in Figures 20 to 23. Seasonal effects are apparent in all three burns and summer peak values for alkalinity, conductivity and total organic carbon are consistently higher in the Experimental Burn than in the other two burns, which track each other closely. Peak nitrate concentrations in the Allt Riabhach na Bioraich Burn in early 2001 are slightly higher than the coincident peak values of the Control Burn, whilst levels in the Experimental Burn remain much lower.

5.2 BIOLOGY

5.2.1 EPILITHIC DIATOMS

The data for epilithic diatoms are provided graphically in Figures 24, 25 and 26 and trend test statistics are shown in Table 1.

The Control Burn diatom assemblage for 2000 remains dominated by the three species that have consistently been most abundant since monitoring started in 1992: *Tabellaria flocculosa*, *Synedra miniscula* and *Brachysira vitrea*, which between them account for more than 85% of the sample.

Diatoms in the Experimental Burn persisted in being the most variable of any of the study burns. In 2000 *Brachysira vitrea* and *Peronia fibula* accounted for nearly 50% of the total assemblage. *Tabellaria flocculosa* was the next most common species whilst *Eunotia naegelii*, *Eunotia incisa* and *Frustulia rhomboids* all occurred at around 5%.

In the Allt Riabhach na Bioraich Burn in 2000 the diatom flora once again remained remarkably stable, with the slightly increased abundance of *Synedra miniscula* at about 5% being the only change compared with the previous year. *Tabellaria flocculosa* was the most plentiful species, followed by *Brachysira vitrea.*

Detrended Correspondence Analysis on the diatom data from all three burns established that the datasets had short, time constrained, gradient lengths of less than 3 standard deviation units and were therefore appropriate for further Principal Components Analysis. The PCA first axis eigenvalues (λ_1^{PCA}), which provide the maximum proportion of total between-year variance that can be explained by a single hypothetical linear variable, are provided in Table 1. This table also shows RDA Axis 1 eigenvalues, which give the variance that can be explained by a time trend (λ_1^{RDA}). Variance explained by time at all three sites is small relative to variance on the first Principal Component. Subsequent Monte Carlo permutation tests demonstrated that there was no significant linear trend in the species assemblages of any of the three burns at the $P > 0.05$ level. This result implies that cattle grazing is not having a measurable effect on the flora of the Experimental Burn to date.

Table 1 Diatom Trend Test Statistics

	λ_1^{PCA}	λ_1^{RDA}	$\lambda_1^{RDA}/\lambda_1^{PCA}$	**Restricted P Value**
Control Burn	0.34	0.06	0.18	0.15
Experimental Burn	0.32	0.12	0.38	0.12
Allt Riabhach na Bioraich Burn	0.25	0.07	0.28	0.50

5.2.2 MACROINVERTEBRATES

Macroinvertebrate data are provided in Table 3 and Figures, 27, 28 and 29. Tables 4 to 6 and Figures 30, 31 and 32 detail macroinvertebrate summary statistics. These demonstrate that the total numbers of taxa recorded in each burn, and the total numbers of individuals caught, increased over the previous sampling year. However, whilst diversity increased slightly in the Control and Allt Riabhach na Bioraich burns it decreased in the Experimental Burn. Water quality indicator statistics were also lower in the Experimental Burn on the most recent sampling occasion, though still falling within the range of previous years. No overall trends are apparent in the summary statistics during the duration of monitoring.

In the Control Burn the acid sensitive mayfly *Baetis rhodani* was the commonest taxon for the first time. Stoneflies, as in past years, constituted a large proportion of the assemblage though the beetle *Limnius volckmari's* abundance was reduced. The assemblage of the Allt Riabhach na Bioraich Burn comprised over 40% Chironomidae (midge larvae) in 2001, the first time this group has been dominant in this burn since monitoring began. Otherwise, and similar to the Control Burn, stoneflies and the beetles *Limnius volckmari* and *Oulimnius tuberculatus* made up the bulk of the species present.

In 2001 Chironomidae continued to dominate the species assemblage of the Experimental Burn, constituting nearly 40% of the sample. Limnephilidae caddis larvae, which had been abundant for the previous three years, were reduced to less than 5%. In their place the mayfly *Leptophlebia vespertina* and the caddis *Plectrocnemia conspersa* were the next most common species.

Results from the statistical analysis on the macroinvertebrate data are presented in Table 2. The gradient lengths obtained using Detrended Correspondence Analysis on the macroinvertebrate data from three study burns confirmed their suitability for Principal Components Analysis. In all streams the variance explained by time is small compared to variance on the Principal Component. Subsequent significance tests suggest that there are no time trends at any of the three sites and thus demonstrate that cattle have not as yet had a detectable effect on the macroinvertebrate fauna of the Experimental Burn.

Table 2 Macroinvertebrate Trend Test Statistics

	λ_1^{PCA}	λ_1^{RDA}	$\lambda_1^{RDA}/\lambda_1^{PCA}$	**Restricted P Value**
Control Burn	0.35	0.19	0.54	0.25
Experimental Burn	0.33	0.14	0.42	0.55
Allt Riabhach na Bioraich Burn	0.43	0.15	0.35	0.81

5.2.3 AQUATIC MACROPHYTES

Tables 7, 8 and 9 summarize aquatic macrophyte data for the three study burns and Figures 3 to 5 illustrate the survey stretches. Surveys were not performed in 2000 due to time constraints. Sampling of the Experimental Burn in 2001 was impossible due to physical erosion of the survey stretch. Aquatic macrophyte cover for the two surveyed burns remained consistent with previous years although total cover in the Control burn was slightly less than the maximums recorded in the first three years of monitoring. The Allt Riabhach na Bioraich Burn continued to have the least aquatic macrophyte cover of any study burn in 2001. As in the Control Burn the liverwort *Scapania undulata* was the most abundant species.

5.2.4 FISH

Data for the fish populations in the three study burns are presented in Figures 33 to 35 and Table 10. Trout are continuing to spawn in all three burns with young fish more abundant in each than when sampled in 2000. Increases in young fish are especially apparent in the Control and Experimental burns. More mature fish continue to be less abundant however, especially in the Control Burn where numbers have been low in six of the nine years studied. In the Experimental Burn the gradually rising trend in mature fish density observed in the previous report (Shilland *et al.* 2001) has not persisted as numbers have fallen slightly in 2001. The data would not appear to show consistently rising or falling Trout densities in either age class in any of the burns.

6 DISCUSSION

The statistics performed on the macroinvertebrate and diatom data continue to identify no significant temporal trends as yet. It seems that management changes have not detectably affected the biology of the Experimental Burn. Potential trends of increasing alkalinity and selected base cations at the Lower Experimental Burn sampling location, relative to the Control Burn, were not proved statistically significant when flow was also accounted for. Further monitoring should help to establish whether or not a more robust trend presents itself, though it is too early to speculate on the potential biological or hydrological causes of any increases.

From the data it is clear that the Allt Riabhach na Bioraich Burn provides a very good baseline for the investigation of further experimental grazing. Indeed Larsen *et al.* (1998) identify a lack of pre-experimental data as a key limitation in the design of the majority of livestock grazing studies. Seven years of biological and chemical data are now available to provide this essential basis for comparison.

For the first time physical erosion by cattle of the stream banks of the Experimental Burn rendered the usual aquatic macrophyte survey stretch unsuitable for sampling in 2001. With its smaller width this stream is more vulnerable to such disturbance than the other two study burns. Bank erosion and the commensurate exposure of stream-bank soil have been seen in other studies (Wohl & Carline, 1996, Sovell *et al*. 2000) and are one of the more obvious and frequently encountered effects of riparian cattle grazing.

The extension to the aquatic macrophyte monitoring programme discussed in the last report (Shilland *et al*. 2001) has unfortunately been abandoned. Despite an extensive search it proved impossible to find a suitable representative control stretch in Loch Laidon to compare to the shallow bay where the Allt Riabhach na Bioraich Burn enters the loch. It would appear that this bay is unique within the study area in terms of its substrates and aquatic macrophyte assemblage.

The Loch Laidon land-use study continues to accumulate an extremely valuable dataset that is also wholly compatible with the Acid Waters Monitoring Network (Monteith *et al.* 2000). In a review paper of studies investigating the effects of livestock on streams Larsen *et al*. (1998) note the paucity of projects continuing longer than three years and state that “Long term studies are rare, but they offer the best solution for clarifying linkages between land use and environmental impacts.”

7 ACKNOWLEDGEMENTS

Funding for this work comes from the Rannoch Trust and Scottish Natural Heritage. Special thanks go to Nicholas Thexton for the collection of water samples.

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Figure 1 The Loch Laidon catchment indicating the boundaries of Rannoch Moor NNR and SSSI.

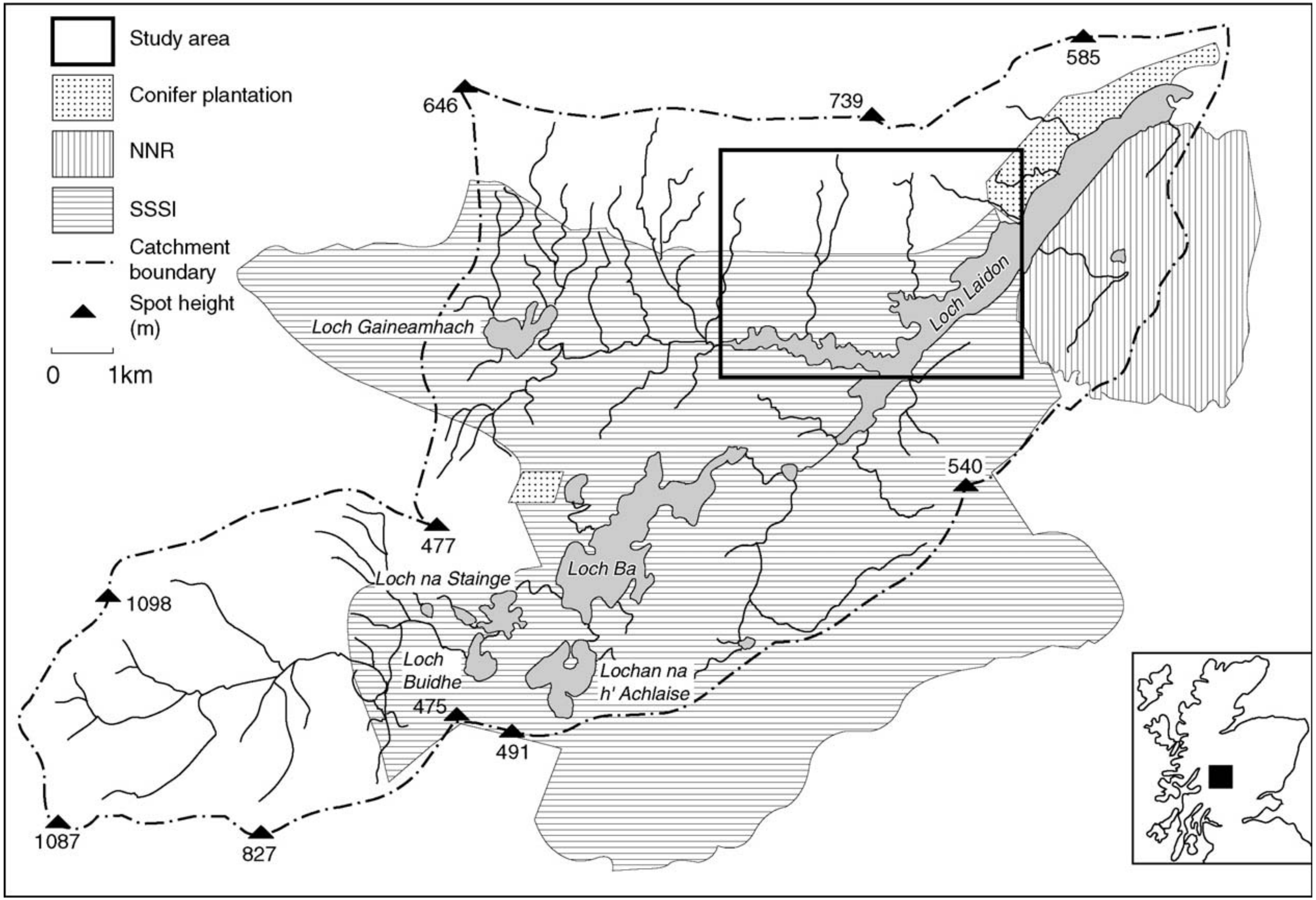

Figure 2 Loch Laidon study area.

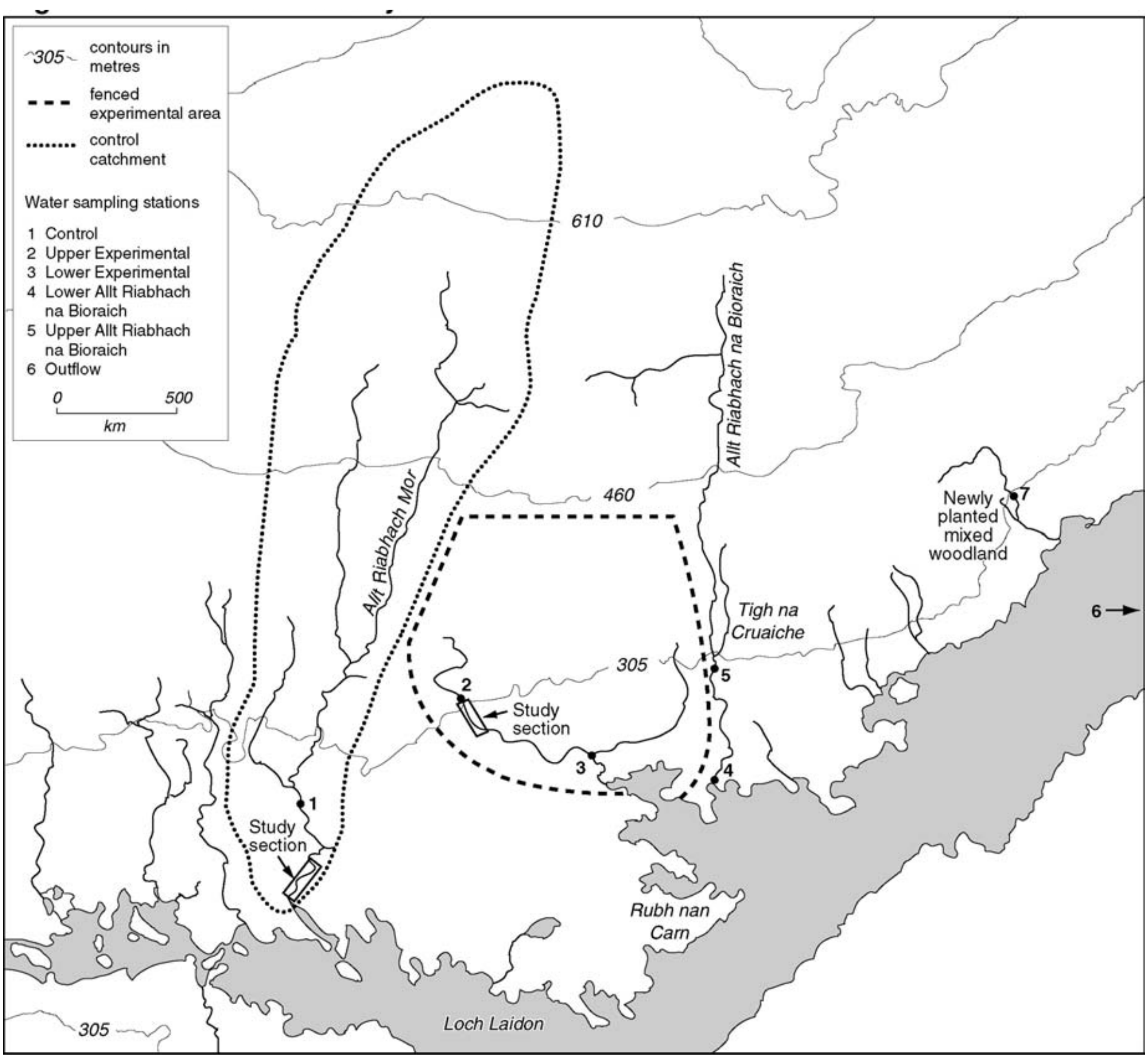

Figure 3 Control Burn

Figure 4 Experimental Burn

Figure 5 Allt Riabhach na Bioraich Burn

Figure 6 The ratio of alkalinity and its temporal variability in spot samples from the Experimental and Control burns, August 1992 – December 2001.

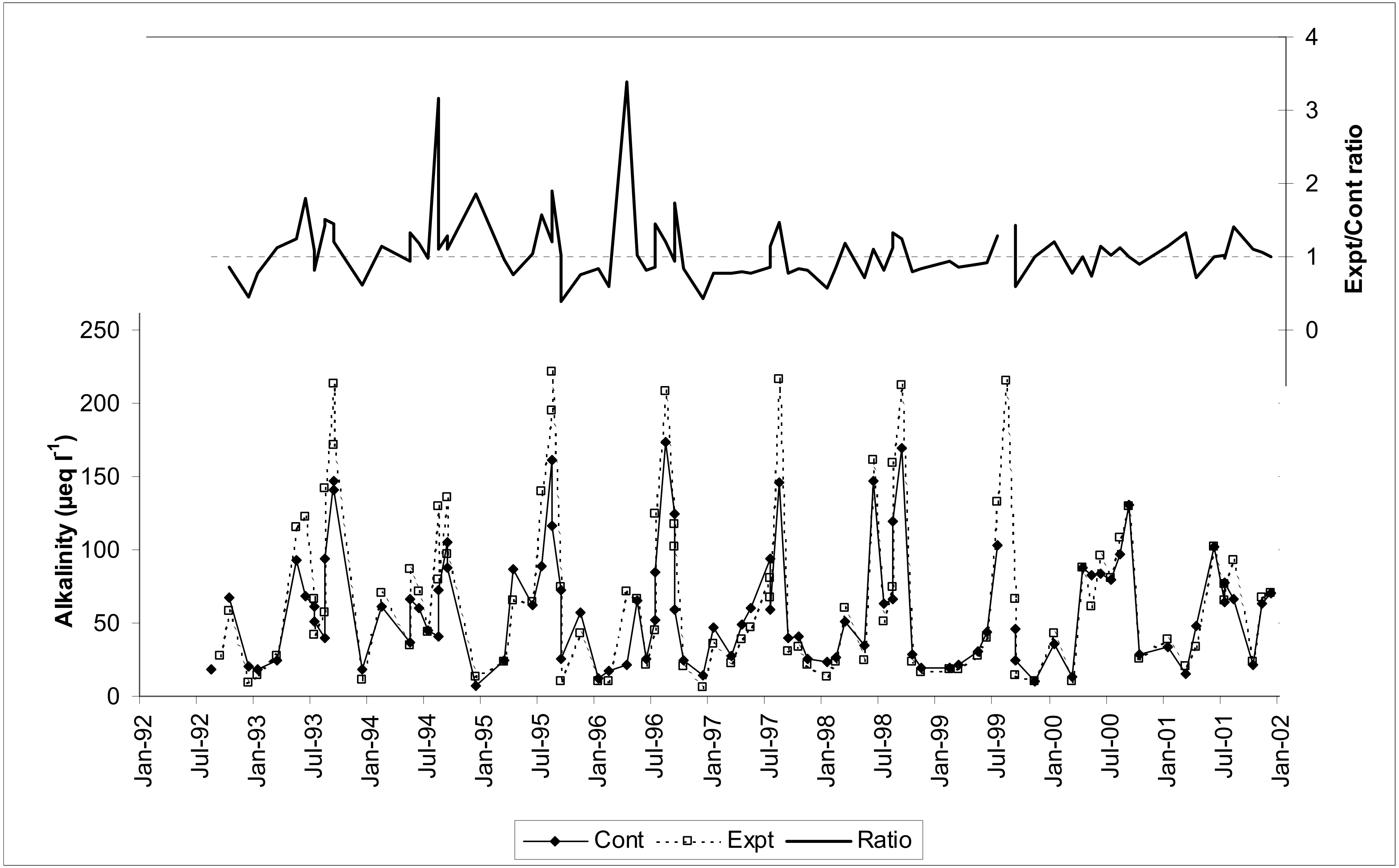

Figure 7 The ratio of conductivity and its temporal variability in spot samples from the Experimental and Control burns, August 1992 – December 2001.

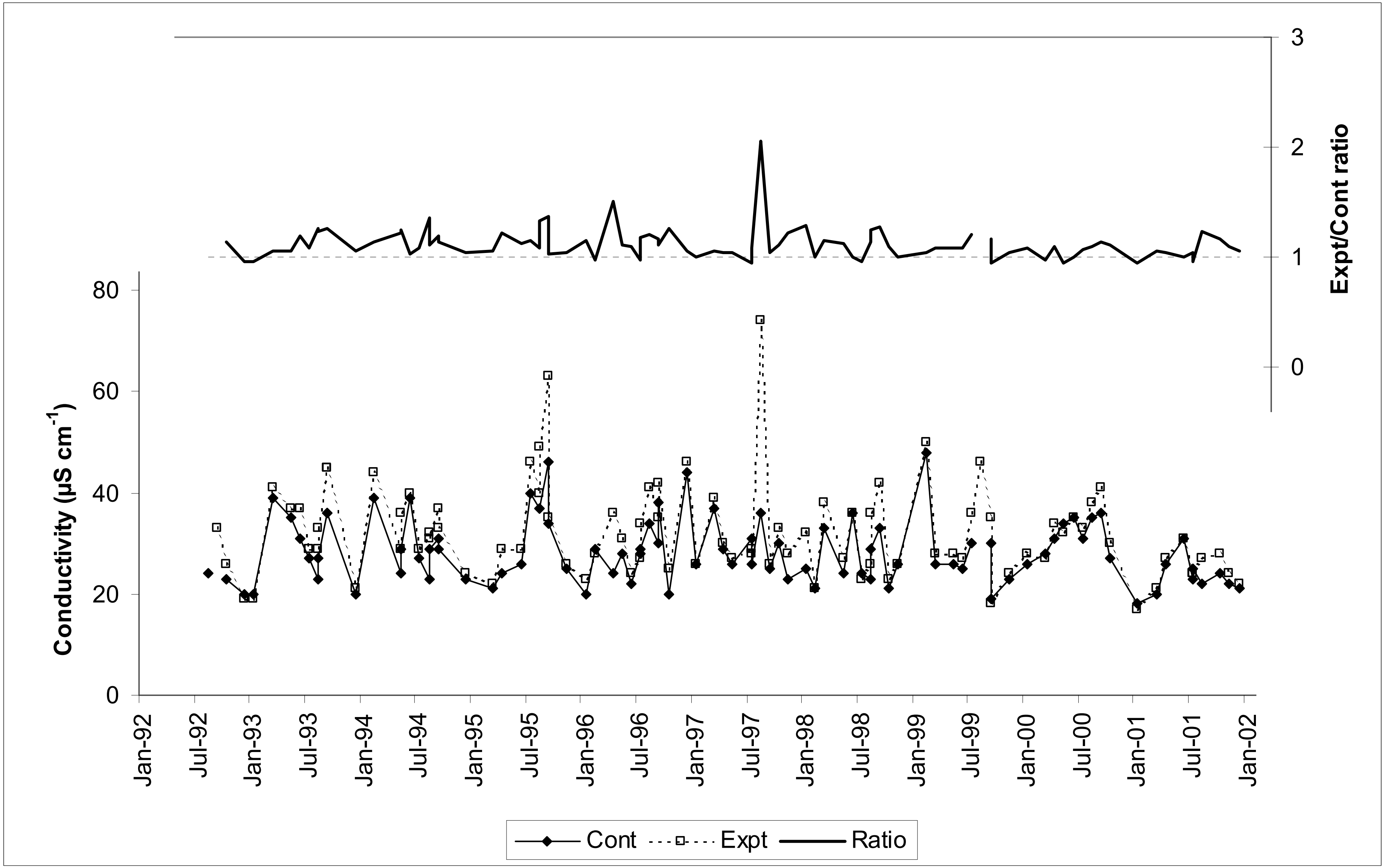

Figure 8 Temporal variability of nitrate in spot samples from the Experimental and Control Burns, August 1992- December 2001.

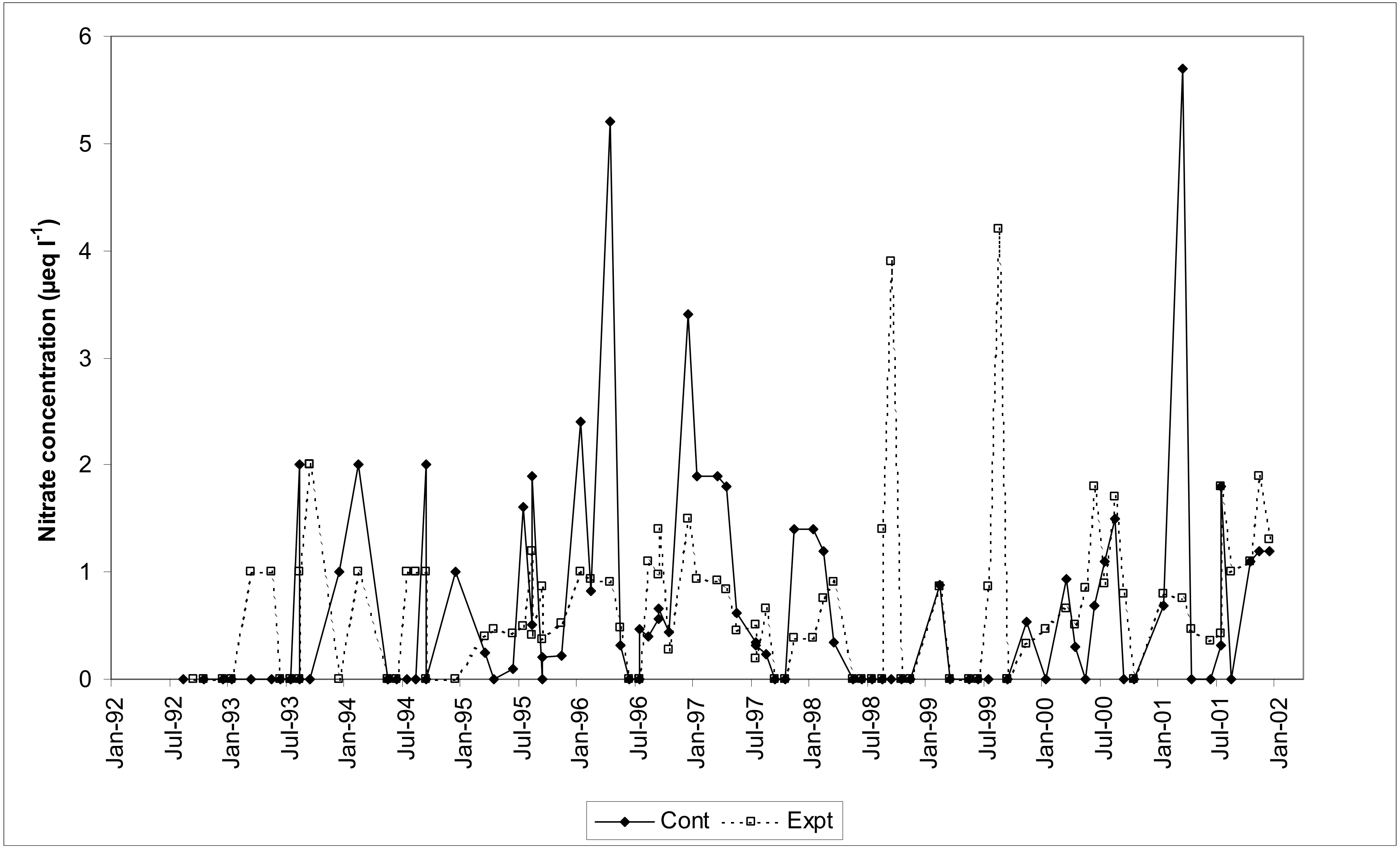

Figure 9 The relationship between the ratio of alkalinity in spot samples from the Experimental and Control burns and the stage board height of the Control burn over the period August 1992 – December 2001.

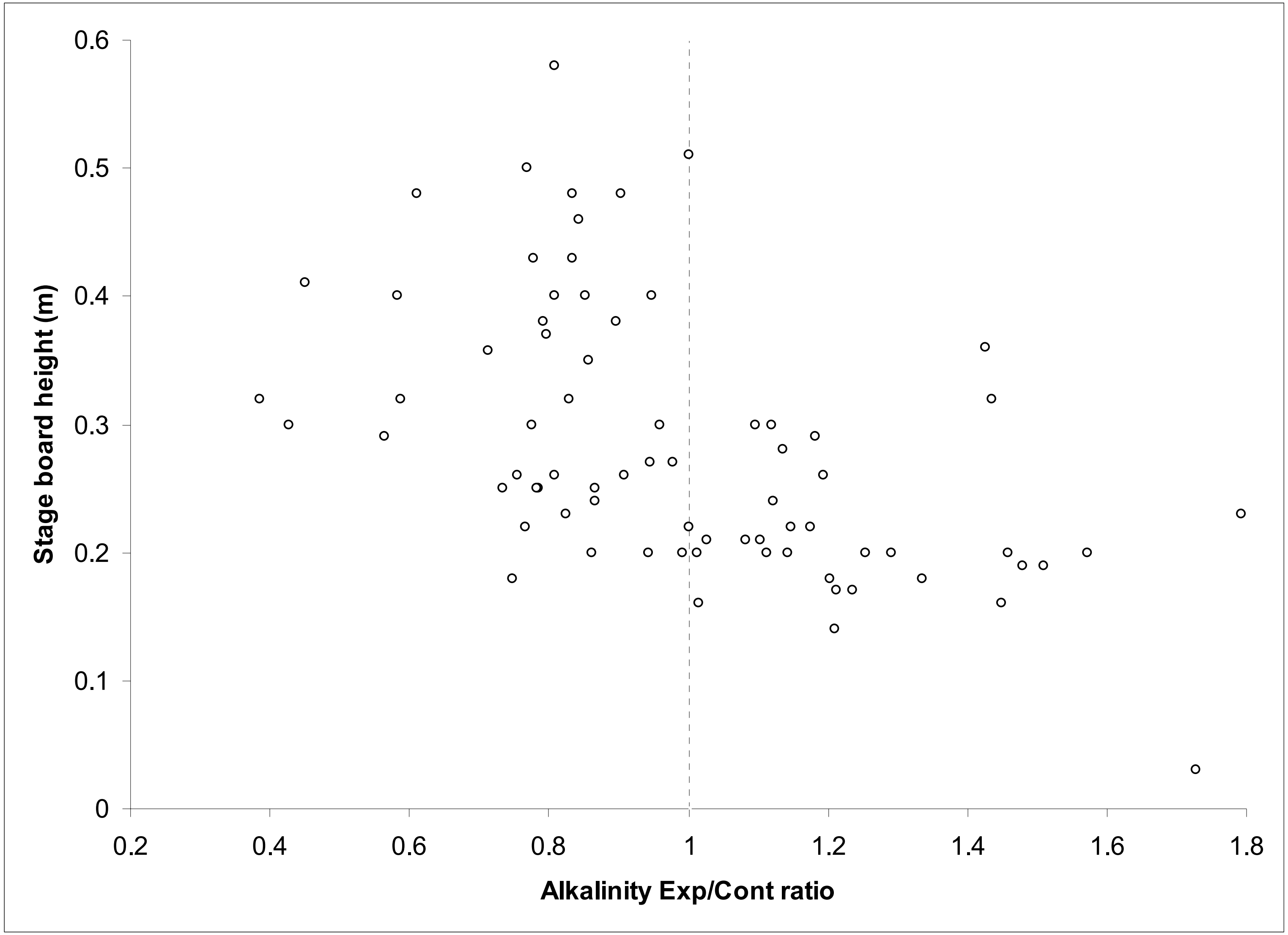

Figure 10 Comparison of the nitrate concentration of the Control and Experimental Burn (Lower site) June 1995 – December 2001.

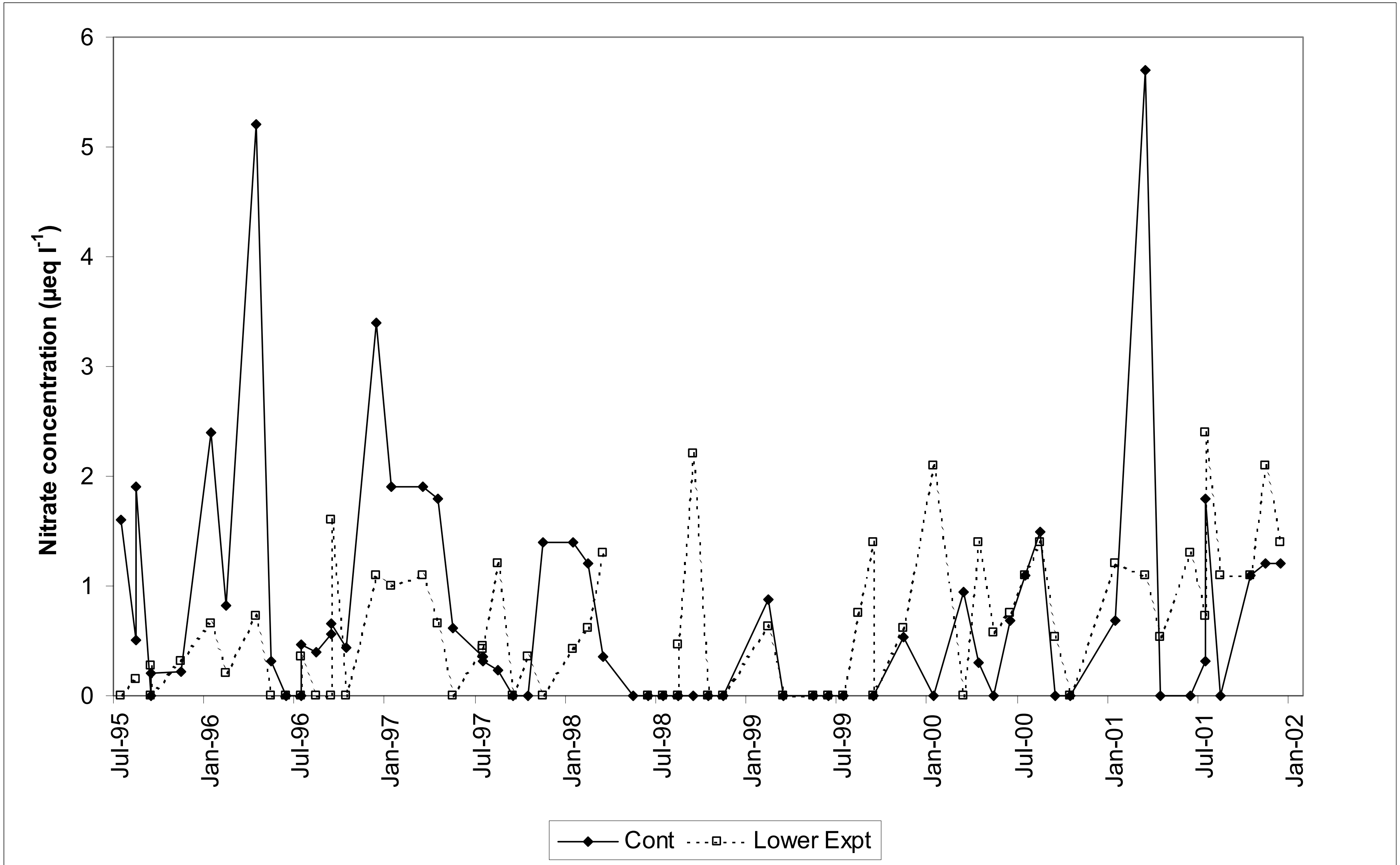

Figure 11 The ratio of alkalinity and its temporal variability in spot samples from the Control and Experimental Burn (Lower site) June 1995 – December 2001.

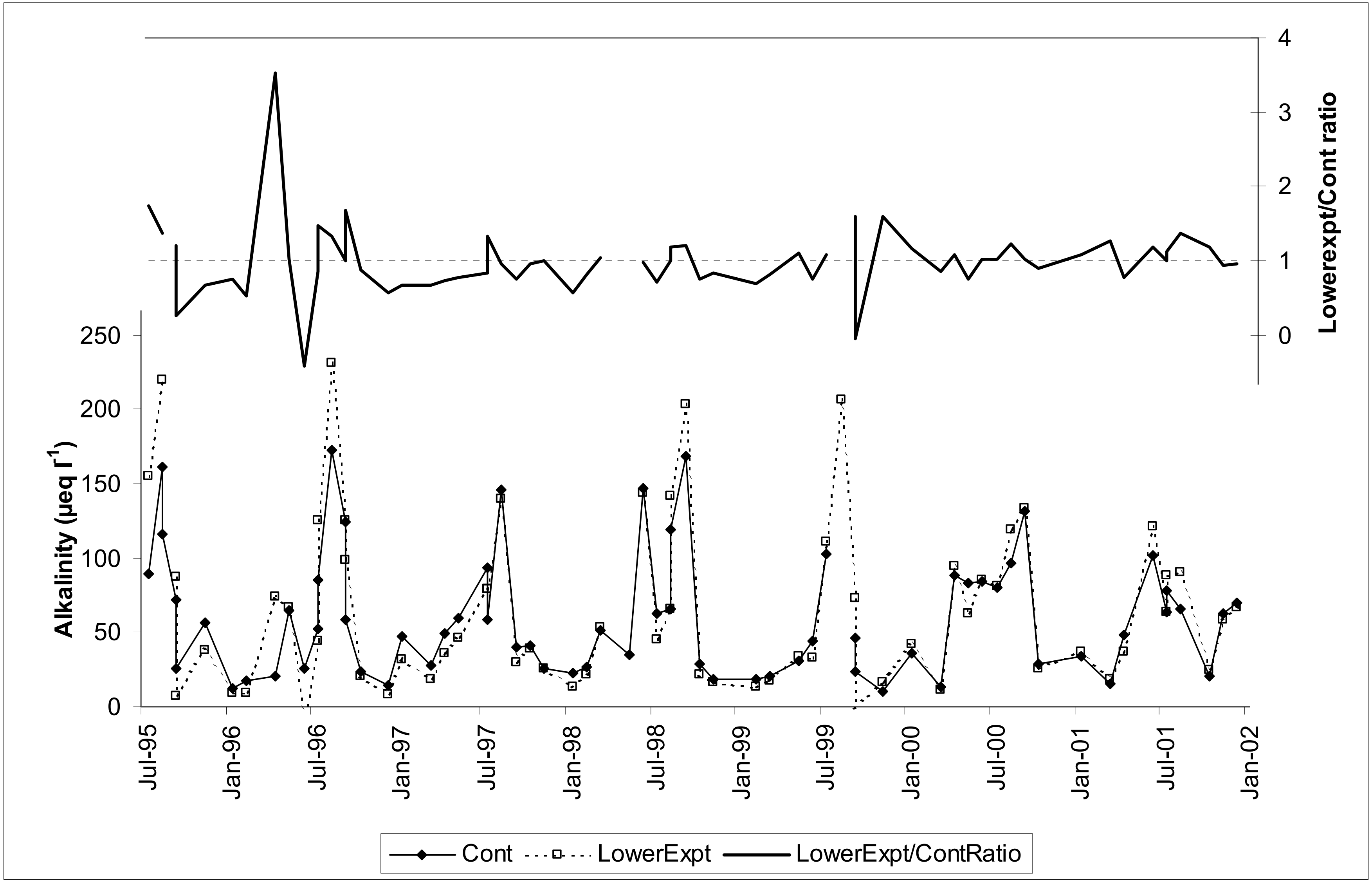

Figure 12 The ratio of Calcium and its temporal variability in spot samples from the Control and Experimental Burn (Lower site) June 1995 – December 2001.

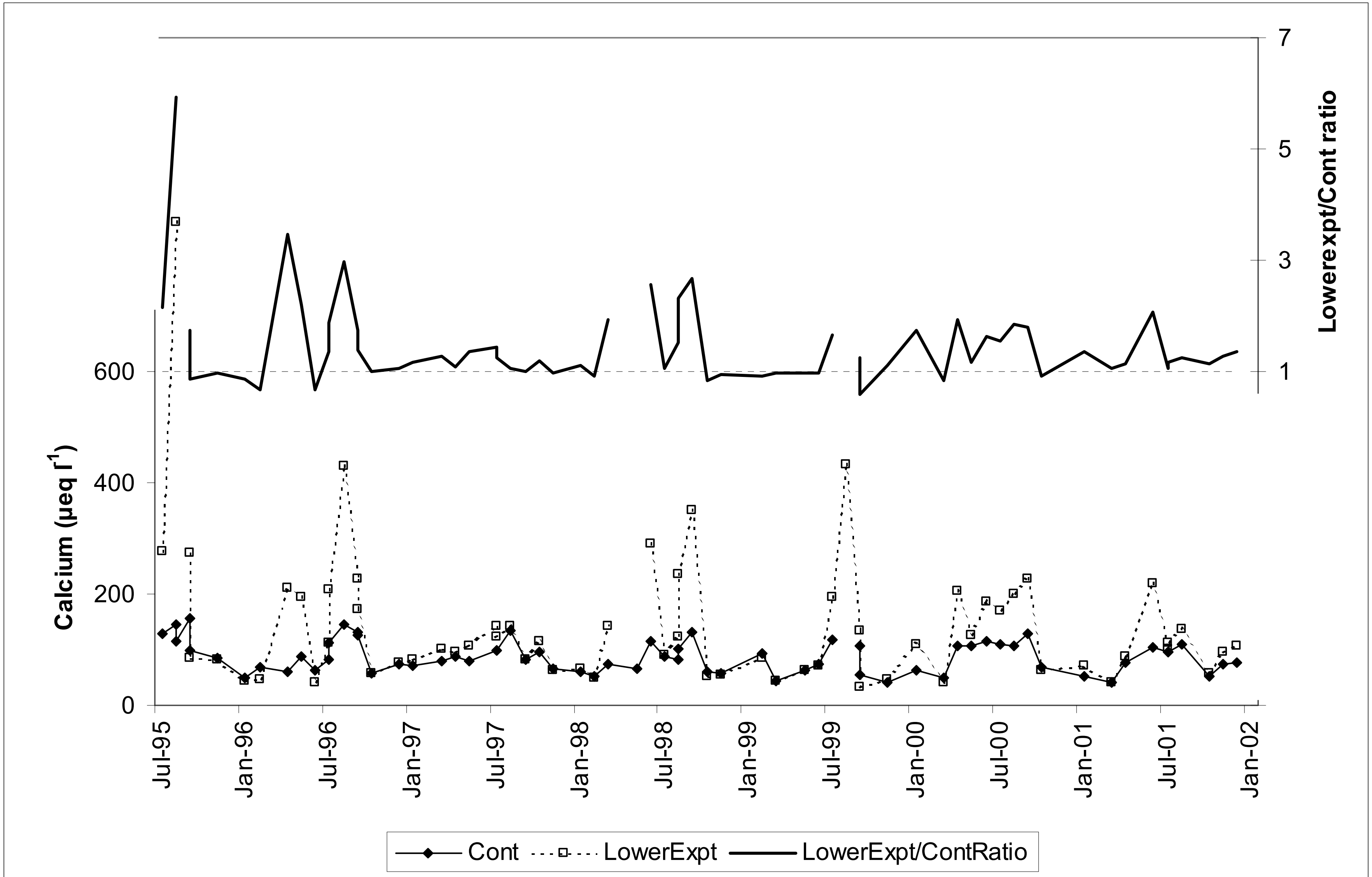

Figure 13 The ratio of Magnesium and its temporal variability in spot samples from the Control and Experimental Burn (Lower site) June 1995 – December 2001.

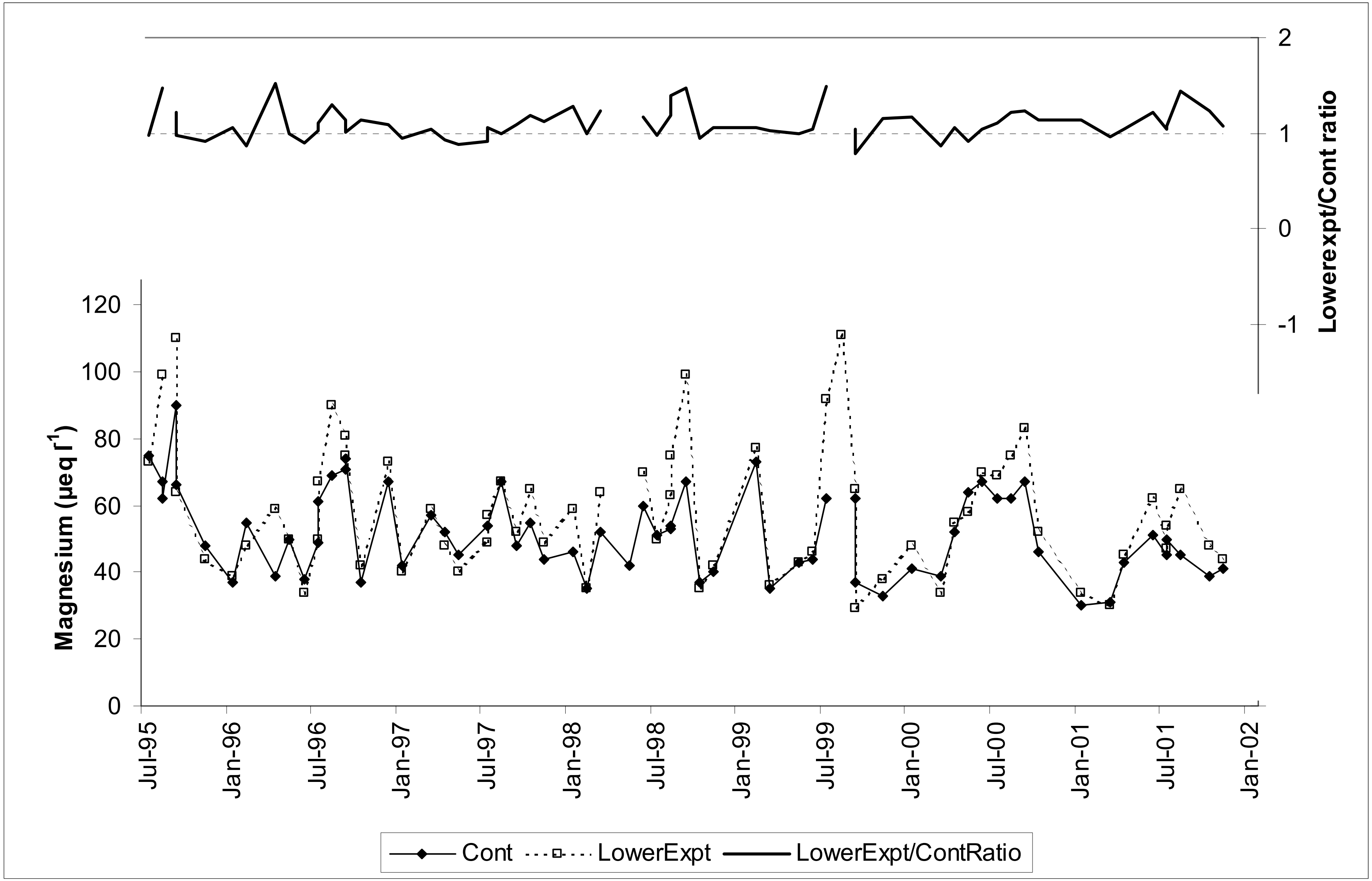

Figure 14 The ratio of Potassium and its temporal variability in spot samples from the Control and Experimental Burn (Lower site) June 1995 – December 2001.

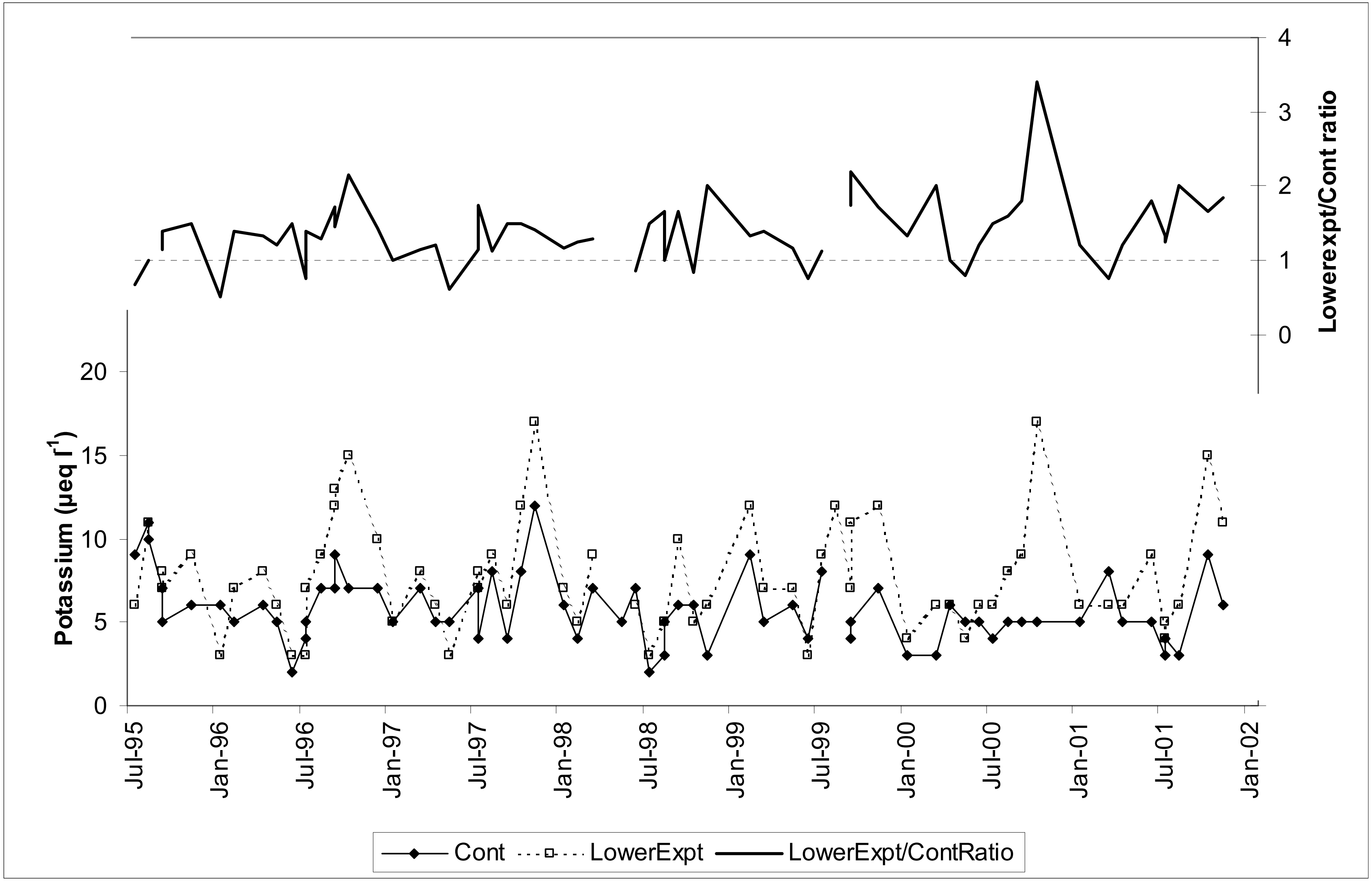

Figure 15 The ratio of conductivity and its temporal variability in spot samples from the Control and Experimental burn (Lower site) June 1995 – December 2001.

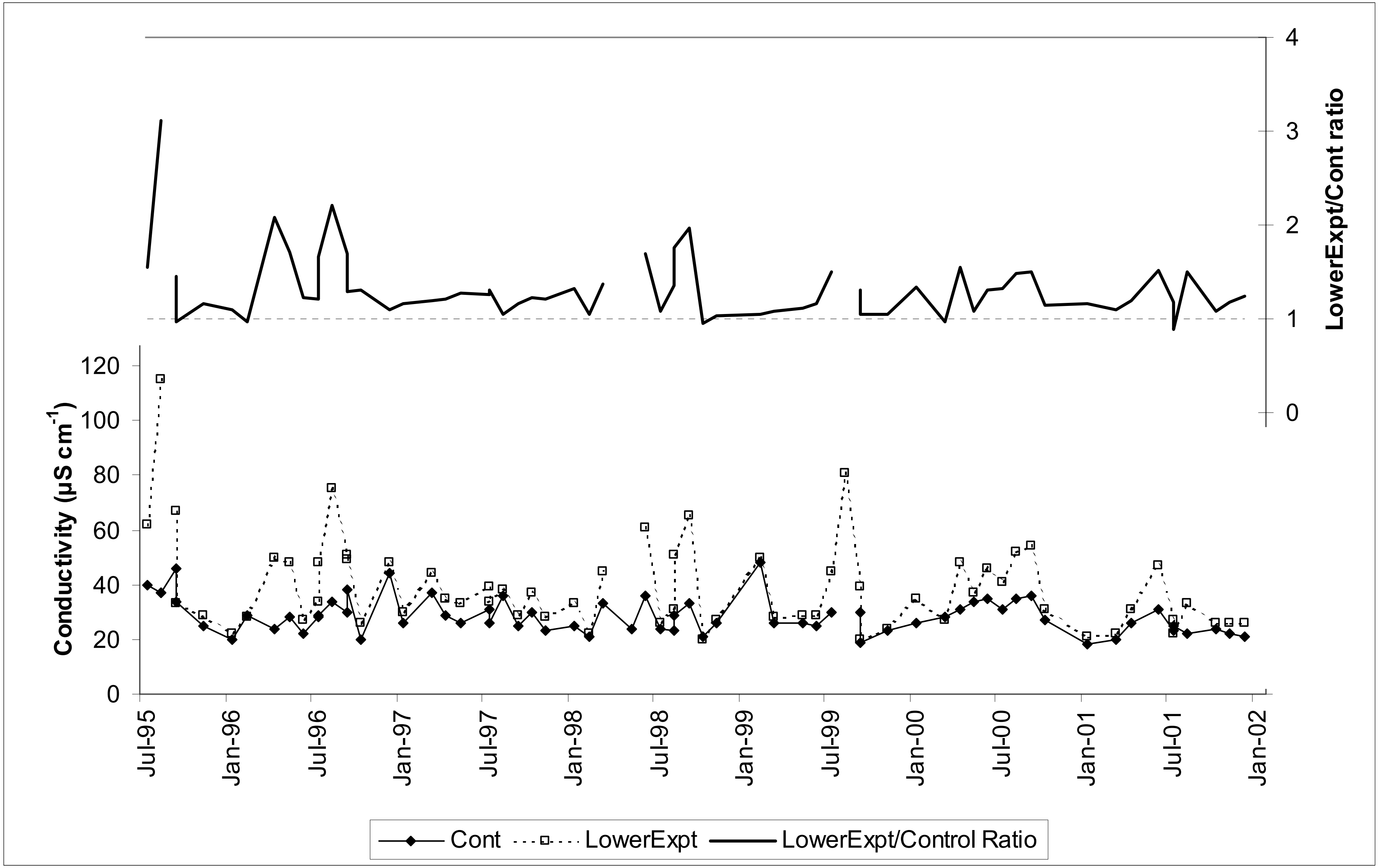

Figure 16 Residuals for Lower Experimental-Control Alkalinity once the effect of 'hydrology' has been removed.

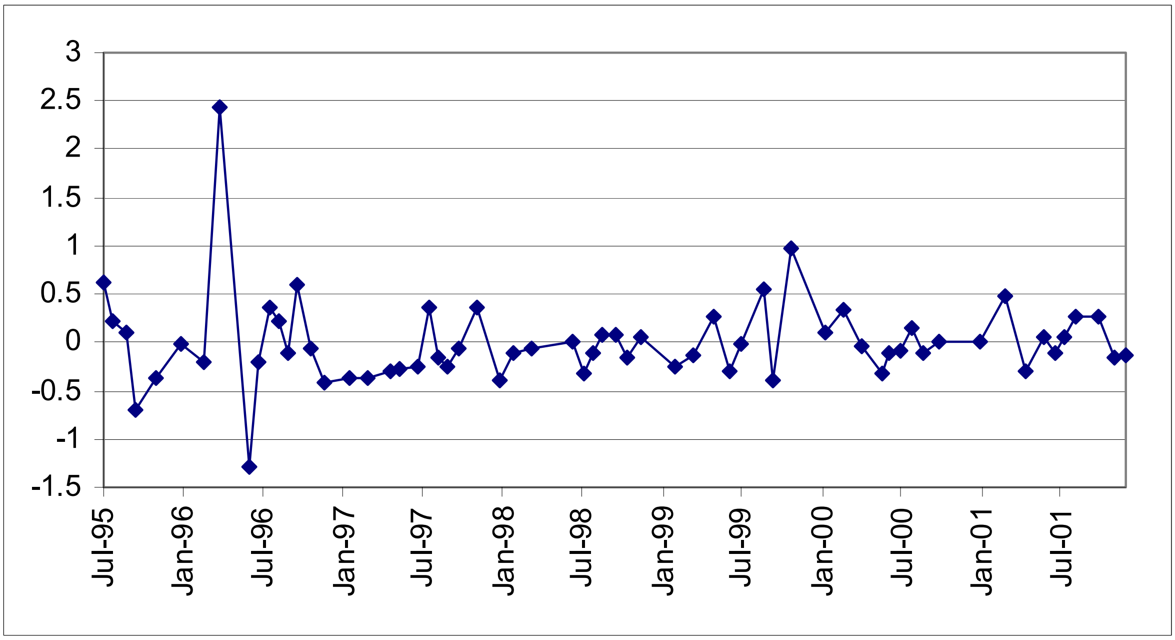

Figure 17 Residuals for Lower Experimental-Control Calcium once the effect of 'hydrology' has been removed

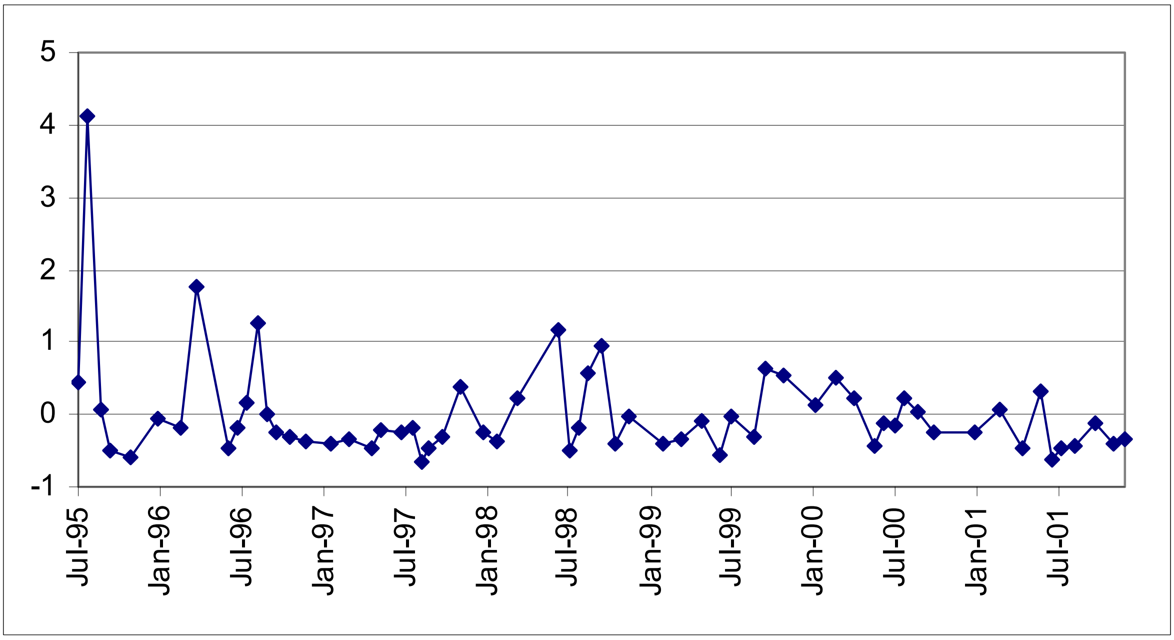

Figure 18 Residuals for Lower Experimental-Control Magnesium once the effect of 'hydrology' has been removed

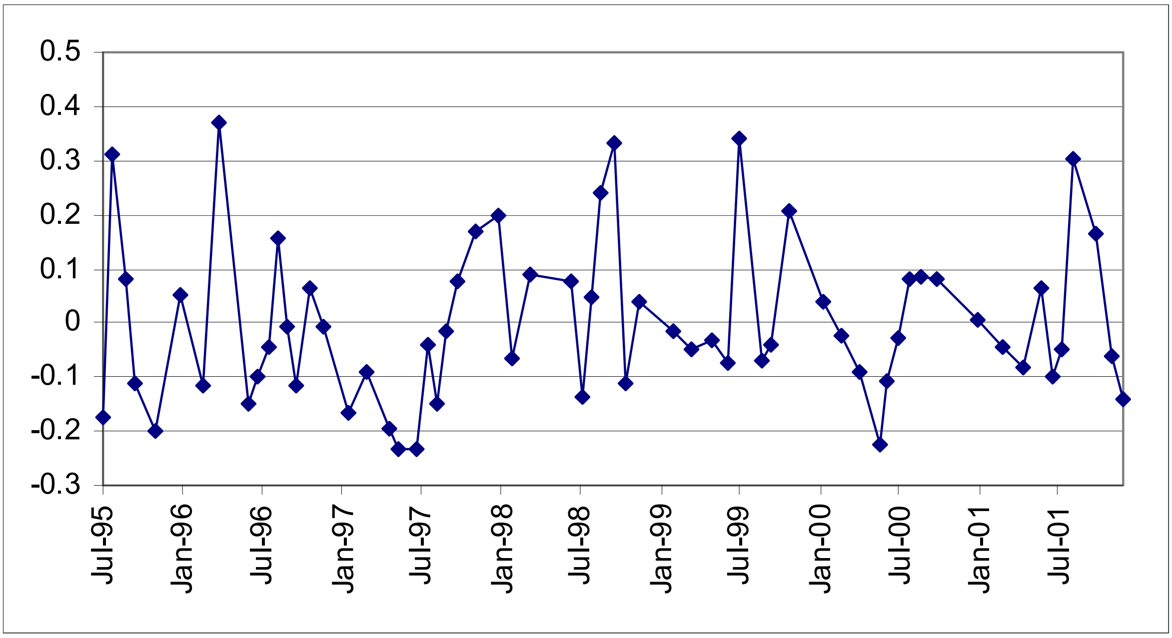

Figure 19 Residuals for Lower Experimental-Control Potassium once the effect of 'hydrology' has been removed

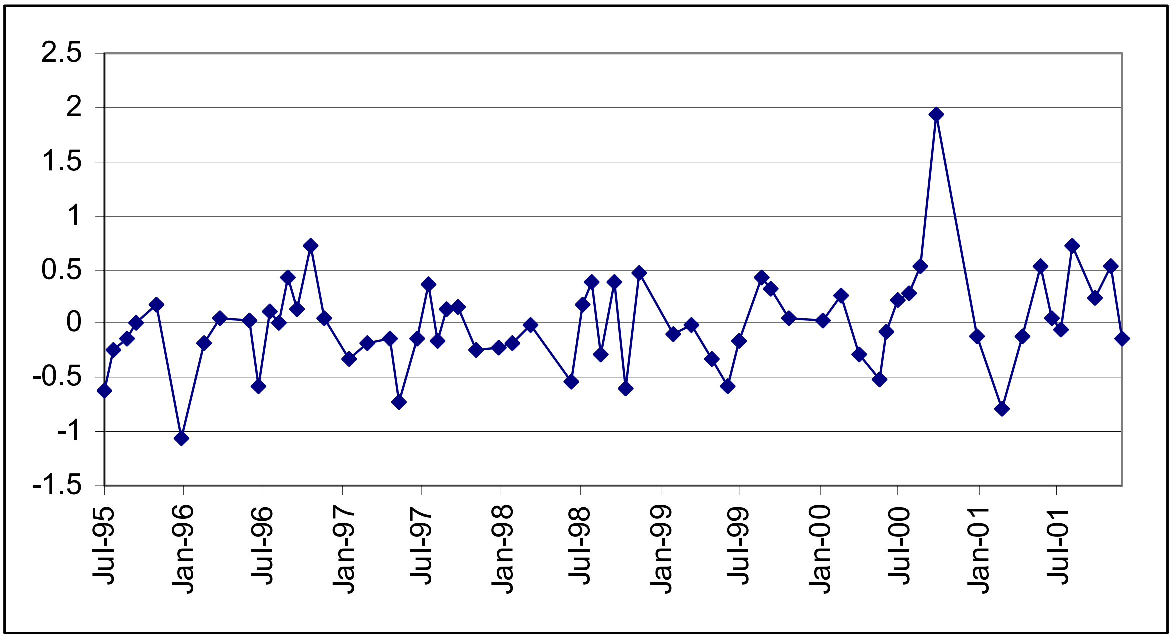

Figure 20 A comparison of alkalinity in spot samples from the Control burn, Experimental burn (Lower site) and the Allt Riabhach na Bioraich, June 1995 – December 2001.

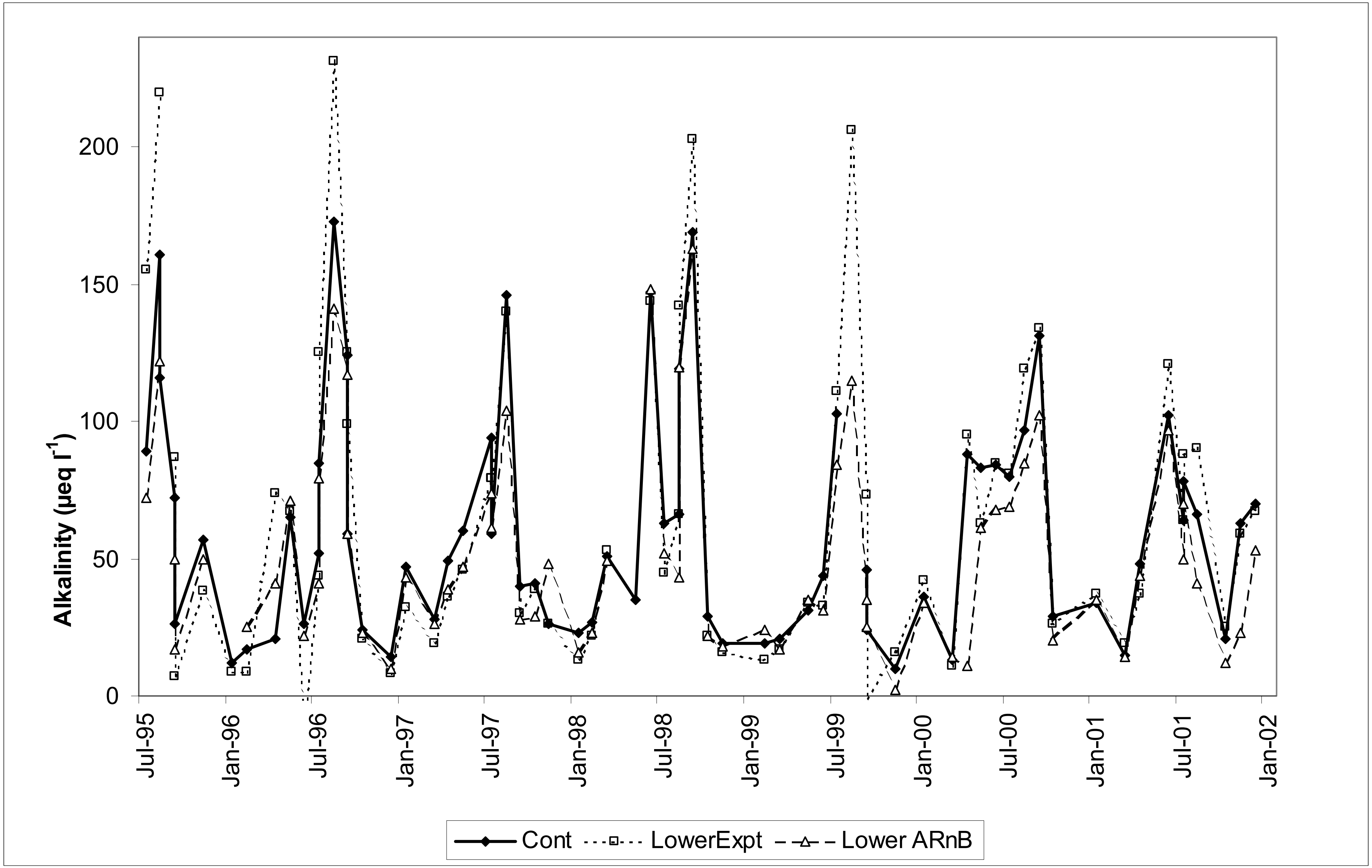

Figure 21 A comparison of conductivity of spot samples from the Control burn, Experimental burn (Lower site) and the Allt Riabhach na Bioraich, June 1995 – December 2001.

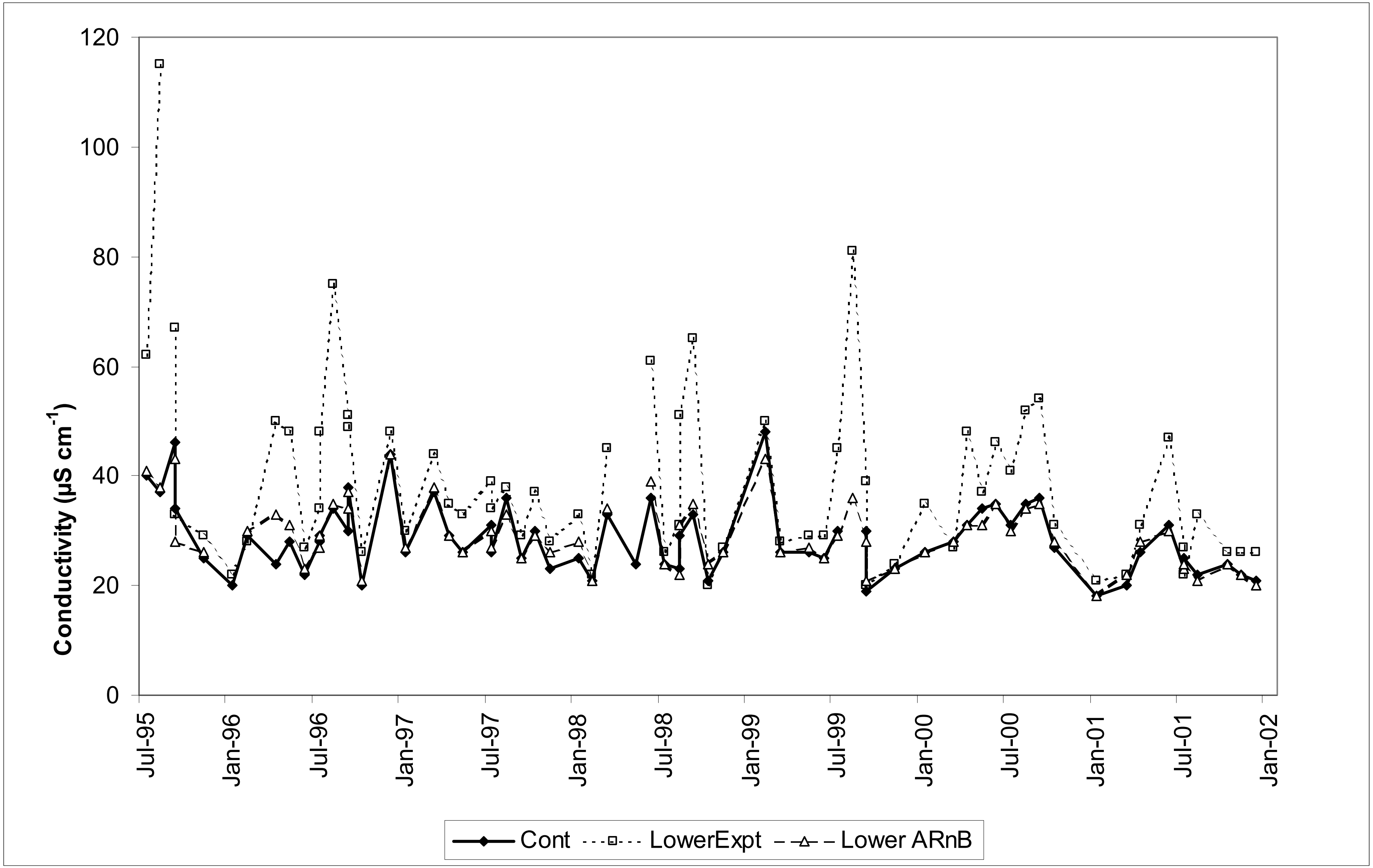

Figure 22 A comparison of nitrate concentrations of spot samples from the Control burn, Experimental burn (Lower site) and the Allt Riabhach na Bioraich, June 1995 – December 2001.

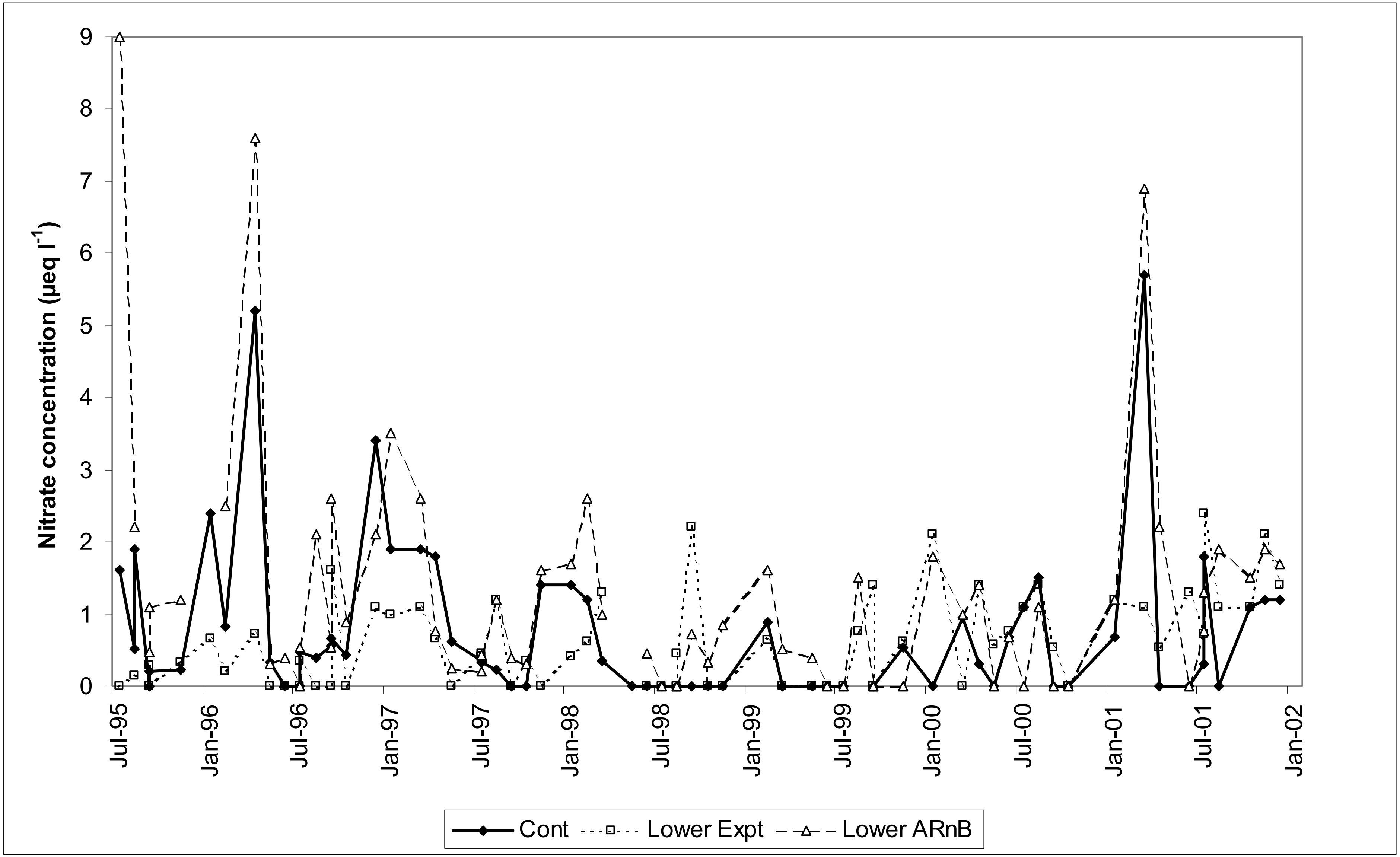

Figure 23 A comparison of Total Organic Carbon concentrations of spot samples from the Control burn, Experimental burn (Lower site) and the Allt Riabhach na Bioraich, June 1995 – December 2001.

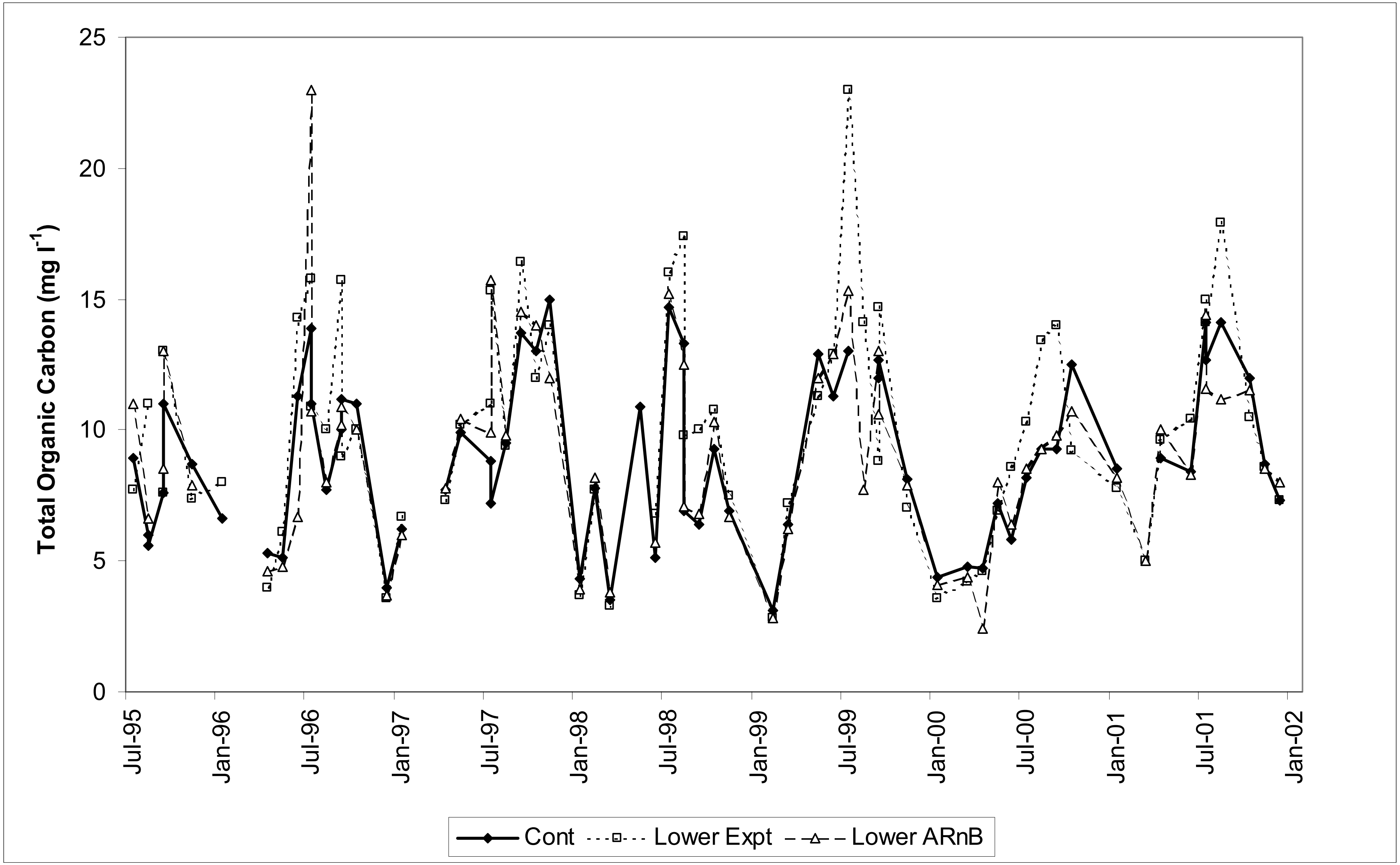

Figure 24 Control Burn Diatom Abundances

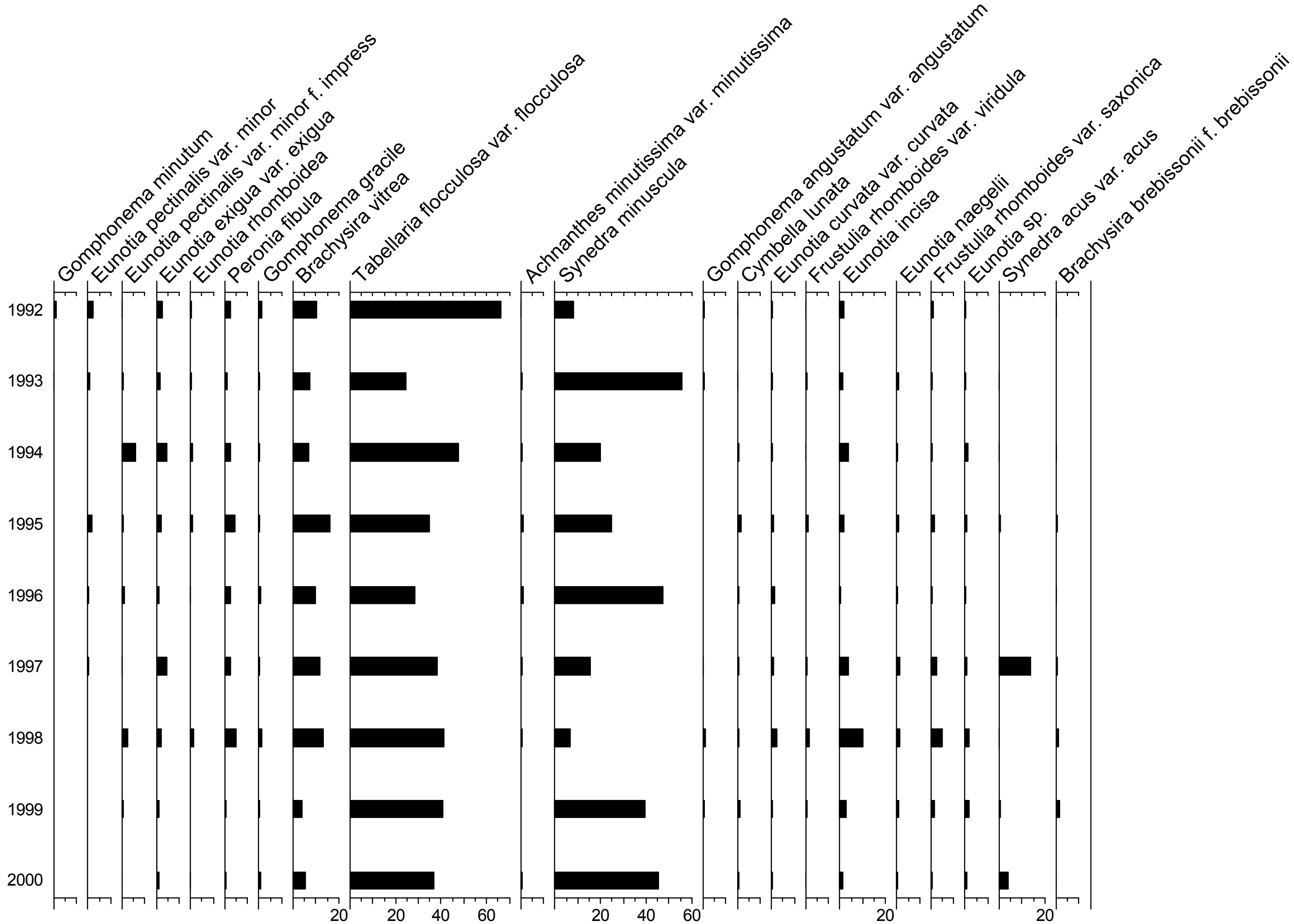

Figure 25 Experimental Burn Diatom Abundances

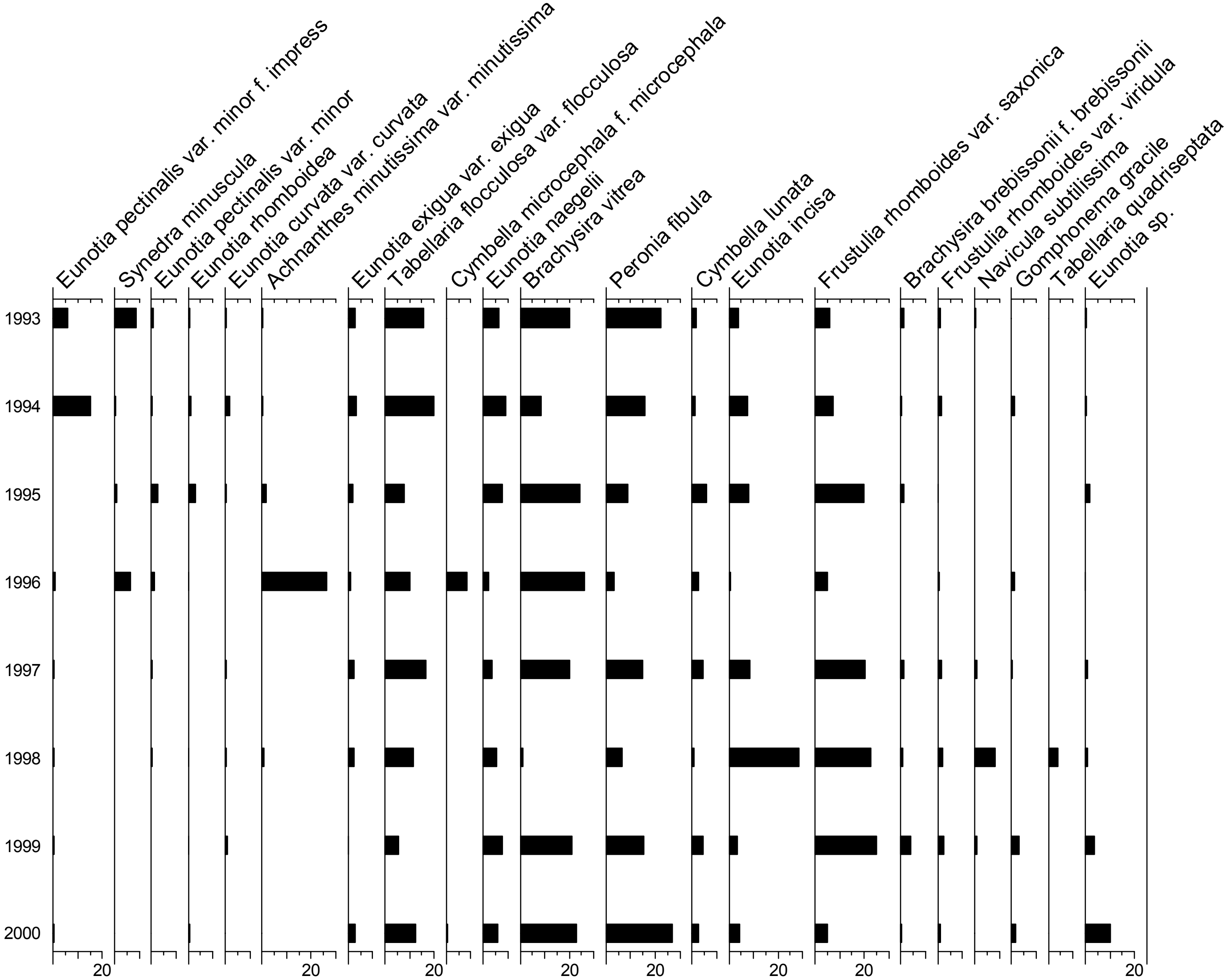

Figure 26 Allt Riabhach na Bioraich Diatom Abundances

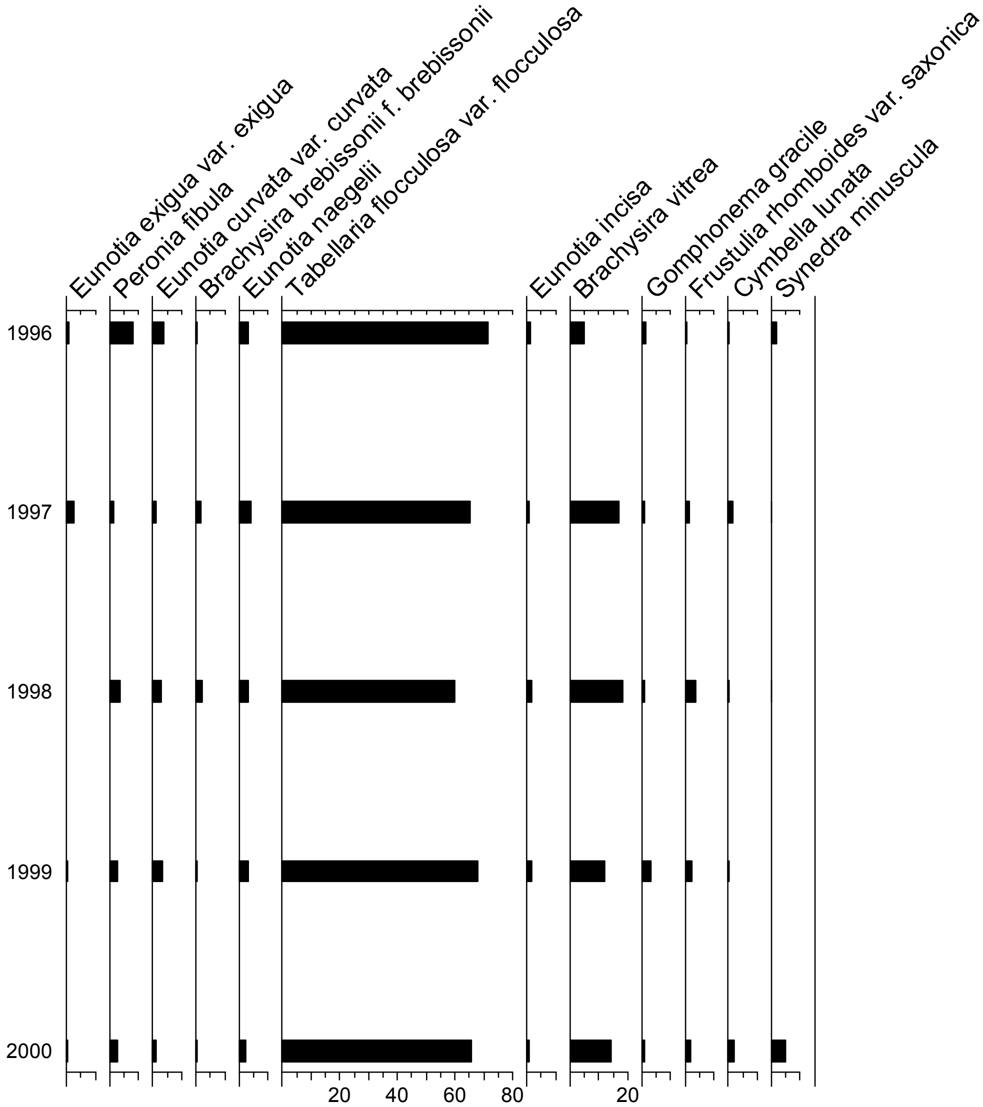

Figure 27 Control Burn Macroinvertebrate Abundances

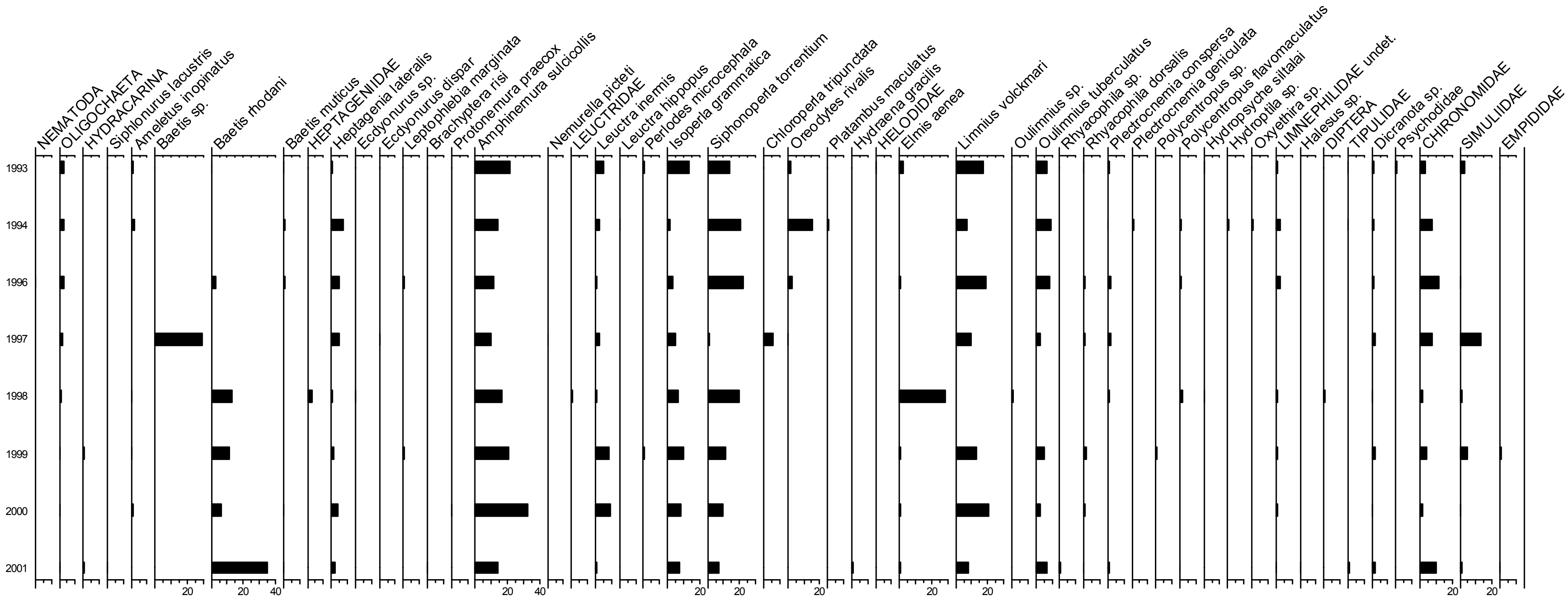

Figure 28 Experimental Burn Macroinvertebrate Abundances

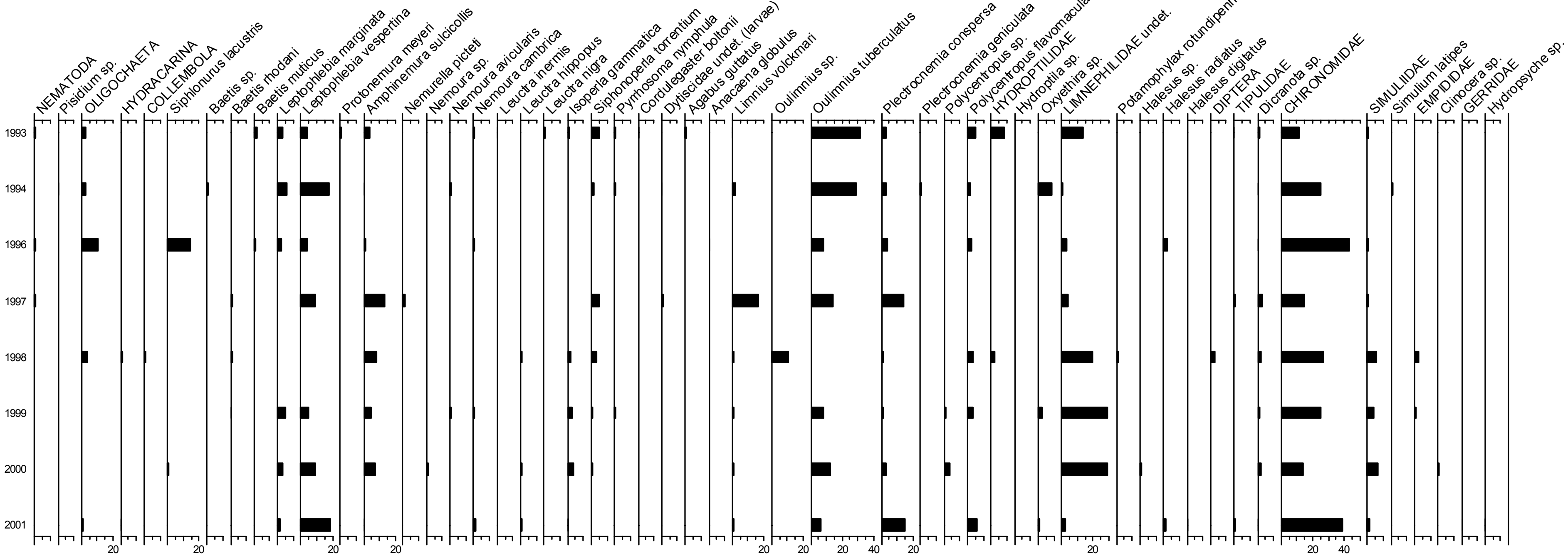

Figure 29 Allt Riabhach na Bioraich Burn Macroinvertebrate Abundances

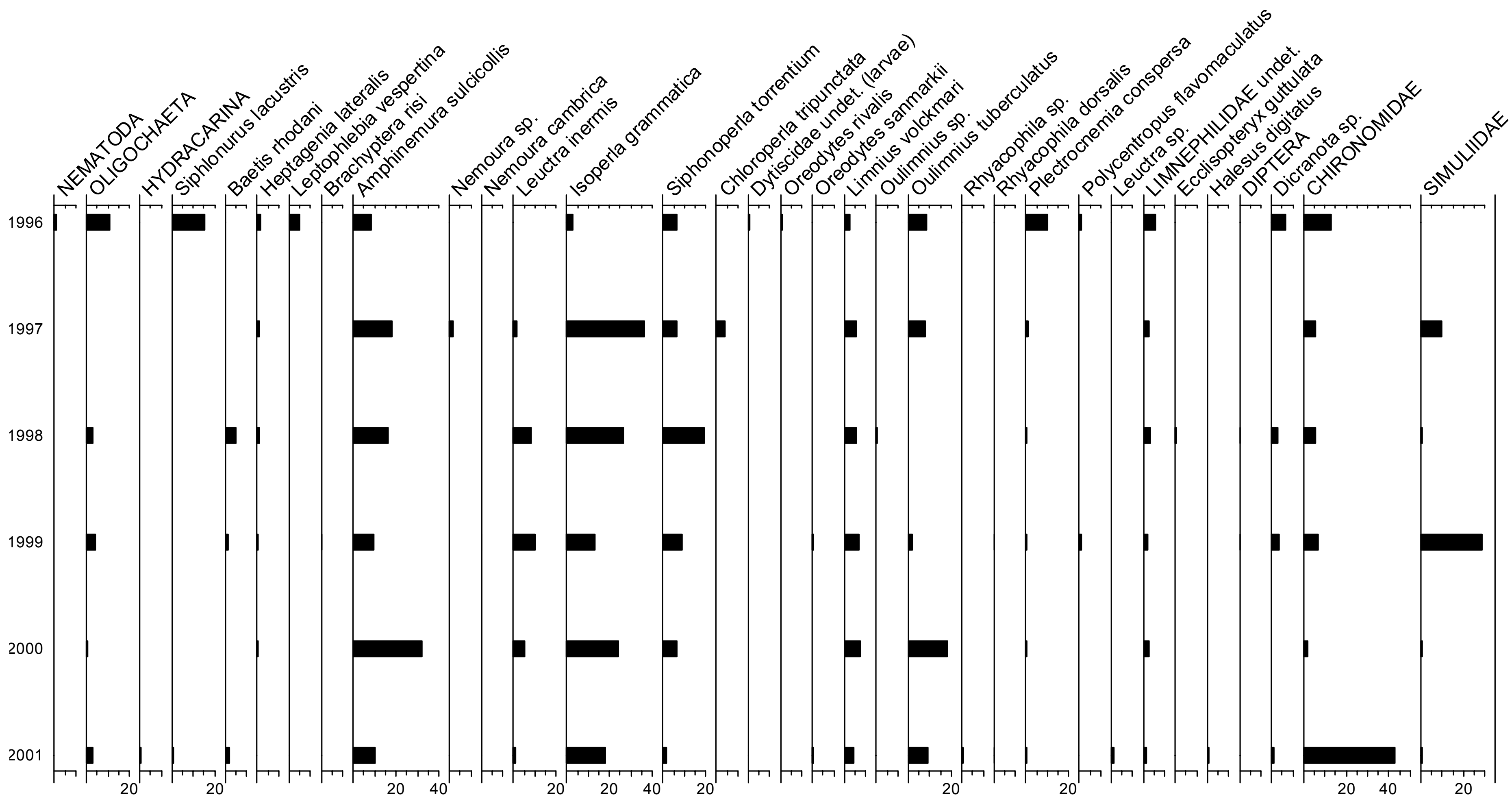

Table 3 Macroinvertebrate taxon list and total abundances.

TAXON	CONTROL BURN								EXPERIMENTAL BURN								ALLT RIABHACH NA BIORAICH BURN					
	1993	**1994**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**1993**	**1994**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
NEMATODA			1						2		1	1					1					
Pisidium sp.										1												
OLIGOCHAETA	22	6	8	3	5	2	1	3	14	10	26		3			3	12		5	12	1	13
HYDRACARINA						1		4					1			1						2
COLLEMBOLA													1									
Siphlonurus lacustris								1			35				1		17					3
Ameletus inopinatus	11	4			1	1	3															
Baetis sp.				52						1												
Baetis rhodani	5		7		39	30	20	142				1	1	1					8	4		8
Baetis muticus	3	2	3				1	1	9		3											
HEPTAGENIIDAE					9																	
Heptagenia lateralis	3	18	11	9	2	3	13	10									2	1	2	1	2	
Ecdyonurus sp.					1																	
Ecdyonurus dispar				1																		
Leptophlebia marginata			1			1			16	19	6			7	5	3						
Leptophlebia vespertina									20	61	9	9		7	15	42	5					
Brachyptera risi								1												1		
Protonemura praecox							1															
Protonemura meyeri									1													
Amphinemura sulcicollis	168	32	27	17	52	54	103	57	20	1	2	14	7	7	12	1	9	23	28	25	99	45
Nemurella picteti				1								1										
Nemoura sp.															1			2				
Nemoura avicularis										2				1								
Nemoura cambrica									2		1			1		3				1		
LEUCTRIDAE					1																	
Leuctra inermis	41	6	1	5	3	22	30	2	1									2	14	27	17	3
Leuctra hippopus		1											1		1	1						
Leuctra nigra									1													

TAXON	CONTROL BURN								EXPERIMENTAL BURN								ALLT RIABHACH NA BIORAICH BURN					
	1993	1994	1996	1997	1998	1999	2000	2001	1993	1994	1996	1997	1998	1999	2000	2001	1996	1997	1998	1999	2000	2001
Perlodes microcephala	2					1																
Isoperla grammatica	106	4	8	9	20	25	25	32	7				2	4	6	1	3	46	45	36	74	79
Siphonoperla torrentium	109	48	54	2	61	29	30	29	23	5		5	3	1	2		7	8	33	24	20	8
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		1
Agabus guttatus									1													
Platambus maculatus		1																				
Hydraena gracilis								2														
Anacaena globulus											1											
HELODIDAE	1																					
Elmis aenea	17		1		88	2	1	1														
Limnius volckmari	129	16	46	17		34	65	32	2	5		17	1	1	1	2	3	7	9	18	22	20
Oulimnius sp.					3								9						1			
Oulimnius tuberculatus	55	22	21	5		14	8	27	151	98	19	15		12	20	14	9	10		4	56	40
Rhyacophila sp.								1														3
Rhyacophila dorsalis	1		1	2		4	2	1												1		2
Plectrocnemia conspersa	6	1	5	3	2			4	13	9	9	15	1	2	5	35	11	1	1	1	2	3
Plectrocnemia geniculata		2								1												
Polycentropus sp.						2								2	6							
Polycentropus flavomaculatus		2	3		4			1	23	6	6		3	5		13	1			3		
Hydropsyche siltalai	1				1																	
HYDROPTILIDAE									38				2									
Hydroptila sp.		2									1											
Oxyethira sp.		1								29				4		2						

TAXON	CONTROL BURN								EXPERIMENTAL BURN								ALLT RIABHACH NA BIORAICH BURN					
	1993	**1994**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**1993**	**1994**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
LIMNEPHILIDAE undet.	10	7	6		3	3	4	1	66	2	7	4	17	41	47	5	6	3	6	5	8	6
Ecclisopteryx guttulata																			1			
Potamophylax rotundipennis													1									
Halesus sp.								1							1							
Halesus radiatus											6					4						
Halesus digitatus																1						2
DIPTERA					2								2						1	1		
TIPULIDAE	2	1						2	1			1				1						
Dicranota sp.	8	2	3	3	1	5	1	8	6	2	1	3	2	2	3	1	7		5	9		5
Psychodidae	1																					
CHIRONOMIDAE	26	17	28	13	6	11	4	40	56	86	104	15	24	36	22	89	14	7	10	18	6	186
SIMULIIDAE	23		1	23	3	11	1	5	2		1	1	5	6	11	3		12	1	76	1	2
Simulium latipes										3												
EMPIDIDAE						2		1					2	1								
Clinocera sp.															1							
Leuctra sp.																						6
GERRIDAE																1						
Hydropsyche sp.																1						

Figure 30 Selected Control Burn Macroinvertebrate Summary Statistics

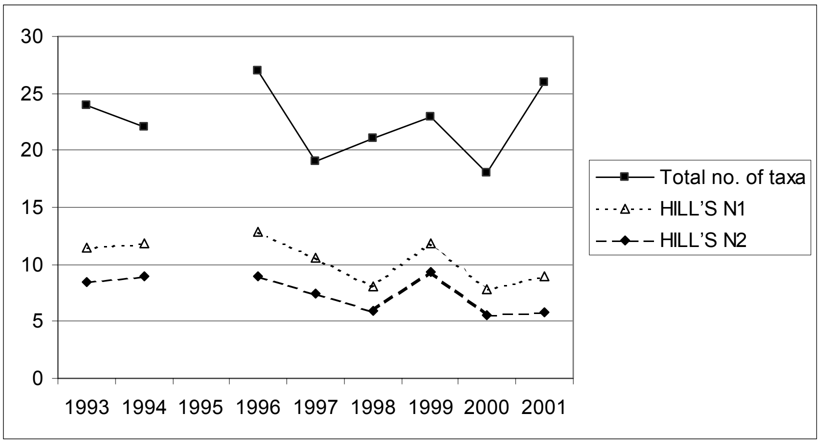

Figure 31 Selected Experimental Burn Macroinvertebrate Summary Statistics

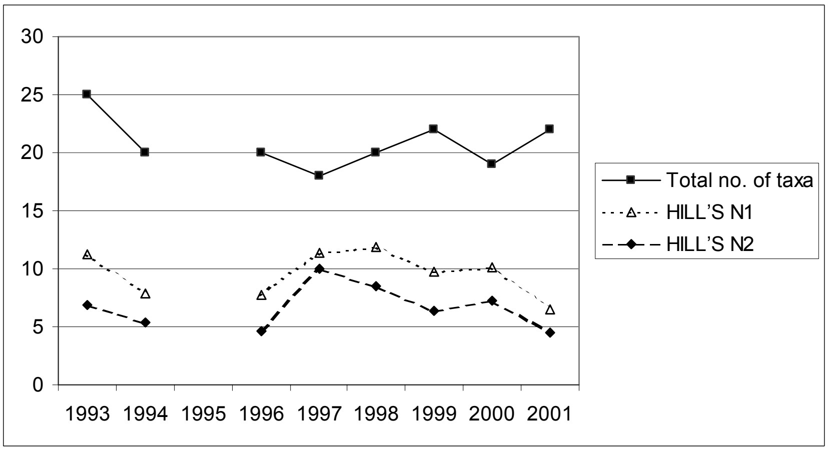

Figure 32 Selected Allt Riabhach na Bioraich Macroinvertebrate Summary Statistics

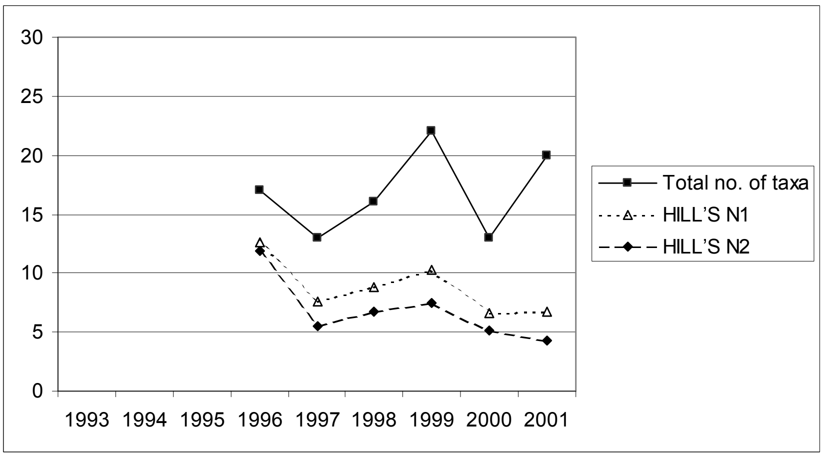

Table 4 Control Burn Macroinvertebrate Summary Statistics

Year	1993	1994	1996	1997	1998	1999	2000	2001
Total Count	768	231	256	178	307	257	314	409
Total no. of taxa	24	22	27	19	21	23	18	26
RICHNESS (rareftn 100)	17	17	18	15	12	17	13	15
HILL'S N1	11.5	11.9	12.8	10.6	8.01	11.8	7.8	8.9
HILL'S N2	8.4	9.0	9.0	7.5	5.9	9.3	5.6	5.8
EVENNESS (E5)	0.71	0.73	0.68	0.68	0.69	0.76	0.67	0.61
BMWP	110	99	125	88	88	118	93	108
ASPT	6.4	6.6	6.6	6.3	6.3	6.6	6.1	6.7

Table 5 Experimental Burn Macroinvertebrate Summary Statistics

Year	1993	1994	1996	1997	1998	1999	2000	2001
Total Count	477	231	247	110	96	142	162	227
Total no. of taxa	25	20	20	18	20	22	19	22
RICHNESS (rareftn 100)	18	14	14	16	19	19	16	13
HILL'S N1	11.3	7.9	7.7	11.4	11.9	9.8	10.1	6.6
HILL'S N2	6.9	5.4	4.6	10.0	8.5	6.4	7.3	4.5
EVENNESS (E5)	0.57	0.64	0.54	0.87	0.69	0.61	0.69	0.67
BMWP	108	83	82	67	94	84	93	80
ASPT	6.4	5.5	5.9	6.1	6.3	6.5	7.01	5.71

Table 6 Allt Riabhach na Bioraich Burn Macroinvertebrate Summary Statistics

Year	1996	1997	1998	1999	2000	2001
Total Count	109	128	171	268	315	437
Total no. of taxa	17	13	16	22	13	20
RICHNESS (rareftn 100)	17	12	13	16	10	13
HILL'S N1	12.6	7.6	8.8	10.3	6.6	6.7
HILL'S N2	11.9	5.5	6.8	7.5	5.1	4.2
EVENNESS (E5)	0.94	0.67	0.74	0.69	0.73	0.57
BMWP	89	78	83	105	75	95
ASPT	6.9	7.1	6.4	6.6	6.1	6.3

Table 7 Control Burn Aquatic Macrophyte Cover

	1992	1993	1994	1995	1996	1997	1998	1999	2001
Batrachospermum sp.	+	0.7	+		+				+
Marsupella emarginata var *aquatica*	4.4	4.0	4.9	0.4	1.5	0.2	1.9	1.2	+
Scapania undulata	2.8	3.7	1.7	0.9	2.0	1.9	3.7	3.3	2.9
Racomitrium aciculare	0.3	+	2.1	0.4	+	+		0.7	0.1
Juncus bulbosus var *fluitans*	0.1	+							
TOTAL COVER (excluding filamentous green algae)	7.6	8.4	8.7	1.7	3.5	2.2	5.6	5.2	3.0
Filamentous green algae	+	10.7	+	0.1	+	+	+	1.3	+

Sampling stretch 50m long.

Table 8 Experimental Burn Aquatic Macrophyte Cover

	1993	1994	1995	1996	1997	1998	1999
Batrachospermum sp.	33.3	12.7	54.2	32.8	35.0	28.8	17.8
Marsupella emarginata var *aquatica*	38.0	37.3	9.4	27.4	23.2	25.7	26.7
Scapania undulata		5.0	21.7	12.0	11.8	15.2	22.1
Juncus bulbosus var *fluitans*	2.6	9.0	2.7	6.6		3.3	0.2
TOTAL COVER (excluding filamentous green algae)	73.9	64.0	88.0	78.8	70.0	73.0	66.8
Filamentous green algae	68.0	+					

Sampling stretch 20m long.
No 2001 data for experimental burn due to physical erosion of the limited stretch suitable for monitoring.

Table 9 Allt Riabhach na Bioraich Burn Aquatic Macrophyte Cover

	1996	1997	1998	1999	2001
Batrachospermum sp.		1.6	0.3	0.3	0.4
Marsupella emarginata var *aquatica*	+				
Scapania undulata	0.4	0.2	0.7	0.5	0.9
Racomitrium aciculare			0.2	0.2	0.2
TOTAL COVER (excluding filamentous green algae)	0.4	1.8	1.2	1.0	1.5
Filamentous green algae	0.4		+	+	+

Sampling stretch 50m long.

Figure 33 Control Burn Fish Densities

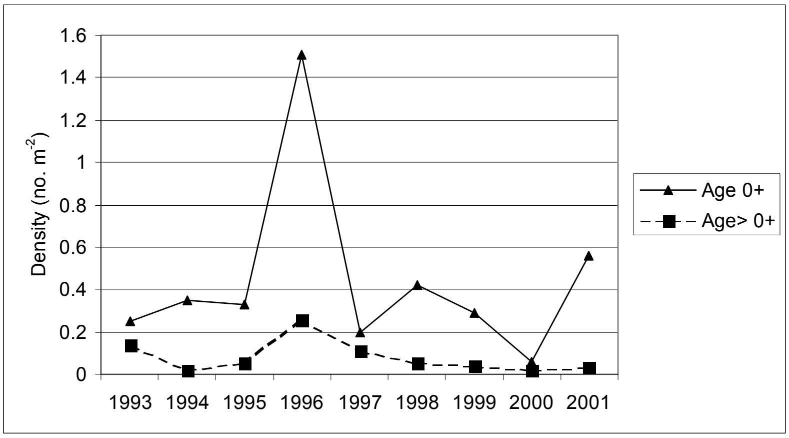

Figure 34 Experimental Burn Fish Densities

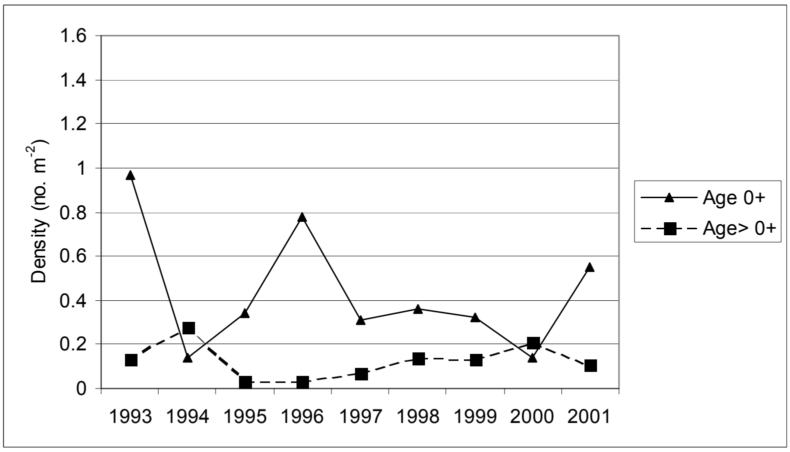

Figure 35 Allt Riabhach na Bioraich Fish Densities

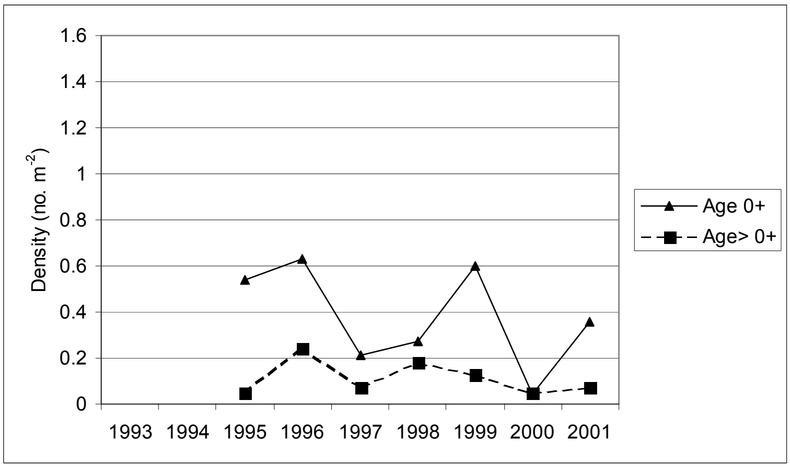

Table 10 Fish Population Data

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
Control Burn	2001	116	0.56	0.03
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
Experimental Burn	2001	45	0.55	0.11
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
ARnB Burn	2001	73	0.36	0.07

9 APPENDICES

Appendix 1 Water Chemistry for the Control Burn August 1992 – December 2001

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
12/08/92	5.4	18	24	106	3	34	68	94	0	26	1		70	18	0.74		
30/10/92	6.4	67	23	112	4	32	68	99	0	28	0		29	4	0.32	5	
06/12/92	5.7	20	20	104	3	17	43	103	0	25	1		33	2	0.25	3.5	
04/01/93	5.6	18	20	105	4	25	41	101	0	44	0		21	3	0.27	3.8	
30/03/93	5.9	25	39	203	5	44	67	278	0	41	1		20	3	0.17	3.1	
03/05/93	6.5	93	35	177	6	42	97	186	0	35	0		9	5	0.17	3.3	
18/06/93	6.3	68	31	145	4	39	88	130	0	30	1	19	15	29	0.55	9.4	
10/07/93	6.3	61	27	141	4	33	77	129	0	19	2	26	71	1	0.61	9.1	
25/07/93	6.0	51	27	134	3	38	92	117	0	16	2		72	0	0.78	11	
09/08/93	5.9	40	23	114	3	33	72	98	2	11	4		92	13	0.88		
22/08/93	6.5	94	27	148	4	42	91	141	0	18	2		39	4	0.48		
04/09/93	6.7	14	36	168	7	46	111	151	0	26	0		17	1	0.29		
29/09/93	6.9	14	36	161	6	47	114	155	0	31	0		26	5			
06/12/93	5.5	18	20	99	4	25	32	86	1	38	1		37	5	0.459	6.7	
18/02/94	6.3	61	39	210	6	66	101	211	2	41	0	5	14	0	0.132		0
01/05/94	6.0	37	24	141	9	34	56	123	0	25	0	10	36	8	0.309	4.4	0
12/05/94	6.4	66	29	161	6	48	82	143	0	30	0		22	5	0.213	3.2	0
10/06/94	6.3	60	39	201	9	68	110	174	0	85	1		30	4	0.283		0
08/07/94	5.9	45	27	151	6	52	83	111	0	35	1		80	0	0.632		0
07/08/94	6.1	41	23	140	5	46	71	109	0	26	4	58	60	2			0
25/08/94	6.4	72	29	152	5	61	113	118	0	27	1		41	1			0
03/09/94	6.6	10	31	163	6	60	110	125	2	24	1	2.5	28	7	0.339	5.5	0
22/09/94	6.5	88	29	152	6	56	119	123	0	23	1		26	17	0.385	7.5	0
29/12/94	5.1	7	23	108	4	30	31	126	1	23	1		24	0	0.198	4	0
27/03/95	5.8	24	21	121	6	31	41	122	0.25	22	0	2.5	29	2	0.239	4.8	0
27/04/95	6.6	87	24	133	8	43	81	107	0	20	0	2.5	16	0	0.204	4.8	0
02/06/95	6.3	62	26	137	4	41	75	103	0.1	18	3	3	29	28	0.49	9.9	0

Appendix 1 Cotd.

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
15/07/95	6.6	89	40	178	9	75	128	127	1.6	96	0	2.5	29	1	0.34	8.9	0
06/08/95	7.0	16	37	195	1	67	146	143	0.51	44	0		21	0	0.285	6	0
25/08/95	6.7	11	37	186	1	62	115	144	1.9	37	1	2.5	20	1	0.262	5.6	0
04/09/95	6.5	72	46	188	7	90	157	118	0	175	0	6	34	3	0.313	7.6	0
24/09/95	5.7	26	34	156	5	66	99	108	0.2	107	0		62	4	0.469	11	0
11/11/95	6.2	57	25	124	6	48	85	95	0.22	39	0	2.5	65	2	0.43	8.7	0
10/01/96	5.3	12	20	100	6	37	50	78	2.4	59	0	2.5	44	5	0.297	6.6	3
27/02/96	5.4	17	29	152	5	55	68	166	0.82	60			28	2	0.238		0
03/04/96	5.7	21	24	124	6	39	61	112	5.2	49	1	2.5	28	0	0.243	5.3	3
02/05/96	6.2	65	28	136	5	50	88	113	0.32	49	0	2.5	30	4	0.251	5.1	0
12/06/96	5.6	26	22	109	2	38	62	88	0	21	3	10	70	2	0.586	11.3	0
04/07/96	6.2	52	28	131	4	49	83	93	0	47	2	2.5	48	10	0.513	13.9	0
27/07/96	6.5	85	29	143	5	61	112	102	0.47	31	1	2.5	48	2	0.551	11	0
18/08/96	6.9	17	34	160	7	69	144	110	0.4	26	0	2.5	24	0	0.386	7.7	0
07/09/96	6.6	12	30	159	7	71	131	114	0.56	24	1	2.5	31	5	0.496	10	0
28/09/96	6.3	59	38	164	9	74	125	163	0.66	62	0	2.5	58	5	0.486	11.2	0
30/10/96	5.6	24	20	94	7	37	57	79	0.44	18	4		69	10	0.564	11	0
03/12/96	5.4	14	44	219	7	67	73	296	3.4	40	0	2.5	38	1	0.165	4	3
28/01/97	6.2	47	26	128	5	42	72	102	1.9	43	0	2.5	40	0	0.301	6.2	2
10/03/97	6.9	28	37	190	7	57	80	228	1.9	41	0						0
30/04/97	6.2	49	29	170	5	52	89	162	1.8	25	1	2.5	46	0	0.384	7.7	0
21/05/97	6.3	60	26	142	5	45	79	118	0.62	19	1	2.5	52	4	0.487	9.9	1
05/07/97	6.5	94	31	160	7	54	100	121	0.35	29	0	2.5	29	10	0.41	8.8	4
30/07/97	6.2	59	26	135	4	54	100	104	0.32	13	2	2.5	86	4	0.87	7.2	0
19/08/97	6.9	14	36	169	8	67	135	122	0.23	24	0	2.5	32	9	0.447	9.5	0
07/09/97	6.0	40	25	130	4	48	82	106	0	17	1	2.5	88	4	0.708	13.7	0
05/10/97	6.0	41	30	143	8	55	96	145	0	20	0	2.5	58	10	0.607	13	0
14/11/97	5.6	26	23	119	1	44	65	101	1.4	28	1	6	73	7	0.64	15	1
05/01/98	5.9	23	25	139	6	46	60	159	1.4	29	0	2.5	34	2	0.213	4.3	0

Appendix 1 Cotd.

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
05/02/98	5.8	27	21	105	4	35	53	94	1.2	27	1	2.5	44	0	0.313	7.8	0
21/03/98	6.3	51	33	174	7	52	74	192	0.35	29	0	2.5	20	5	0.161	3.5	0
07/05/98	5.9	35	24	137	5	42	66	115	0	15	1	2.5	45	8	0.525	10.9	0
20/06/98	6.7	14	36	177	7	60	114	120	0	35	2	2.5	1	13	0.204	5.1	0
20/07/98	6.2	63	24	125	2	51	87	82	0	13	1	2.5	66	1	0.716	14.7	0
09/08/98	6.2	66	23	129	3	53	82	79	0	13	1	2.5	59	16	0.704	13.3	0
29/08/98	6.6	11	29	143	5	54	102	92	0	19	9	11	29	2	0.365	6.9	0
27/09/98	6.8	16	33	151	6	67	132	108	0	23	0	2.5	21	2		6.4	0
25/10/98	5.8	29	21	101	6	37	61	89	0	18	2	2.5	51	3	0.49	9.3	0
25/11/98	5.6	19	26	129	3	40	57	146	0	24	2	2.5	34	2	0.327	6.9	0
12/02/99	5.7	19	48	258	9	73	92	337	0.88	37	1	6	15	2	0.112	3.1	0
25/03/99	5.7	21	26	147	5	35	45	161	0	20	1	2.5	28	4	0.289	6.4	1
10/05/99	5.8	31	26	149	6	43	64	133	0	27	3	6	53	4	0.58	12.9	0
17/06/99	6.0	44	25	146	4	44	73	134	0	10	2	6	63	4	0.552	11.3	0
12/07/99	6.5	10	30	168	8	62	118	127	0	18	0		57	2	0.617	13	0
01/09/99	6.0	46	30	146	4	62	106	120	0	54	3	6	59	7	0.581	12	0
26/09/99	5.6	24	19	104	5	37	54	81	0	16	4	6	50	3	0.612	12.7	0
06/11/99	5.2	10	23	115	7	33	42	126	0.53	21	0	2.5	30	6	0.357	8.1	0
20/01/00	6.1	36	26	141	3	41	63	145	0	26	2	2.5	33	0	0.197	4.4	0
05/03/00	5.4	13	28	168	3	39	48	185	0.94	27	1	2.5	26	1	0.192	4.8	0
14/04/00	6.5	88	31	166	6	52	106	158	0.3	21	0	2.5	16	7	0.209	4.7	0
31/05/00	6.5	83	34	188	5	64	108	149	0	59	0	2.5	26	13	0.336	7.2	0
17/06/00	6.5	84	35	190	5	67	114	181	0.69	31	0	2.5	32	0	0.25	5.8	0
12/07/00	6.7	80	31	169	4	62	110	147	1.1	26	0	2.5	25	11	0.354	8.2	0
05/08/00	6.6	97	35	175	5	62	108	146	1.5	38	0	2.5	30	3	0.391	9.3	2
04/09/00	6.7	13	36	170	5	67	128	154	0	18	0	6	20	6	0.425	9.3	0
08/10/00	5.7	29	27	142	5	46	68	144	0	16	0	2.5	67	9	0.613	12.5	0
09/01/01	6.0	34	18	102	5	30	52	75	0.68	22	0	21	50	1	0.413	8.5	0
08/03/01	5.5	15	20	95	8	31	40	92	5.7	32	0	10	41	1	0.227		1

Appendix 1 Cotd.

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
26/04/01	6.2	48	26	130	5	43	77	115	0	32	0	6	26	24	0.416	8.9	1
06/06/01	6.6	10	31	150	5	51	105	103	0	34	0	2.5	18	9	0.387	8.4	0
03/07/01	6.3	64	23	125	3	45	96	75	0.31	17	0	6	86	4	0.769	14.1	0
23/07/01	6.3	78	25	123	4	50	97	90	1.8	15	0	2.5	40	14	0.645	12.7	3
19/08/01	6.3	66	22	108	3	45	110	70	0	13	3	6	37	23	0.725	14.1	0
07/10/01	5.5	21	24	111	9	39	51	112	1.1	15	2	6	44	9	0.548	12	0
14/11/01	6.3	63	22	107	6	41	75	88	1.2	19	2	2.5	32	3	0.379	8.7	0
10/12/01	6.4	70	21	113	7	43	78	86	1.2	22	1	6	33	4	0.356	7.3	0

Appendix 2 Water chemistry for the Experimental Burn (Upper site) September 1992- December 2001

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
18/09/92	5.7	28	33	136	3	36	113	152	0	82	0		21	1	0.41		
30/10/92	6.1	58	26	130	3	32	61	128	0	26	0		15	0	0.27	4.4	
06/12/92	5.2	9	19	93	2	14	27	88	0	23	0		27	0	0.26	3.4	
04/01/93	5.4	14	19	98	2	21	31	86	0	35	0		12	0	0.27	3.8	
30/03/93	5.8	28	41	230	5	44	64	296	1	45	2		9	3	0.17	2.9	
03/05/93	6.4	11	37	204	7	44	95	192	1	29	0		5	2	0.26	4.2	
18/06/93	6.3	12	37	202	4	44	100	156	0	16	0	19	19	9	0.51	8.2	
10/07/93	6.0	66	29	164	4	35	76	139	0	18	3	22	46	1	0.7	9.5	
25/07/93	5.7	42	29	156	2	42	73	130	0	12	3		48	9	0.86	13	
09/08/93	5.9	57	29	151	4	42	76	131	0	8	5		54	0	0.88		
22/08/93	6.3	14	33	186	6	60	108	159	1	14	3		28	2	0.65		
04/09/93	6.4	21	45	210	7	68	159	171	2	22	1		10	2	0.41		
29/09/93	6.6	17	45	209	1	64	135	207	2	28	0		20	0			
06/12/93	5.2	11	21	105	3	24	26	87	0	39	6		24	2	0.492	6.8	
18/02/94	6.3	70	44	243	6	75	109	246	1	49	1	0	5	0	0.096		0
01/05/94	5.8	35	29	183	4	44	58	159	0	28	1	13	26	7	0.414	5.4	0
12/05/94	6.3	87	36	202	7	58	90	176	0	26	0		19	4	0.279	5	7
10/06/94	6.2	71	40	224	5	62	100	200	0	51	0		22	2	0.292		0
08/07/94	5.7	44	29	178	3	53	75	122	1	24	2		45	1	0.836		0
07/08/94	6.7	13	31	181	1	78	137	141	1	19	4	60	17	6			0
25/08/94	6.2	80	32	177	7	71	111	141	1	18	2		28	3			0
03/09/94	6.5	13	37	200	1	81	136	153	1	16	5	2.5	18	3	0.488	7.6	0
22/09/94	6.2	97	33	186	7	66	123	160	0	13	2		21	0		7.3	0
29/12/94	5.4	13	24	125	6	39	36	139	0	24	1		35	3	0.238	4.6	0
27/03/95	5.7	23	22	129	5	32	40	121	0.4	21	2	2.5	18	1	0.26	5.3	0
27/04/95	6.1	65	29	168	1	48	80	158	0.46	24	1	2.5	30	1	0.284	6.6	0
02/06/95	6.2	64	29	169	5	47	68	129	0.42	13	1	2.5	35	7	0.548	11	0

Appendix 2 Cotd.

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
15/07/95	6.4	14	46	202	6	86	154	138	0.49	94	1	2.5	12	2	0.343	8.5	0
06/08/95	6.5	19	40	219	8	86	164	155	1.2	30	1		15	1	0.417	8.6	0
25/08/95	6.8	22	49	225	7	99	176	171	0.41	35	1	2.5	9	0	0.266	6.1	0
04/09/95	6.2	74	63	239	8	13	208	125	0.87	302	0	6	14	0	0.239	6.8	0
24/09/95	5.2	10	35	167	5	66	84	115	0.37	112	0		37	5	0.494	12	0
11/11/95	5.9	43	26	139	4	47	72	98	0.52	37	0	2.5	32	6	0.473	8.7	0
10/01/96	5.3	10	23	126	6	42	47	96	1	68	0	2.5	35	5	0.305	6.6	2
27/02/96	5.2	10	28	152	4	51	55	166	0.94	56			19	8	0.237		0
03/04/96	6.2	71	36	189	1	62	105	172	0.91	75	1	2.5	15	0	0.17	4.7	4
02/05/96	6.0	66	31	159	6	51	83	132	0.48	44	0	2.5	21	3	0.311	6.5	2
12/06/96	5.4	21	24	127	2	36	47	103	0	17	3	3	41	2	0.627	12.6	0
04/07/96	5.8	45	27	144	3	51	77	104	0	32	1	2.5	23	13	0.586	19.8	0
27/07/96	6.2	12	34	168	4	71	128	122	0	19	2	2.5	20	2	0.52	12.7	0
18/08/96	6.7	20	41	198	7	89	169	140	1.1	20	1	2.5	14	1	0.464	9.7	0
07/09/96	6.1	11	35	174	9	78	130	136	0.98	16	2	2.5	27	4	0.677	14	0
28/09/96	6.3	10	42	194	9	78	128	183	1.4	42	1	2.5	18	1	0.372	9.3	0
30/10/96	5.5	20	25	118	1	41	53	112	0.27	20	2		46	8	0.505	10	0
03/12/96	5.1	6	46	227	7	72	73	305	1.5	40	0	2.5	25	1	0.166	3.9	0
28/01/97	5.9	36	26	142	4	39	58	106	0.94	43	0	2.5	26	1	0.371	7.4	2
10/03/97	5.6	22	39	204	6	57	70	241	0.92	38	0						0
30/04/97	5.8	39	30	178	5	49	72	168	0.84	17	0	2.5	27	0	0.37	7.5	0
21/05/97	5.9	47	27	152	3	43	67	125	0.45	13	2	2.5	33	0	0.55	11.2	0
05/07/97	6.1	81	29	166	8	50	87	114	0.51	14	1	2.5	30	10	0.59	12	6
30/07/97	6.0	67	28	155	4	58	93	112	0.19	9	2	2.5	39	0	0.841	17.7	0
19/08/97	6.5	21	74	229	1	95	380	148	0.66	233	1	2.5	25	0	0.638	14	0
07/09/97	5.6	31	26	140	4	52	73	116	0	12	2	2.5	59	6	0.766	15	0
05/10/97	5.7	34	33	158	9	64	86	183	0	14	1	2.5	46	1	0.541	12	0
14/11/97	5.4	21	28	143	1	51	59	127	0.39	27	1	2.5	50	3	0.697	16	0
05/01/98	5.4	13	32	167	5	61	62	214	0.39	29	0	2.5	25	0	0.195	4	0
05/02/98	5.6	23	21	110	3	35	45	93	0.75	27	1	2.5	26	0	0.361	8.2	0

Appendix 2 Cotd.

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
21/03/98	6.1	60	38	185	6	58	80	208	0.91	26	0	2.5	9	5	0.135	3.4	0
07/05/98	5.6	25	27	146	4	43	53	129	0	13	1	2.5	30	5	0.507	10.9	0
20/06/98	6.4	16	36	194	6	65	119	129	0	20	2	2.5	16	0	0.271	6.9	0
20/07/98	5.8	51	23	130	1	52	74	77	0	9	2	2.5	46	1	0.773	16.3	0
09/08/98	6.0	74	26	140	4	62	86	86	0	10	2	2.5	43	3	0.751	16.5	0
29/08/98	6.3	15	36	172	7	76	129	117	1.4	15	3	6	24	0	0.437	9	0
27/09/98	6.4	21	42	189	8	96	169	145	3.9	17	2	2.5	35	3	0.529	11	2
25/10/98	5.5	23	23	109	9	43	55	103	0	17	2	2.5	38	0	0.522	9.8	0
25/11/98	5.4	16	26	136	4	42	52	144	0	22	1	2.5	39	4	0.371	7.9	0
12/02/99	5.7	18	50	278	7	83	93	363	0.87	36	0	6	13	2	0.119	3.7	0
25/03/99	5.5	18	28	167	5	37	42	177	0	20	1	2.5	29	0	0.358	7.9	2
10/05/99	5.6	28	28	168	6	44	55	153	0	18	3	6	49	1	0.608	14.3	0
17/06/99	5.8	40	27	164	2	46	60	143	0	7	3	6	47	1	0.613	12.3	0
12/07/99	6.2	13	36	196	6	87	129	138	0.86	11	31		50	5	0.93	19.3	0
03/08/99	6.4	21	46	222	1	10	167	158	4.2	20	1	6	34	10	0.639	13.3	0
01/09/99	6.0	66	35	173	5	70	109	157	0	46	0	2.5	18	2	0.431	9.7	0
26/09/99	5.3	14	18	92	9	33	41	75	0	10	4	6	30	6	0.624	13.7	0
06/11/99	5.2	10	24	129	1	36	45	134	0.33	22	0	2.5	22	1	0.354	5.9	0
20/01/00	6.0	43	28	167	3	47	70	167	0.47	32	6	6	13	0	0.171	3.9	0
05/03/00	5.3	10	27	161	5	35	40	171	0.66	25	1	2.5	19	0	0.19	4.5	0
14/04/00	6.3	88	34	191	6	54	104	182	0.51	19	0	2.5	7	3	0.186	4.7	0
31/05/00	6.1	61	32	193	3	56	84	155	0.85	30	0	2.5	24	9	0.444	9.6	0
17/06/00	6.4	96	35	207	5	68	100	177	1.8	18	0	2.5	15	9	0.347	8.1	0
12/07/00	6.3	81	33	189	4	67	104	158	0.89	19	2	6	23	6	0.503	12	0
05/08/00	6.3	10	38	194	5	73	110	154	1.7	26	4	6	23	1	0.546	13.6	2
04/09/00	6.3	13	41	200	7	83	129	182	0.8	10	0	6	22	9	0.624	13	0
08/10/00	5.6	26	30	160	1	54	64	171	0	13	1	2.5	37	7	0.628	11.9	0
09/01/01	5.9	39	17	100	4	31	49	69	0.8	18	0	6	22	2	0.383	7.9	0
08/03/01	5.5	20	21	109	5	31	40	100	0.75	39	0	2.5	29	0	0.327		1

Appendix 2 Cotd.

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
26/04/01	5.9	34	27	147	5	45	65	135	0.46	28	0	6	21	10	0.414	9.7	2
06/06/01	6.3	10	31	164	4	53	95	119	0.36	16	0	6	12	4	0.388	9.2	1
03/07/01	5.9	65	24	137	3	48	78	84	0.43	12	0	11	54	0	0.792	15.1	0
23/07/01	6.2	77	24	135	4	54	78	90	1.8	11	0	6	35	3	0.69	14.3	2
19/08/01	6.1	93	27	127	5	64	93	90	1	10	5	6	13	12	0.693	15.5	1
07/10/01	5.6	23	28	112	1	48	51	137	1.1	15	2	6	30	0	0.488	11.5	0
14/11/01	6.3	67	24	119	1	48	76	107	1.9	17	3	6	16	4	0.361	10	0
10/12/01	6.2	70	22	114	8	46	72	94	1.3	21	7	8	12	5	0.338	7.6	0

Appendix 3 Water chemistry for the Experimental Burn (Lower site) July 1995 - December 2001

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
15/07/95	6.6	15	62	210	6	73	276	148	0	206	1	2.5	12	0	0.348	7.7	0
06/08/95	6.7	22	115	287	1	99	868	154	0.15	749	2		18	2	0.524	11	0
04/09/95	6.3	87	67	245	8	11	275	144	0.28	337	0	11	16	0	0.28	7.6	0
24/09/95	5.1	7	33	165	7	64	86	120	0	109	0		33	4	0.514	13	0
11/11/95	5.7	38	29	139	9	44	82	113	0.32	55	0	2.5	51	3	0.384	7.4	0
10/01/96	5.2	9	22	119	3	39	43	82	0.66	69	0	2.5	40	2	0.369	8	2
27/02/96	5.2	9	28	148	7	48	46	165	0.21	51			19	12	0.167		0
03/04/96	6.3	74	50	185	8	59	211	168	0.72	188	1	2.5	11	0	0.149	4	0
02/05/96	6.0	67	48	167	6	50	195	134	0	175	0	2.5	18	3	0.299	6.1	0
12/06/96	4.9	-11	27	128	3	34	41	109	0	21	3	4	36	2	0.7	14.3	0
04/07/96	5.8	44	34	151	3	50	113	111	0	79	0	2.5	26	6	0.538	15.8	0
27/07/96	6.1	12	48	184	7	67	209	140	0.35	111	2	6	18	6	0.488	10.9	3
18/08/96	6.6	23	75	227	9	90	430	148	0	278	1	2.5	14	1	0.477	10	0
07/09/96	6.0	12	51	193	1	81	228	147	0	118	3	3.5	41	2	0.75	15.7	0
28/09/96	6.3	99	49	206	1	75	172	199	1.6	94	1	2.5	12	1	0.35	9	0
30/10/96	5.4	21	26	122	1	42	57	113	0	27	0		49	10	0.479	10	0
03/12/96	5.4	8	48	230	1	73	77	309	1.1	50	1	2.5	22	10	0.155	3.6	3
28/01/97	5.8	32	30	145	5	40	83	114	1	75	0	2.5	24	1	0.328	6.7	2
10/03/97	5.5	19	44	207	8	59	101	243	1.1	77	0						0
30/04/97	5.7	36	35	179	6	48	96	174	0.66	48	0	2.5	25	1	0.344	7.3	2
21/05/97	6.1	46	33	154	3	40	107	128	0	65	1	2.5	31	0	0.474	10.2	0
05/07/97	6.0	79	39	176	8	49	143	127	0.42	80	1	2.5	21	7	0.502	11	3
30/07/97	6.0	79	34	169	7	57	124	135	0.45	38	2	16	29	3	0.731	15.3	3
19/08/97	6.6	14	38	173	9	67	142	124	1.2	39	1	2.5	29	0	0.445	9.4	3
07/09/97	5.7	30	29	149	6	52	81	125	0	28	1	2.5	64	4	0.766	16.4	3
05/10/97	5.7	39	37	171	1	65	115	194	0.35	39	0	2.5	36	2	0.519	12	0
14/11/97	5.5	26	28	144	1	49	63	134	0	29	1	17	43	4	0.613	14	0

Appendix 3 Cotd.

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
05/01/98	5.4	13	33	170	7	59	67	215	0.42	36	0	2.5	20	0	0.176	3.7	0
05/02/98	5.6	22	22	115	5	35	48	100	0.61	32	1	2.5	28	2	0.323	7.7	0
21/03/98	6	53	45	210	9	64	142	241	1.3	95	0	2.5	13	4	0.131	3.3	2
20/06/98	6.2	14	61	209	6	70	291	132	0	232	1	2.5	4	13	0.27	6.8	0
20/07/98	5.7	45	26	137	3	50	91	86	0	29	5	6	42	42	0.759	16	0
09/08/98	5.8	66	31	143	5	63	124	85	0	51	2	2.5	50	2	0.808	17.4	0
29/08/98	6.2	14	51	178	5	75	235	118	0.46	145	3	6	31	0	0.47	9.8	0
27/09/98	6.3	20	65	207	1	99	351	149	2.2	218	1	2.5	32	2	0.482	10	3
25/10/98	5.5	22	20	100	5	35	51	89	0	20	2	2.5	57	6	0.496	10.8	0
25/11/98	5.4	16	27	143	6	42	54	151	0	26	1	2.5	31	4	0.351	7.5	0
12/02/99	5.4	13	50	255	1	77	84	336	0.63	36	0	6	15	1	0.082	2.8	0
25/03/99	5.5	17	28	163	7	36	44	174	0	24	1	2.5	28	4	0.32	7.2	1
10/05/99	5.7	34	29	168	7	43	63	161	0	30	2	6	40	1	0.474	11.3	0
17/06/99	5.7	33	29	169	3	46	72	155	0	26	4	6	31	9	0.607	12.9	0
12/07/99	5.8	11	45	207	9	92	195	150	0	75	3		109	7	1.195	23	0
03/08/99	6.2	20	81	246	1	11	432	156	0.76	312	0	2.5	31	3	0.684	14.1	0
01/09/99	6.2	73	39	175	7	65	133	164	1.4	67	3	6	19	0	0.38	8.8	0
26/09/99	4.9	-1	20	88	1	29	32	74	0	10	6	8	30	8	0.691	14.7	0
06/11/99	5.4	16	24	131	1	38	47	137	0.61	23	0	6	34	5	0.352	7	0
20/01/00	5.9	42	35	168	4	48	110	171	2.1	71	1	6	11	2	0.149	3.6	0
05/03/00	6.3	11	27	158	6	34	40	171	0	27	0	2.5	22	0	0.161	4.2	0
14/04/00	6.3	95	48	200	6	55	205	184	1.4	128	0	2.5	7	3	0.191	4.6	0
31/05/00	6.1	63	37	200	4	58	127	165	0.58	78	0	2.5	22	13	0.31	6.9	0
17/06/00	6.2	85	46	217	6	70	185	186	0.76	105	1	2.5	31	1	0.356	8.6	0
12/07/00	6.3	81	41	200	6	69	170	169	1.1	86	0	6	15	9	0.468	10.3	0
05/08/00	6.2	11	52	215	8	75	201	178	1.4	114	1	6	24	6	0.535	13.4	2
04/09/00	6.2	13	54	217	9	83	228	189	0.54	114	0	6	31	2	0.64	14	2
08/10/00	5.6	26	31	161	1	52	63	170	0	18	1	2.5	52	1	0.58	9.2	0
09/01/01	5.9	37	21	103	6	34	71	76	1.2	41	0	6	37	2	0.347	7.8	0

Appendix 3 Cotd.

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
08/03/01	5.6	19	22	107	6	30	42	100	1.1	39	0	6	21	2	0.235	5	1
26/04/01	5.9	37	31	149	6	45	88	137	0.54	51	0	2.5	21	8	0.421	9.6	0
06/06/01	6.3	12	47	199	9	62	218	140	1.3	133	0	6	22	0	0.4	10.4	5
03/07/01	5.9	64	27	137	4	47	101	83	0.73	41	4	6	42	16	0.791	15	0
23/07/01	6.2	88	22	144	5	54	112	96	2.4	41	0	6	16	7	0.632	14.1	3
19/08/01	6.0	90	33	126	6	65	137	90	1.1	52	5	6	15	12	0.73	17.9	1
07/10/01	5.6	25	26	117	1	48	58	130	1.1	19	3	6	31	6	0.49	10.5	2
14/11/01	6.3	59	26	114	1	44	95	103	2.1	46	2	2.5	19	1	0.334	8.6	0
10/12/01	6.2	67	26	119	8	43	106	97	1.4	61	3	6	13	0	0.338	7.3	0

Appendix 4 Water chemistry for the Allt Riabhach na Bioraich (Lower site) June 1995 - December 2001

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
02/06/95	6.1	48	25	137	5	41	68	109	0.51	26	0	2.5	53	0	0.431	8.8	0
15/07/95	6.3	72	41	175	9	76	128	121	9	104	0	2.5	30	8	0.436	11	0
06/08/95	6.8	12	38	207	1	65	142	148	2.2	80	1		15	3	0.287	6.6	0
04/09/95	6.1	50	43	182	9	84	132	118	0.47	156	0	6	39	0	0.347	8.5	0
24/09/95	5.4	17	28	150	6	63	85	107	1.1	96	0		66	8	0.517	13	0
11/11/95	6.0	50	26	130	6	47	81	94	1.2	43	1	2.5	65	0	0.411	7.9	0
27/02/96	5.6	25	30	155	5	55	74	166	2.5	64			29	1	0.213		1
03/04/96	6.0	41	33	153	1	59	100	135	7.6	88	0	2.5	29	2	0.194	4.6	6
02/05/96	5.9	71	31	139	6	48	98	115	0.3	60	0	2.5	32	2	0.241	4.8	0
12/06/96	5.5	22	23	115	3	37	51	91	0.4	23	3	4	40	29	0.563	6.7	0
04/07/96	5.9	41	27	130	4	49	85	96	0	46	0	2.5	47	14	0.553	23	0
27/07/96	6.3	79	29	140	5	57	117	100	0.54	34	1	2.5	42	4	0.532	10.7	0
18/08/96	6.6	14	35	158	7	62	144	108	2.1	39	2	2.5	24	2	0.398	8	0
07/09/96	6.3	11	34	162	1	65	137	117	0.54	40	2	2.5	35	4	0.485	10.2	0
28/09/96	6.2	59	37	169	1	74	120	174	2.6	57	1	2.5	46	9	0.484	10.9	0
30/10/96	5.6	23	21	97	7	36	53	80	0.89	22	1		90	7	0.525	10	0
03/12/96	5.2	10	44	218	8	71	75	293	2.1	42	0	2.5	35	7	0.16	3.7	0
28/01/97	6.0	43	27	129	6	41	73	104	3.5	49	4	6	45	0	0.305	6	2
10/03/97	5.6	26	38	184	9	56	77	218	2.6	46	1						0
30/04/97	5.9	39	29	154	5	48	79	149	0.76	27	0	2.5	43	1	0.382	7.8	0
21/05/97	6.0	47	26	144	5	45	76	120	0.24	25	1	2.5	52	7	0.501	10.4	4
05/07/97	6.2	74	30	148	7	51	97	108	0.2	35	1	2.5	55	0	0.48	9.9	3
30/07/97	6.1	61	27	136	5	54	97	104	0.44	27	1	2.5	70	8	0.769	15.7	0
19/08/97	6.6	10	33	163	8	60	112	120	1.2	22	1	2.5	32	0	0.478	9.8	0
07/09/97	5.6	28	25	125	4	47	71	103	0.4	20	2	2.5	89	10	0.74	14.5	0
05/10/97	5.7	29	29	143	7	57	84	145	0.31	24	0	2.5	82	5	0.644	14	0
14/11/97	6.0	48	26	139	8	50	76	114	1.6	30	1	2.5	57	5	0.561	12	0

Appendix 4 Cotd.

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
05/01/98	5.4	16	28	146	6	49	55	168	1.7	31	0	2.5	31	0	0.209	3.9	1
05/02/98	5.7	23	21	115	7	36	53	102	2.6	30	1	2.5	47	1	0.346	8.2	3
21/03/98	6.0	49	34	171	8	50	77	183	1	40	0	2.5	24	2	0.149	3.8	2
20/06/98	6.4	14	39	180	9	60	138	120	0.45	62	1	2.5	23	0	0.228	5.7	0
20/07/98	5.9	52	24	129	4	48	77	81	0	18	1	2.5	85	3	0.735	15.2	0
09/08/98	5.8	43	22	123	4	44	71	82	0	20	1	2.5	55	9	0.634	12.5	0
29/08/98	6.3	12	31	156	8	51	106	101	0	34	1	2.5	27	1	0.35	7.1	0
27/09/98	6.5	16	35	159	8	66	159	109	0.72	51	1	2.5	21	0	0.312	6.8	0
25/10/98	5.4	22	24	109	1	43	51	107	0.32	20	2	2.5	49	12	0.513	10.3	0
25/11/98	5.5	18	26	134	5	40	55	145	0.85	26	1	2.5	45	4	0.318	6.7	0
12/02/99	5.8	24	43	238	8	69	89	299	1.6	38	1	2.5	16	0	0.098	2.8	0
25/03/99	5.5	17	26	142	6	35	42	158	0.52	23	1	2.5	39	0	0.274	6.2	0
10/05/99	5.8	35	27	149	9	45	68	139	0.4	28	3	6	51	0	0.558	12	0
17/06/99	5.7	31	25	142	2	42	61	129	0	14	2	2.5	52	20	0.617	12.9	0
12/07/99	6.2	84	29	168	7	57	105	124	0	27	0		82	2	0.752	15.3	0
03/08/99	6.5	11	36	179	9	59	138	145	1.5	51	0	6	24	0	0.372	7.7	0
01/09/99	5.8	35	28	136	5	54	78	110	0	40	2	2.5	61	10	0.647	13	0
26/09/99	5.5	25	21	108	5	36	52	88	0	21	3	6	68	5	0.563	10.6	0
06/11/99	5.0	2	23	110	6	35	31	119	0	22	1	2.5	18	2	0.303	7.9	0
20/01/00	5.8	34	26	140	4	40	71	140	1.8	33	1	2.5	31	2	0.19	4.1	0
05/03/00	5.4	14	28	163	4	39	52	182	1	29	0	2.5	24	2	0.188	4.4	0
14/04/00	5.4	11	31	188	3	43	57	215	1.4	27	0	2.5	10	5	0.108	2.4	0
31/05/00	6.3	61	31	174	5	57	95	145	0	47	0	2.5	34	15	0.364	8	0
17/06/00	6.2	68	35	187	6	61	100	179	0.69	40	0	2.5	34	3	0.269	6.4	0
12/07/00	6.3	69	30	163	5	59	109	139	0	31	0	6	29	12	0.397	8.5	0
05/08/00	6.4	85	34	174	6	58	104	143	1.1	45	0	6	26	3	0.389	9.3	3
04/09/00	6.5	10	35	169	6	62	118	152	0	27	0	6	24	4	0.439	9.8	0
08/10/00	5.4	20	28	144	6	46	62	146	0	20	2	6	83	9	0.636	10.7	0
09/01/01	5.9	35	18	97	4	31	55	73	1.2	25	0	6	47	0	0.372	8.2	0

Appendix 4 Cotd.

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
08/03/01	5.5	14	22	98	8	32	41	97	6.9	36	0	6	21	8	0.222	5	2
26/04/01	6.0	44	28	141	9	43	76	123	2.2	37	0	2.5	35	11	0.47	10	3
06/06/01	6.4	97	30	151	6	53	98	108	0	36	4	6	23	4	0.371	8.3	2
03/07/01	5.9	50	23	125	3	43	77	79	0.76	22	2	2.5	95	14	0.788	14.4	1
23/07/01	6.3	70	24	126	4	47	80	86	1.3	20	0	5	46	2	0.563	11.6	2
19/08/01	6.0	41	21	108	3	35	64	82	1.9	23	3	6	24	15	0.474	11.2	1
07/10/01	5.3	12	24	99	1	40	46	107	1.5	18	3	6	51	6	0.541	11.5	0
14/11/01	6.0	23	22	108	8	39	67	88	1.9	25	5	6	34	4	0.379	8.5	0
10/12/01	6.0	53	20	109	8	39	68	86	1.7	29	3	6	22	9	0.371	8	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		4 Aug	4 Aug
2001	28 Sept	18 May		

* Only control burn sampled in 1992