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Land-Use Experiments in the Loch Laidon Catchment:

Fifth report on Stream Water Quality to the Rannoch Trust and Scottish Natural Heritage

Editor: D.T.Monteith

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Land-Use Experiments in the Loch Laidon Catchment: Fifth report on Stream Water Quality to the Rannoch Trust and Scottish Natural Heritage

Editor: D.T.Monteith

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February 1999

Executive summary

- This report summarises data collated over five years of monitoring stream water quality in part of the Loch Laidon catchment. The work is being undertaken as part of the land-use experiments instigated by the Rannoch Trust. Work is co-funded by the Rannoch Trust and Scottish Natural Heritage.

- Two study burns, an Experimental site (cattle grazed during summer) and a Control, have been monitored for chemistry and biology since August 1992. Five years of monitoring provide no significant evidence that cattle grazing has had any chemical or biological impact on the Experimental burn.

- Stage board data suggest that seasonal differences in the relationship of water chemistry between the two burns, which have been observed in previous reports, are likely to result from seasonal changes in hydrology, rather than any influence of summer cattle grazing.

- There is no evidence that the water chemistry of a more recently monitored lower station on the Experimental burn, which might better represent whole catchment effects, is changing in response to grazing.

- The more recently monitored Allt Riabhach na Bioraich is physically, chemically (seasonally and inter-annually) and biologically more similar to the Control burn than the current Experimental burn and would provide a better experimental comparison for the Control were cattle to be introduced to its catchment in the future. Sufficient data have been collected for its base-line (pre-grazing) state to be characterised.

- Given the inadequate coverage of acid-sensitive waters in central Scotland for the purposes of acidification monitoring, the developing water chemistry data sets for the Control burn and the outflow of Loch Laidon will become increasingly useful for the assessment of regional trends in acidification / recovery.

1 Introduction

This report summarises data for the first five years of the Stream Water Quality project, part of the Loch Laidon catchment land-use experiment which aims to explore the impact of cattle grazing on the terrestrial and aquatic environment. The background to the work is described by Allott *et al.* (1994) while annual reports have been published for each subsequent year.

Reports for previous years have concentrated on comparisons of the chemistry and biology of streams in a "Control" and "Experimental" catchment, the latter being grazed by cattle over the summer months. Early analysis which compared the ratio of cation concentrations and alkalinity of the two streams suggested a possible "grazing effect" as the ratio appeared to change markedly during the summer grazing period. However, in the last report we suggested that this feature was more likely due to inherent hydrological differences between the two streams and that the Experimental stream became more alkaline than the Control during summer due to the relatively large contribution of alkaline base-flow for this site at this time of year. It was proposed that the more recently monitored site (the Allt Riabhach na Bioraich) is better suited as an experimental burn due to its more comparable hydrological and lithological characteristics.

In this report we present the most recent time series data (1992-1998) for the original experimental / control pair and further consider the hypothesis that hydrological differences are responsible for the altered relationship in ionic concentrations during the grazing season by referring to stage board records. In addition we present the most recent time series comparison of the control and the Allt Riabhach na Bioraich and review biological data for all three sites.

2 Methodology

Sampling methodologies follow that of Allott *et al.* (1994). This includes frequent (approximately monthly) spot chemistry and annual biological surveys to determine the status of fish, aquatic macrophytes and epilithic diatoms. Macroinvertebrates were not sampled in 1995. Dates of biological sampling are provide in Appendix 5.

Cattle (16 cows, 16 calves and 1 bull) were introduced to the experimental plot on the 11th July and removed on the 30th September 1993. The same grazing period has been implemented in subsequent years although the stock was reduced by 1 cow and 1 calf in 1994.

Since the summer of 1995 spot chemistry samples have been taken from four additional locations which are as follows:

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. Loch Laidon outflow

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

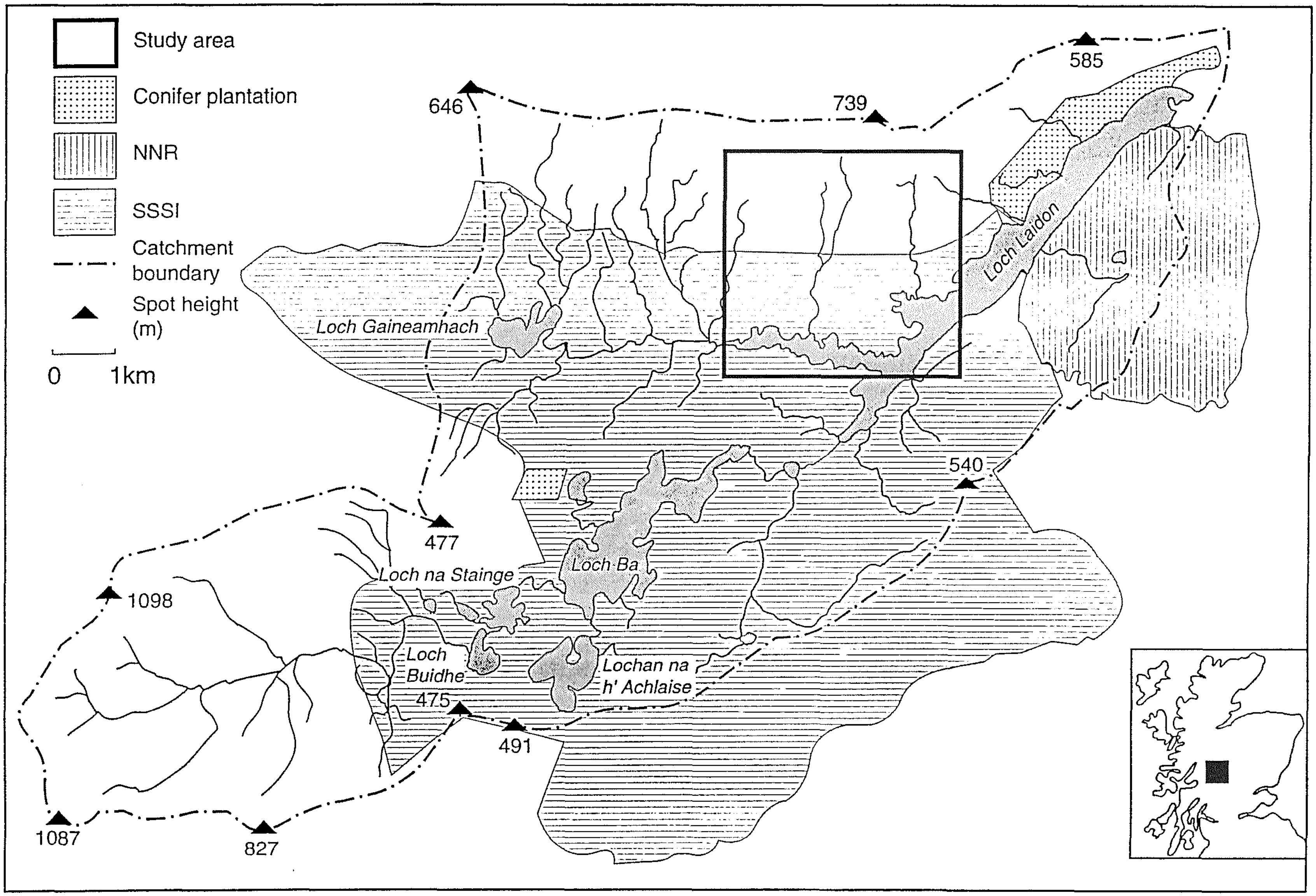
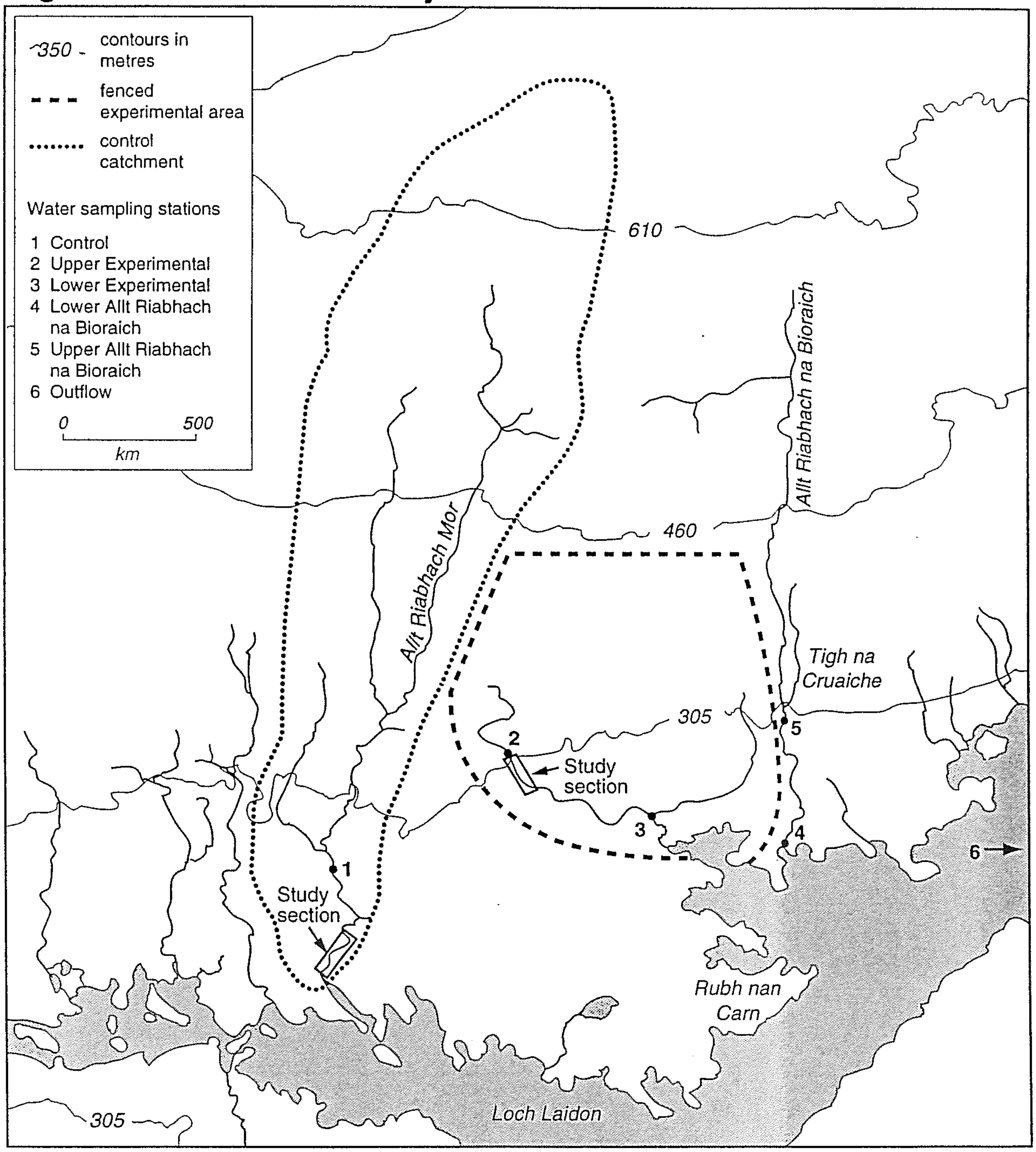


Figure 2: Loch Laidon study area



The Allt Riabhach na Bioraich burn has also been sampled for epilithic diatoms, fish and aquatic macrophytes since 1996 following existing protocols. All sampling sites are indicated on the map of the Loch Laidon study area (Figure 2).

3. Data Analysis and Presentation

Data are transferred to a central database at the Environmental Change Research Centre (ECRC) and for this report are presented as raw data, graphs (for chemistry) and summary statistics. Biological data are presented in the same format as previous reports for specific stretches of the control, experimental and Allt Riabhach na Bioraich burn.

The following diversity and biotic 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 N5 is a measure of the eveness of species occurrences in a sample. E5 approaches zero as a single species becomes more dominant in the community.
E(100) predicts the expected number of taxa in a sample of 100 individuals.
BMWP is a scoring system for macroinvertebrates based on values of 1 to 10 given to each taxonomic family. It provides an indication of water quality; e.g. those families which are very sensitive to organic pollution are assigned a score of 10, while those which thrive in organically polluted systems, such as blood worms, 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.

4 Results

4.1 Water chemistry

4.1.1 Comparison of the two longest time series, i.e. the Control and Upper Experimental burn (1992-1998)

The ratios plotted in Figures 3.1-3.4 demonstrate the continuing inter-annual stability of the relationship between the water chemistry of the Control and Experimental burn, since cattle were introduced to the experimental catchment in 1992. There is no evidence of any trend in the relationship between the two sites for any chemical determinand. The pH plot indicates that the Experimental burn was considerably more acid than the Control during the spring and summer of 1997, but a similar relationship is observed at this time between the Control burn and the Allt Riabhach na Bioraich and therefore this can not be attributed to grazing.

The importance of flow in determining the relative water chemistry of the Control and Experimental burn is demonstrated by Figure 3.5. Here we see that alkalinity of the Experimental burn tends to only exceed the alkalinity of the Control burn during periods of low flow, i.e. when the stage board reading for the Control burn is below 0.3 m. This Figure also suggests that there is a roughly linear inverse relationship between the Experimental/Control ratio for alkalinity and the stage board reading. These findings are consistent with our suggestion in the previous report (Monteith, 1998) that, during low flow, the Experimental burn is likely to be more influenced by mineral enriched baseflow than the Control.

Both burns have nitrate concentrations and seasonal cycles which can be considered typical of upland waters in Scotland in areas of low nitrogen deposition (Curtis *et al.*, 1998), although the Control burn exhibited considerably higher nitrate than the Experimental burn during the winters of 1996 and 1997 (Figure 3.4). Nitrate concentrations in the Experimental burn are generally below the limit of detection during the months of summer grazing. An exception occurred over a two month period in the summer of 1998, when the concentration in the Experimental burn was elevated at a time when that in the Control burn was below detection. The same spike in nitrate is evident in samples from the Lower experimental station (Figure 3.6). It is possible that this event was a direct effect of cattle manure deposited into the stream although this is impossible to verify. It is clear that there has been no long term trend in the relationship of nitrate concentration between the two streams that might indicate any long term process of nutrient enrichment by cattle.

4.1.2 Comparison of the Control and Lower Experimental site

Although providing a more limited time series, we proposed in the previous report that the Lower Experimental site would perhaps provides a better record of integrated catchment effects than the original Upper site. Figures 3.7 and 3.8 demonstrate that, as with the relationships described above, there is no evidence to date of any long term shift in the water chemistry at the Lower site relative to the Control.

4.1.3 Comparison of the water chemistry of the Allt Riabhach na Bioraich with the original Experimental and Control burns

Figures 3.9 - 3.13 demonstrate that the Allt Riabhach na Bioraich is chemically more similar to the Control burn than the existing Experimental burn and therefore better suited for experimental comparisons with the Control. Although, like the Experimental burn, it shows some disparity in pH compared to the Control burn (Figure 3.10) over the winter and spring of 1997, it is generally slightly less acid. The all year round similarity in alkalinity and conductivity (Figure 3.9 and 3.11) between the Allt Riabhach na Bioraich and the Control burn suggests similar hydrological characteristics and, particularly, a similar contribution from relatively mineral rich base flow. Interestingly, these two sites are also better matched in terms of their nitrate and Total organic carbon (TOC) concentrations, showing considerably higher concentrations of nitrate in winter and lower concentrations of TOC in summer than the Experimental burn (Figure 3.12).

4.2 Biology

4.2.1 Epilithic diatoms

There is no significant evidence, after five years of summer grazing in the experimental catchment, of any coherent shift in the epilithic diatom flora of the Experimental burn (Table 2). The data demonstrate considerable inter-annual variability, which is typical of upland running waters, but this is equally apparent in the floral assemblages of the Control burn.

Data for the Allt Riabhach na Bioraich burn continue to show reasonable similarity with the Control burn, although the acid loving species *Tabellaria flocculosa* shows greater dominance in the former. Both burns contain similar proportions of *Brachysira vitrea*, *Eunotia incisa* and *Peronia fibula*, and continue to suggest that they would make a suitable Control/Experimental pair for examining diatom responses.

4.2.2 Macroinvertebrates

Macroinvertebrate data are presented in Table 3. The summary statistics (Table 4) indicate that the total number of individual animals caught and the total number of species represented have fallen at both the Control and the Experimental site over the period of study. Although generally similar in faunal assemblages, the Experimental burn is better represented by taxa with low BMWP scores which are indicative of greater organic enrichment. This could reflect direct cattle impact on the Experimental stream which might limit the occurrence of (high scoring) Mayfly and Stonefly species, but could also result from the more eroded, peaty nature of the Experimental burn sampling stretch. The Experimental burn also shows a decline in the BMWP score which provides tentative evidence of progressive organic enrichment, however it is not possible to establish any statistical significance of a trend, given there have only been four sampling years to date.

The Allt Riabhach na Bioraich has a more limited range of taxa than the Control burn but, like it, includes the Stonefly species which prefer waters with lower levels of organic matter than is apparent at the Experimental site. Although we are limited in our assessment by only having two years of data available, it does appear that the Allt Riabhach na Bioraich is better matched than the Experimental burn with the Control burn. In terms of macroinvertebrate habitat, the open channel and cobble/boulder dominated substrate of the Allt Riabhach na Bioraich provide a much closer comparison with the Control burn.

4.2.3 Aquatic macrophytes

Aquatic macrophyte data for the three burns is summarised in Table 5. There is no evidence of any trend in the assemblage of the Experimental burn over the period of study. The data continue to demonstrate substantial differences in the total plant cover and species representation of the Control and Experimental burns, which are likely to reflect physical differences between the two sites. The Allt Riabhach na Bioraich has particularly poor macrophyte cover and diversity, probably resulting from the susceptibility of this burn to severe spate conditions and channel scouring.

4.2.4 Fish

The data for Trout density (Table 6) demonstrate that there has been no trend in either new recruits or older fish in the experimental burn over the period of study. Considerable inter-annual variability is evident for both classes in all three burns. The Allt Riabhach na Bioraich has similar densities to the other burns, but is probably better suited than the Experimental burn for comparison with the Control, given its more similar physical properties and the larger available sampling area.

5 Discussion

With the possible exception of the macroinvertebrate data, five years of monitoring provide no significant evidence of any chemical or biological effect of cattle grazing on the Experimental burn. As has been discussed in previous reports, the absence of base-line (pre-experiment) data for the Experimental burn, reduces our ability to detect subtle changes which may be due to grazing. However, the absence of any trends in the data for the Experimental burn, or in the chemical concentration Experimental / Control ratios, since the onset of grazing, suggest that cattle impacts have been negligible.

The relatively low macroinvertebrate BMWP scores for the Experimental burn are to be expected, given the peaty nature of its channel and therefore can not be used as evidence of cattle impact. A significant declining trend in the BMWP score at the site would provide a stronger indication of a response to grazing, if this was not observed for the Control burn. However four years of data are insufficient to establish significance and, given the lack of any other evidence, carry little weight at this time.

Application of stage board data as a surrogate for flow estimates demonstrate the importance of flow conditions in determining the chemical relationship between the Control and Experimental burn. This emphasises the limitations of making comparisons of the site relationships between winter (cattle off) and summer (cattle on) periods, as has been attempted in previous reports. Such an approach would be more valid for examination of the relationship between the Control burn and the Allt Riabhach na Bioraich given the year round similarity in alkalinity and conductivity measurements, and their inferred hydrochemical responses.

The most recently collected chemical and biological data confirm that the Allt Riabhach na Bioraich is suitable as an potential experimental comparison with the Control burn. The clearest biological difference between the two sites concerns their aquatic macrophyte populations, the former almost entirely devoid of cover, probably as a result of its susceptibility to scouring during spate conditions. Otherwise, the two sites exhibit broadly similar biological characteristics. We now have adequate base-line data for this site to be used as a second experimental site, by the introduction of cattle to its catchment.

Attempts to install standard ECRC designed sediment traps in deep water locations in Loch Laidon were unsuccessful last year; the trap construction (originally intended for small upland sites) proved inadequate for deployment in such a large loch, subject to considerable wave action and large water level oscillation. However, water samples continue to be taken from the Loch outflow and now form a considerable water chemistry time series. These data will become increasingly important in gauging the response of acid sensitive waters in this part of Scotland (which is not represented by the United Kingdom Acid Waters Monitoring Network) to an anticipated reduction in the deposition of acidic pollutants following emissions reductions.

Acknowledgements

This work is funded by the Rannoch Trust and Scotish Natural Heritage. We particularly wish to thank Nicholas Thexton for the collection of water samples.

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Figure 3.1 The ratio of alkalinity and its temporal variability in spot samples from the Experimental and control burns, August 1992 - October 1998

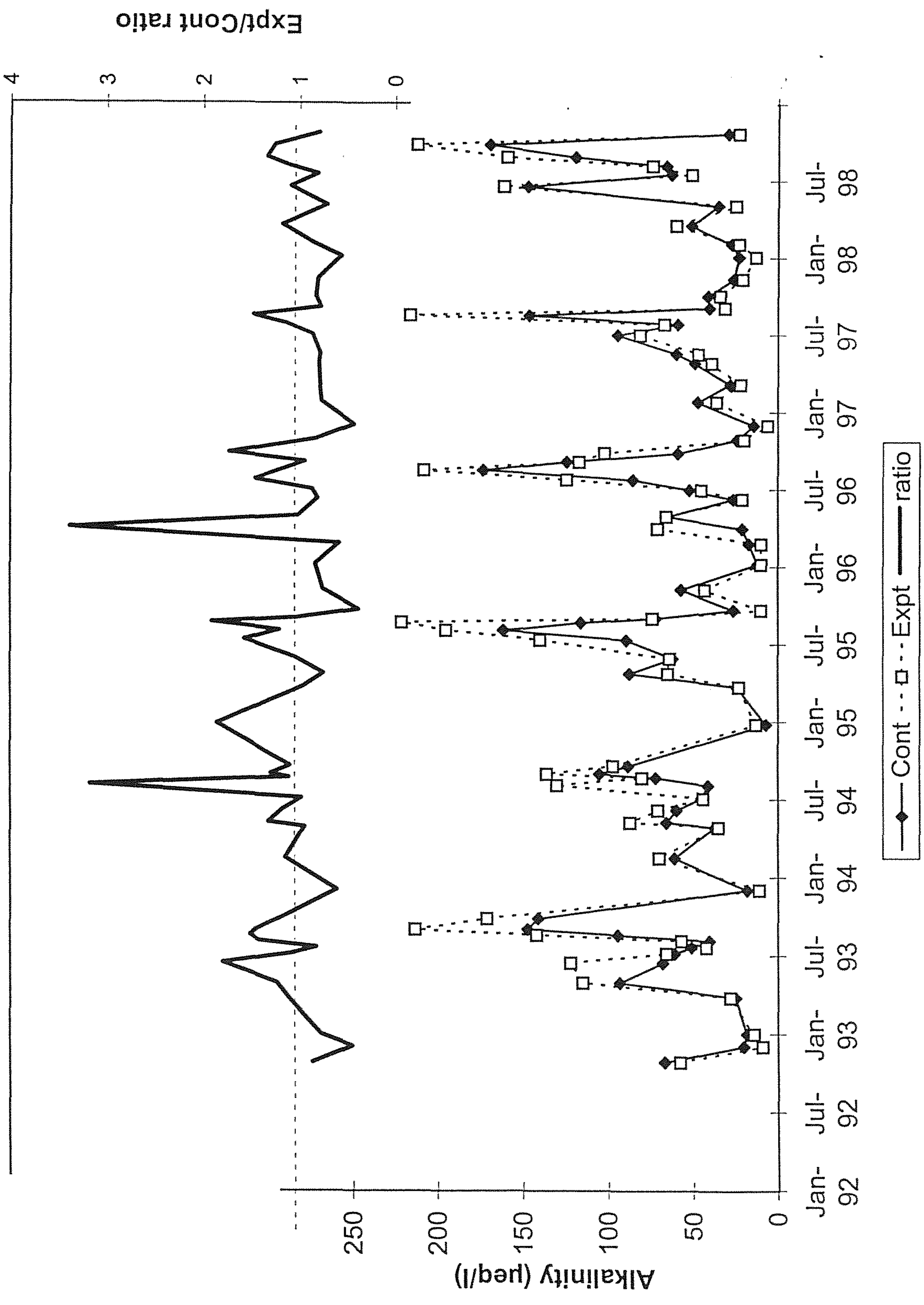

Figure 3.2 The ratio of H^+ concentration and the temporal variability in pH of spot samples from the Experimental and Control burns, August 1992 - October 1998

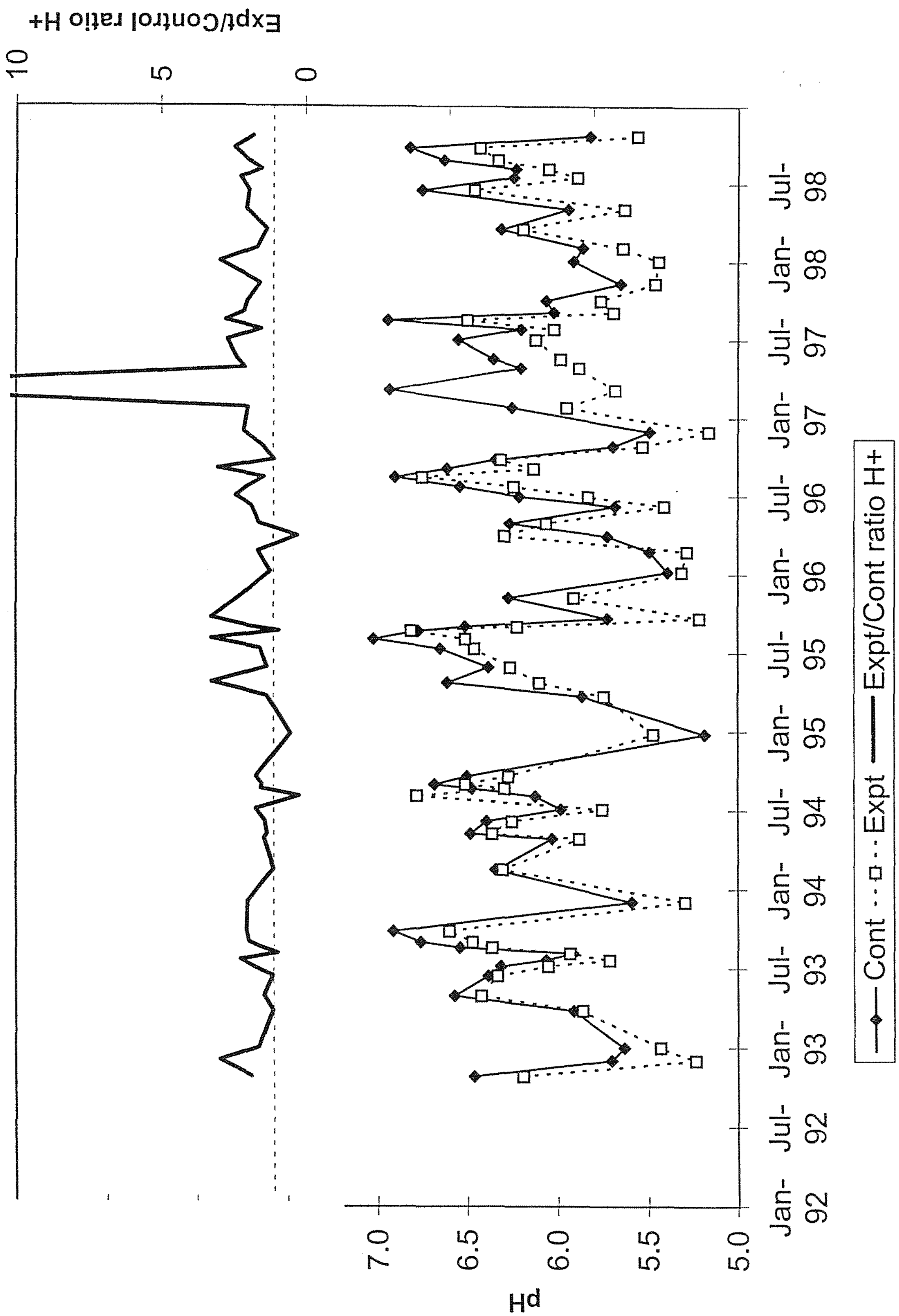

Figure 3.3 The ratio of conductivity and its temporal variability in spot samples from the Experimental and Control burns, August 1992 - October 1998

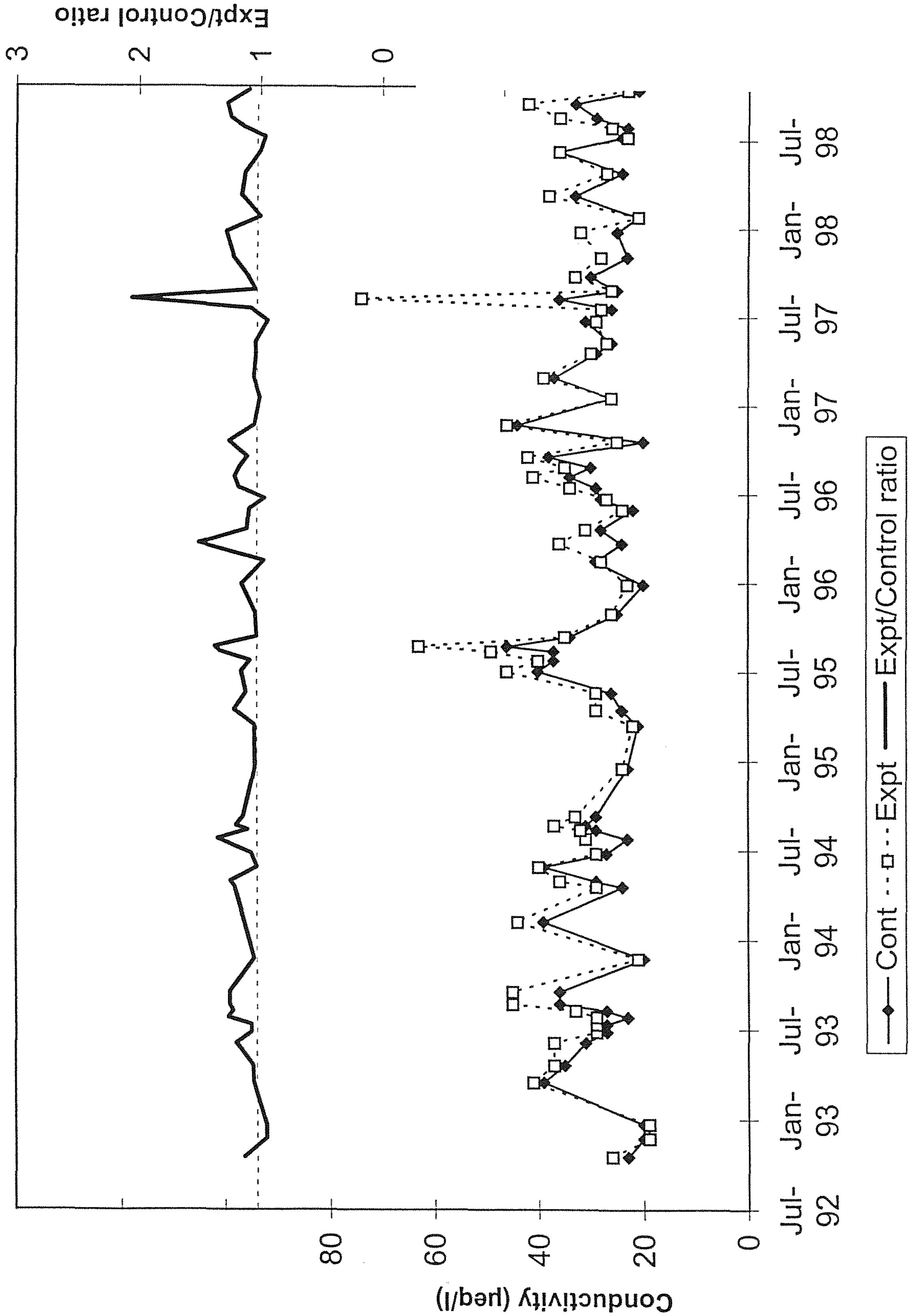

Figure 3.4 Temporal variability of nitrate in spot samples from the Experimental and Control burns, August 1992 - October 1998

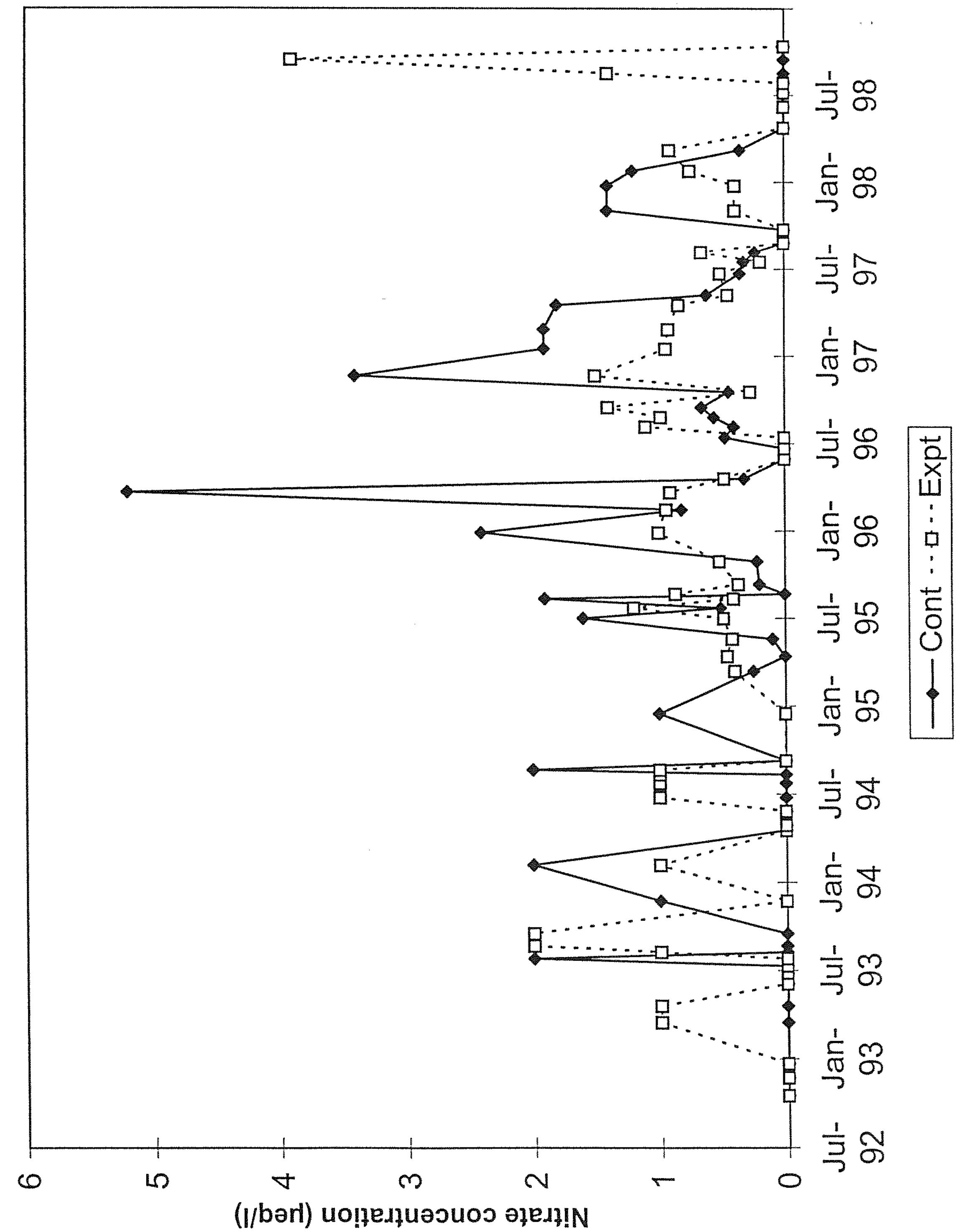

Figure 3.5 The relationship between the ratio of alkalinity in spot samples from the Experimental and Control burns and the stage board height of the Control burn over the period August 1992 - October 1998

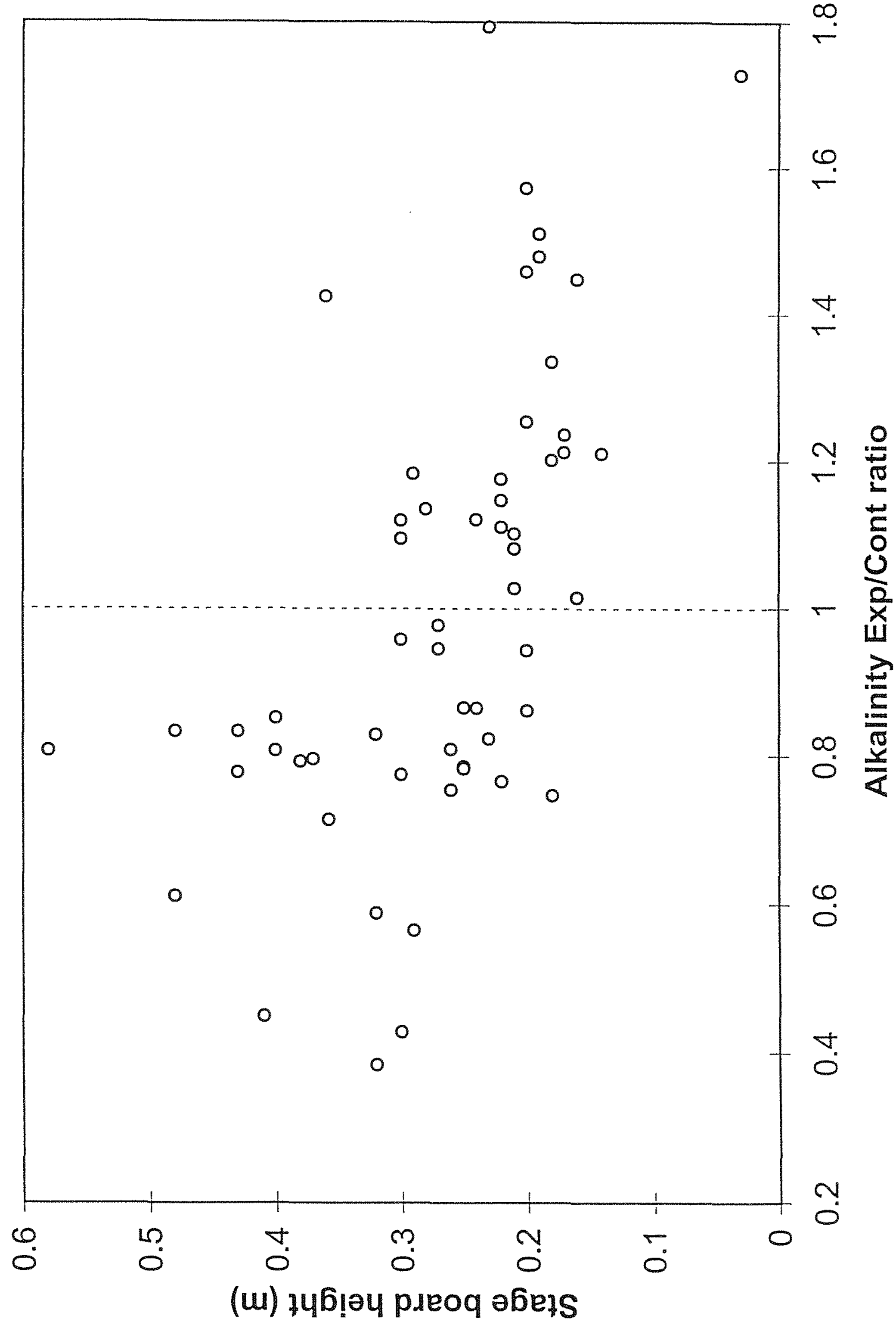

Figure 3.6 Comparison of the nitrate concentration of the Control and Experimental Burn (Lower site) June 1995 - October 1998

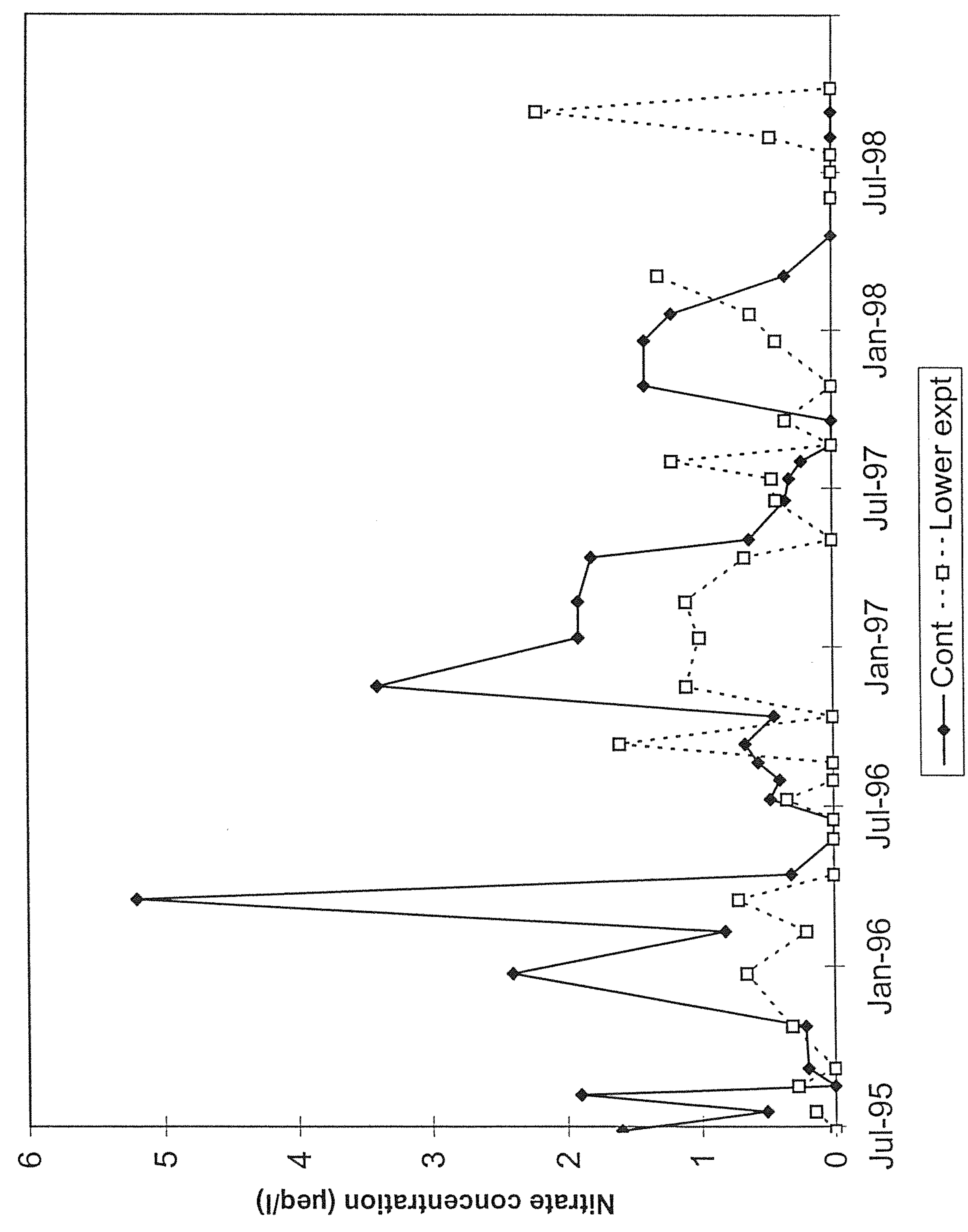

Figure 3.7 The ratio of alkalinity and its temporal variability in spot samples from the Experimental and control burns, August 1992 - October 1998

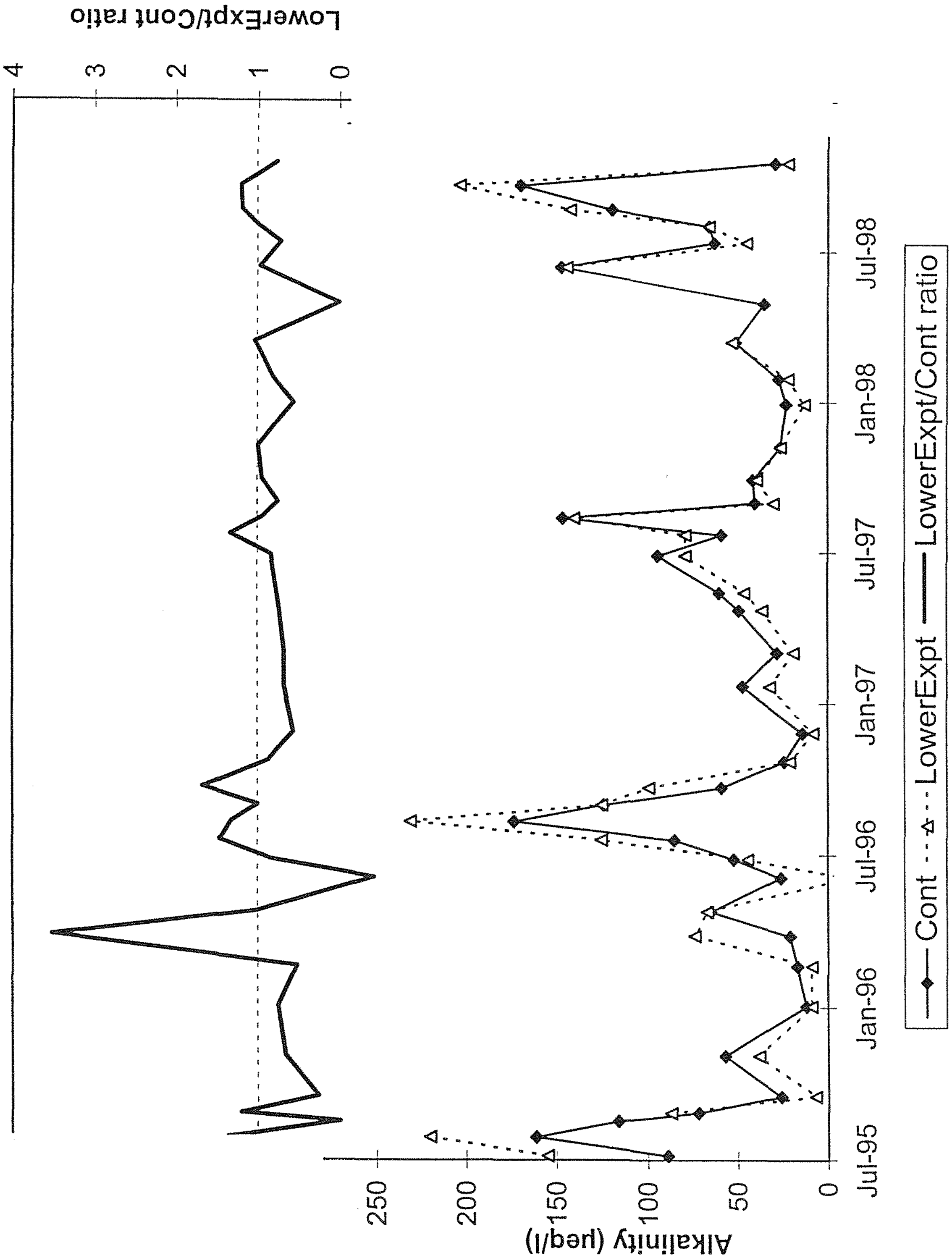

Figure 3.8 The ratio of conductivity and its temporal variability in spot samples from the Experimental and control burns, August 1992 - October 1998

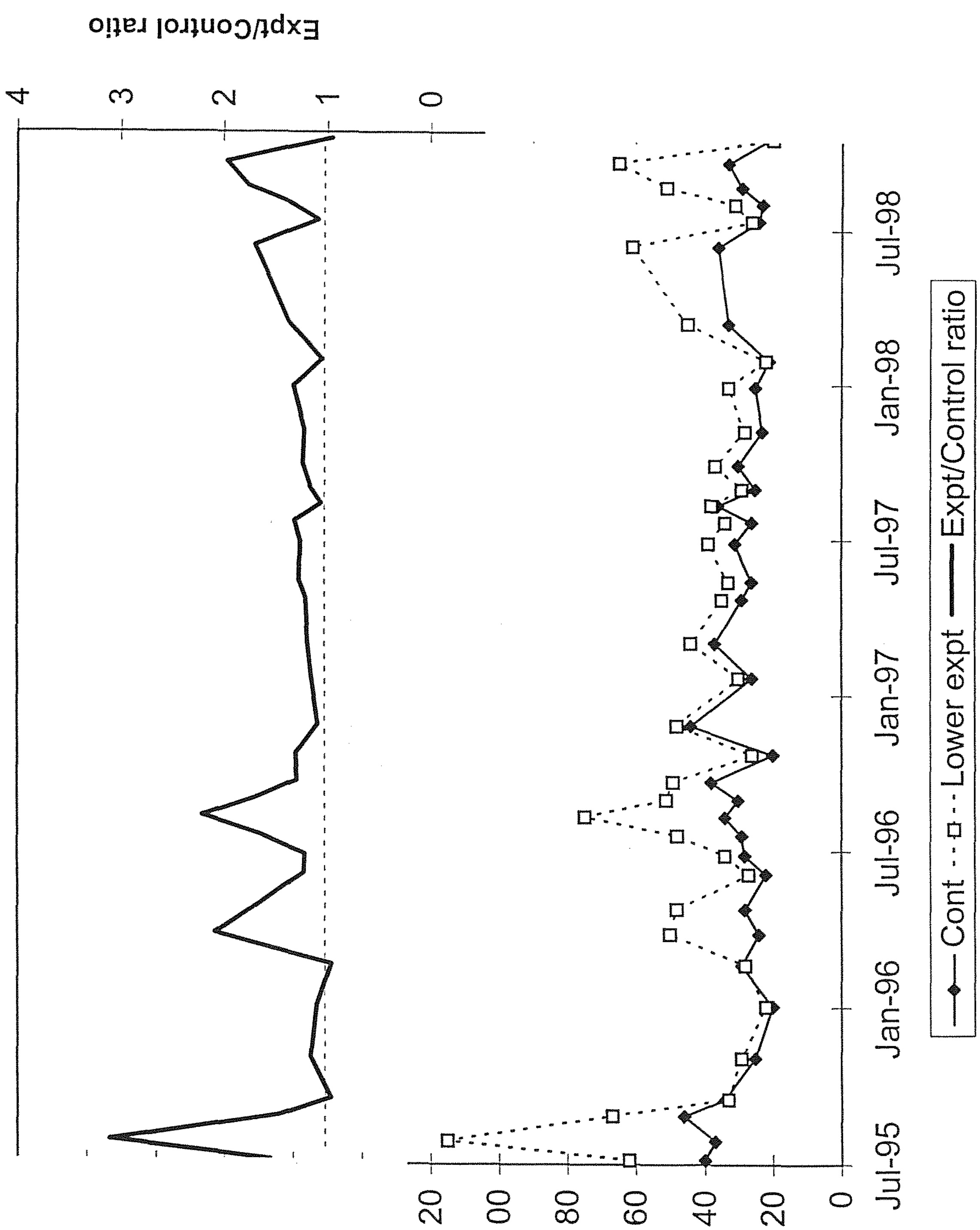

Figure 3.9 A comparison of alkalinity of spot samples from the Control burn, Experimental Burn and the Allt Riabhach na Bioraich, August 1992 - October 1998

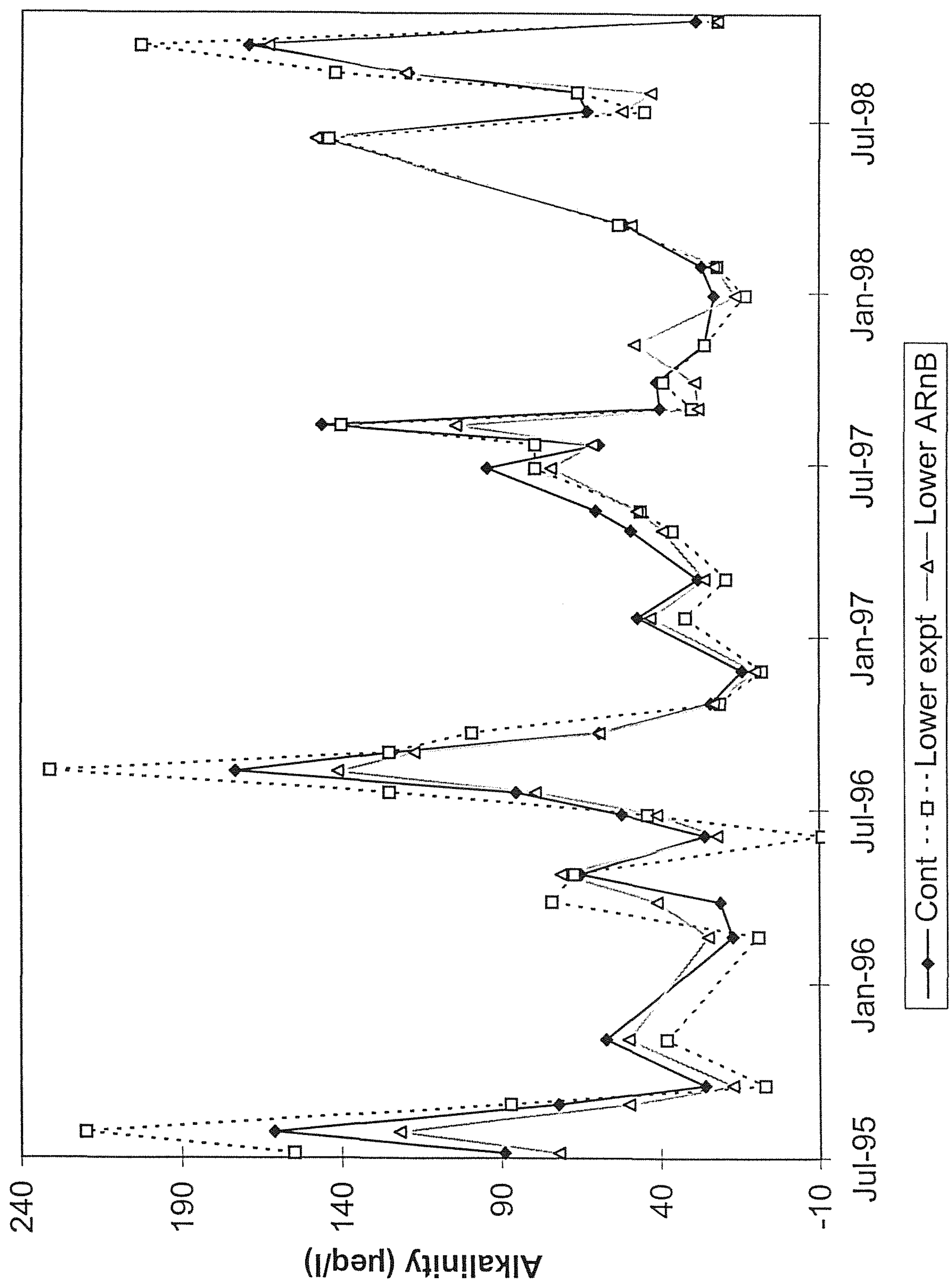

Figure 3.10 A comparison of pH of spot samples from the Control burn, Experimental Burn and the Allt Riabhach na Bioraich, August 1992 - October 1998

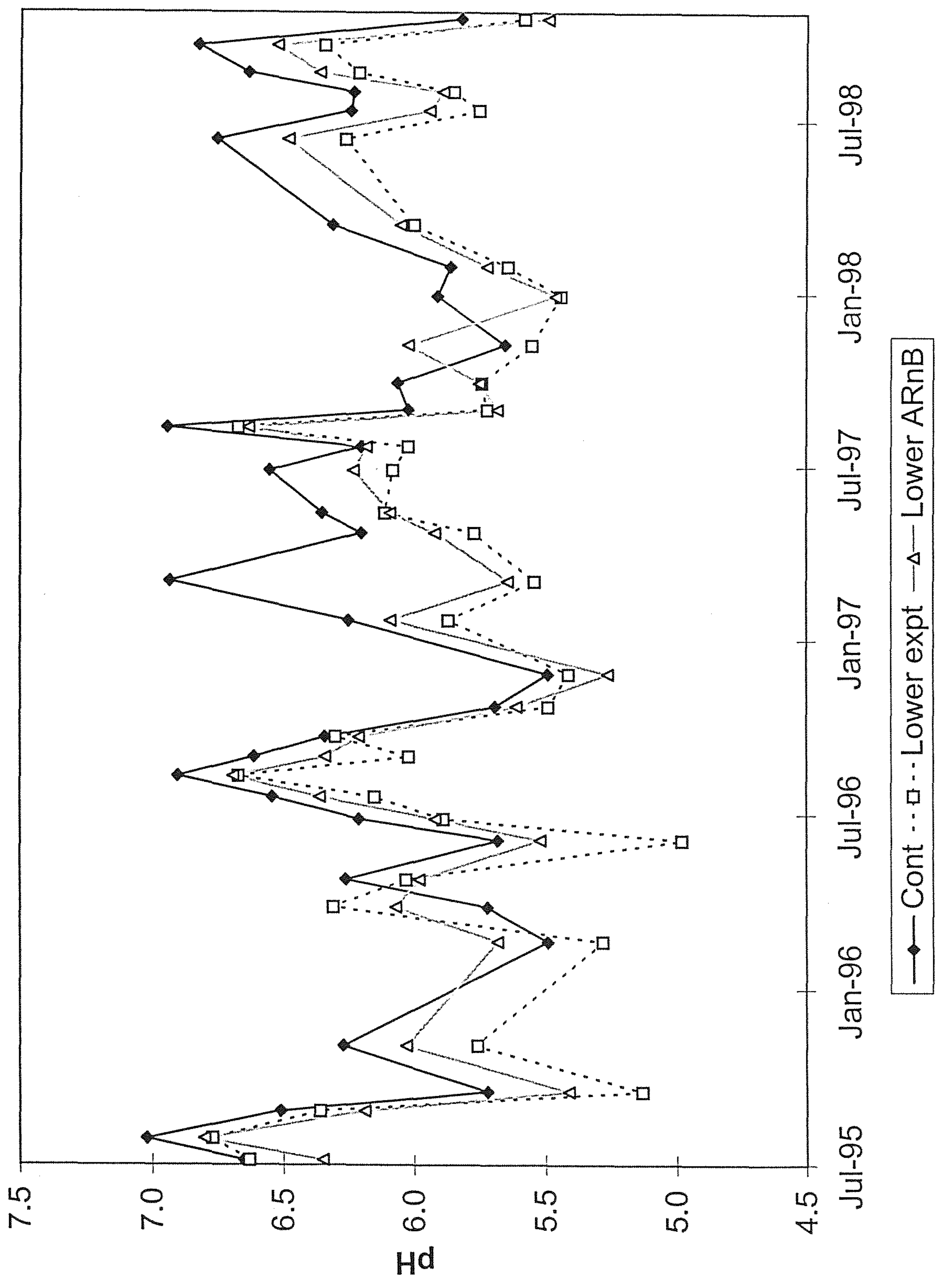

Figure 3.11 A comparison of conductivity of spot samples from the Control burn, Experimental Burn and the Allt Riabhach na Bioraich, August 1992 - October 1998

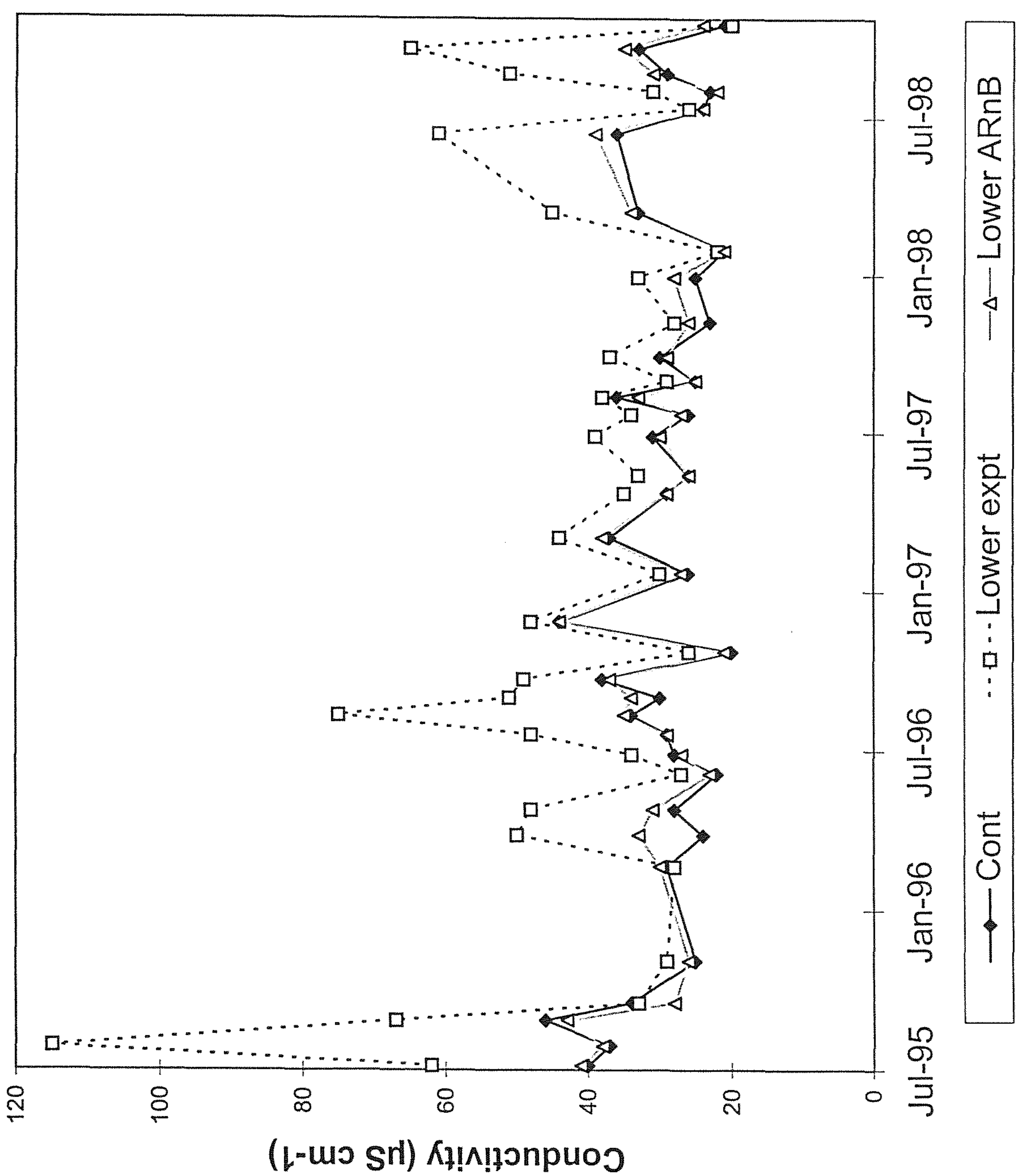

Figure 3.12 A comparison of nitrate concentrations of spot samples from the Control burn, Experimental Burn and the Allt Riabhach na Bioraich, August 1992 - October 1998

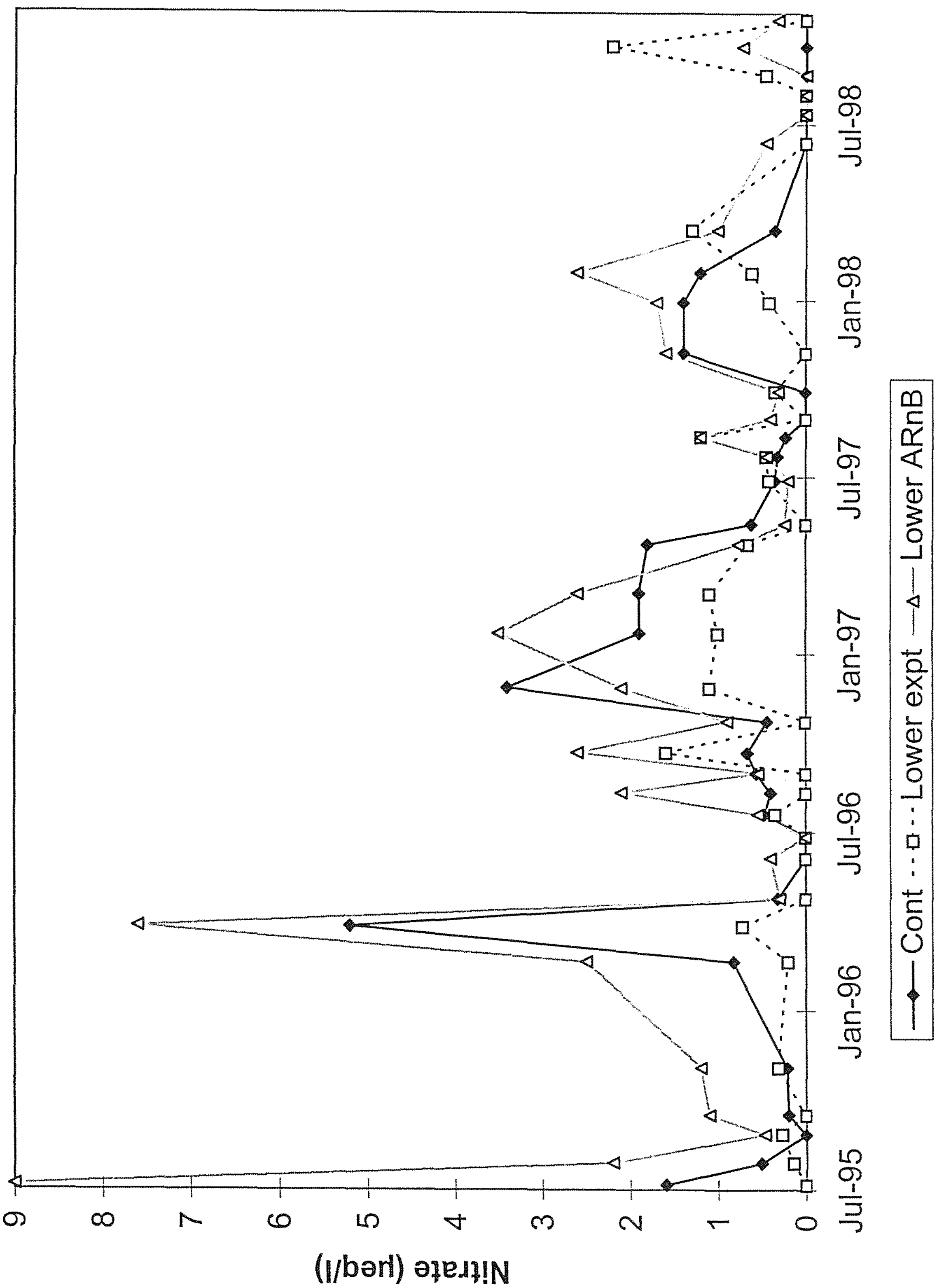

Figure 3.13 A comparison of Total Organic Carbon concentrations of spot samples from the Control burn, Experimental Burn and the Allt Riabhach na Bioraich, August 1992 - October 1998

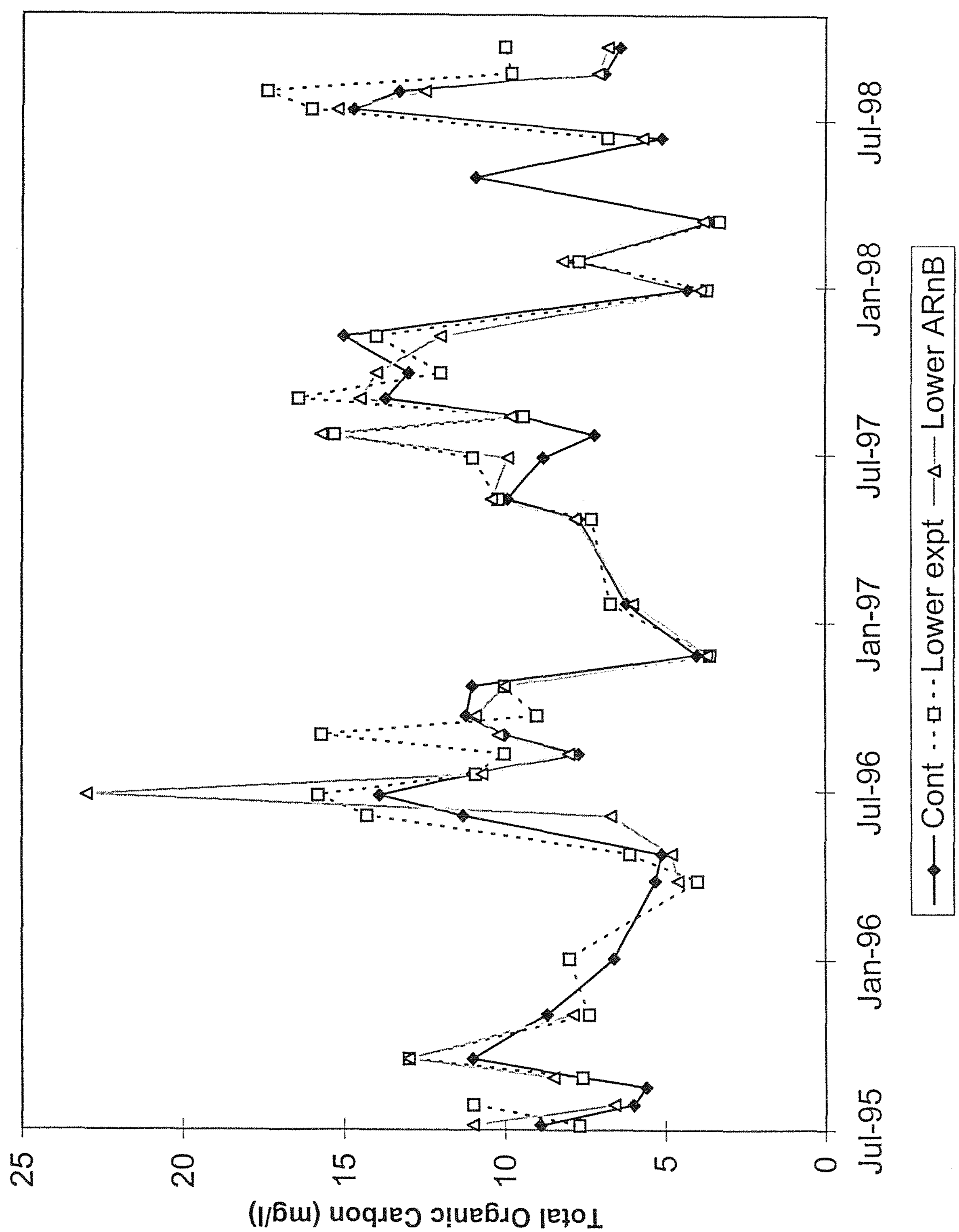

Table 1 **Summary statistics of selected chemical determinands for individual years at the Control, Experimental (EXPT upper and lower) and Allt Riabhach na Bioraich (ARnB upper and lower) burns**

	pH			Alkalinity (μeq l^{-1})			Conductivity (μS cm^{-1})			Nitrate (μeq l^{-1})			Sulphate (μeq l^{-1})			Total phosphorus (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
CONTROL1993	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	44	22.5	19.0	26.0	6.3	0.0	29.0
CONTROL1994	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	85	18.9	2.5	58.0	4.4	0.0	17.0
CONTROL1995	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	175	3.1	2.5	6.0	4.6	0.0	28.0
CONTROL1996	6.03	5.39	6.90	56.0	12.0	173.0	28.8	20.0	44.0	1.2	0.0	5.2	40.5	18	62	3.3	2.5	10.0	3.8	0.0	10.0
CONTROL1997	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	43	2.9	2.5	6.0	5.3	0.0	10.0
UPPEREXPT1993	6.04	5.29	6.60	89.2	11.0	213.0	33.2	19.0	45.0	0.6	0.0	2.0	24.2	8	45	20.5	19.0	22.0	2.7	0.0	9.0
UPPEREXPT1994	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	51	18.9	0.0	60.0	2.9	0.0	7.0
UPPEREXPT1995	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	302	3.0	2.5	6.0	2.6	0.0	7.0
UPPEREXPT1996	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	75	2.6	2.5	3.0	4.0	0.0	13.0
UPPEREXPT1997	5.90	5.46	6.50	59.4	21.0	216.0	34.0	26.0	74.0	0.5	0.0	0.9	42.0	9	233	2.5	2.5	2.5	2.3	0.0	10.0
LOWEREXPT1995	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	749	5.3	2.5	11.0	1.8	0.0	4.0
LOWEREXPT1996	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	278	3.1	2.5	6.0	4.6	0.0	12.0
LOWEREXPT1997	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	80	5.6	2.5	17.0	2.4	0.0	7.0
LOWER_ARnB1995	6.16	5.41	6.80	59.8	17.0	122.0	33.5	25.0	43.0	2.4	0.5	9.0	84.2	26	156	3.4	2.5	6.0	3.2	0.0	8.0
LOWER_ARnB1996	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	88	2.7	2.5	4.0	7.4	1.0	29.0
LOWER_ARnB1997	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	49	2.9	2.5	6.0	4.0	0.0	10.0
UPPER_ARnB1995	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	158	3.4	2.5	6.0	2.3	0.0	8.0
UPPER_ARnB1996	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	82	2.8	2.5	4.0	5.0	1.0	11.0
UPPER_ARnB1997	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	44	2.9	2.5	6.0	7.3	0.0	28.0

Table 2 **Diatom taxon list (% frequency of all taxa >1% in any one sample., + = species present at <1%)).**

	Control burn						Experimental burn					ARnB burn	
Taxon	1992	1993	1994	1995	1996	1997	1993	1994	1995	1996	1997	1996	1997
Achnanthes minutissima	+	+	+	1.3	1.0	+	+	+	1.5	26.9		+	+
Brachysira vitrea	10.7	7.3	6.9	15.9	10.8	11.8	20.1	8.6	24.4	25.4	20.4	4.7	16.9
Brachysira brebissonii	+		+	+	+	+	1.3	+	1.2		1.3	+	1.7
Cymbella microcephala										8.9			
Cymbella lunata	+	+	+	1.5	+	+	1.6	1.0	6.1	2.4	4.6	+	1.6
Eunotia pectinalis var.minor	2.0	+	6.0	2.0	1.0	+	6.0	15.0	2.7	1.2	+		
Eunotia exigua	2.7	1.6	4.5	2.0	1.3	4.7	3.1	3.4	1.8	+	2.5	+	2.4
Eunotia rhomboidea	+	+	1.1	1.1	+		+	1.0	3.0	+		+	
Eunotia incisa	1.6	1.4	3.8	1.8	+	3.6	3.8	7.4	7.9	+	8.5	1.1	1.0
Eunotia naegelii		1.1	+	+	+	1.2	6.6	9.4	7.6	2.1	3.8	3.2	4.3
Eunotia curvata	+	+	+	+	1.6	+	+	1.6	+		+	3.8	1.3
Eunotia sp.	+	+	1.2	+	+	1.0	+	+	1.8	+	+	+	+
F. rhomboides var. *saxonica*	1.0	+	+	1.3	+	2.4	6.0	7.4	20.1	4.9	20.7	+	1.5
F. rhomboides var.*viridula*	+	+	+	+		+	+	1.3	+	+	1.4		+
Gomphonema gracile	1.5	+	+	+	1.0	+		1.2		1.4	+	1.4	1.0
Gomphonema minimum	1.0	+											
Navicula subtilissima						+	+				1.1		
Peronia fibula	2.7	1.2	2.4	4.7	2.8	2.5	22.3	15.6	8.8	3.2	15.0	8.3	1.3
Synedra acus		+	+	+		13.7	+			+			+
Synedra minuscula	8.2	55.4	19.9	25.9	46.8	15.4	8.8	+	+	6.4		2.1	+
Tabellaria flocculosa	65.8	24.9	47.6	34.3	29.1	38.3	15.7	19.9	7.9	9.8	16.5	71.4	65.2

Table 3 Macroinvertebrate taxon list and total abundance

	CONTROL BURN				EXPERIMENTAL BURN				ARnB BURN	
Taxon	93	94	96	97	93	94	96	97	96	97
NEMATODA			1		2		1	1	1	
Pisidium sp.						1				
OLIGOCHAETA	22	6	8	3	14	10	26		12	
Siphlonurus lacustris							35		17	
Ameletus inopinatus	11	4								
Baetis sp.				52		1				
Baetis rhodani	5		7					1		
Baetis muticus	3	2	3		9		3			
Heptagenia lateralis	3	18	11	9					2	1
Ecdyonurus dispar				1						
Leptophlebia marginata			1		16	19	6			
Leptophlebia vespertina					20	61	9	9	5	
Protonemura meyeri					1					
Amphinemura sulcicollis	168	32	27	17	20	1	2	14	9	23
Nemurella picteti				1				1		
Nemoura sp.										2
Nemoura avicularis						2				
Nemoura cambrica					2		1			
Leuctra inermis	41	6	1	5	1					2
Leuctra hippopus		1								
Leuctra nigra					1					
Perlodes microcephala	2									
Isoperla grammatica	106	4	8	9	7				3	46
Siphonoperla torrentium	109	48	54	2	23	5		5	7	8
Chloroperla tripunctata				11						5
Pyrrhosoma nymphula					1	1				
Cordulegaster boltonii					1					
Dytiscidae undet. (larvae)						1		1	1	
Oreodytes rivalis	18	36	7	1					1	
Agabus guttatus					1					
Platambus maculatus		1								
Anacaena globulus							1			
HELODIDAE	1									
Elmis aenea	17		1							
Limnius volckmari	129	16	46	17	2	5		17	3	7
Oulimnius tuberculatus	55	22	21	5	151	98	19	15	9	10
Rhyacophila dorsalis	1		1	2						
Plectrocnemia conspersa	6	1	5	3	13	9	9	15	11	1
Plectrocnemia geniculata		2				1				
Polycentropus flavomaculatus		2	3		23	6	6		1	
Hydropsyche siltalai	1									
HYDROPTILIDAE					38					
Hydroptila sp.		2					1			
Oxyethira sp.		1				29				
LIMNEPHILIDAE undet.	10	7	6		66	2	7	4	6	3
Halesus radiatus							6			
TIPULIDAE	2	1			1			1		
Dicranota sp.	8	2	3	3	6	2	1	3	7	
Psychodidae	1									
CHIRONOMIDAE	26	17	28	13	56	86	104	15	14	7
SIMULIIDAE	23		1	23	2		1	1		12
Simulium latipes						3				

Table 4 Macroinvertebrate summary statisitics

	CONTROL BURN				EXPERIMENTAL BURN				ARnB BURN	
	1993	**1994**	**1996**	**1997**	**1993**	**1994**	**1996**	**1997**	**1996**	**1997**
Total count	768	231	256	178	477	231	247	110	109	128
Total no. of taxa	24	22	27	19	25	20	20	18	17	13
RICHNESS (rareftn100)	17	17	18	15	18	14	14	16	17	12
HILL'S N1	11.5	11.9	12.8	10.6	11.3	7.9	7.7	11.4	12.6	7.6
HILL'S N2	8.4	9.0	9.0	7.5	6.9	5.4	4.6	10.0	11.9	5.5
EVENNESS (E5)	0.71	0.73	0.68	0.68	0.57	0.64	0.54	0.87	0.94	0.67
BMWP	110	99	125	88	108	83	82	67	89	78
ASPT	6.4	6.6	6.6	6.3	6.4	5.5	5.9	6.1	6.9	7.1

Table 5 **Aquatic macrophyte cover**

	CONTROL BURN						EXPERIMENTAL BURN					ARnB BURN	
	92	**93**	**94**	**95**	**96**	**97**	**93**	**94**	**95**	**96**	**97**	**96**	**97**
Batrachospermum sp.	+	0.7	+		+		33.3	12.7	54.2	32.8	35.0		1.6
Marsupella emarginata var. *aquatica*	4.4	4.0	4.9	0.4	1.5	0.2	38.0	37.3	9.4	27.4	23.2	+	
Scapania undulata	2.8	3.7	1.7	0.9	2.0	1.9		5.0	21.7	12.0	11.8	0.4	0.2
Racomitrium aciculare	0.3	+	2.1	0.4	+	+							
Juncus bulbosus var. *fluitans*	0.1	+					2.6	9.0	2.7	6.6			
TOTAL COVER (excluding filamentous green algae)	7.6	8.4	8.7	1.7	3.5	2.2	73.9	64.0	88.0	78.8	70.0		1.8
Filamentous algae	+	10.7	+	0.1	+	+	68.0	+				0.4	

nb. Control burn and Allt Riabhach na Bioraich burn sampling stretches = 50 m length
Experimental burn sampling stretch = 20 m length

Table 6 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
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
ARnB burn	1995	79	0.54	0.05
ARnB burn	1996	57	0.63	0.24
ARnB burn	1997	73	0.21	0.07

Appendix 1 Water chemistry for the Control Burn August 1992 - October 1998

Date	PH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4	Tot-P	Al-NL	Al-L	Abs-250	TOC	NH_4
12-Aug-92	5.44	18	24	106	3	34	68	94	0.0	26	1		70	18	0.740		
30-Oct-92	6.46	67	23	112	4	32	68	99	0.0	28	0		29	4	0.320	5.0	
06-Dec-92	5.70	20	20	104	3	17	43	103	0.0	25	1		33	2	0.250	3.5	
04-Jan-93	5.63	18	20	105	4	25	41	101	0.0	44	0		21	3	0.270	3.8	
30-Mar-93	5.91	25	39	203	5	44	67	278	0.0	41	1		20	3	0.170	3.1	
03-May-93	6.57	93	35	177	6	42	97	186	0.0	35	0		9	5	0.170	3.3	
18-Jun-93	6.38	68	31	145	4	39	88	130	0.0	30	1	19.0	15	29	0.550	9.4	
10-Jul-93	6.31	61	27	141	4	33	77	129	0.0	19	2	26.0	71	1	0.610	9.1	
25-Jul-93	6.06	51	27	134	3	38	92	117	0.0	16	2		72	0	0.780	11.0	
09-Aug-93	5.91	40	23	114	3	33	72	98	2.0	11	4		92	13	0.880		
22-Aug-93	6.54	94	27	148	4	42	91	141	0.0	18	2		39	4	0.480		
04-Sep-93	6.76	147	36	168	7	46	111	151	0.0	26	0		17	1	0.290		
29-Sep-93	6.91	141	36	161	6	47	114	155	0.0	31	0		26	5			
06-Dec-93	5.59	18	20	99	4	25	32	86	1.0	38	1		37	5	0.459	6.7	
18-Feb-94	6.34	61	39	210	6	66	101	211	2.0	41	0	5.0	14	0	0.132		0
01-May-94	6.03	37	24	141	9	34	56	123	0.0	25	0	10.0	36	8	0.309	4.4	0
12-May-94	6.48	66	29	161	6	48	82	143	0.0	30	0		22	5	0.213	3.2	0
10-Jun-94	6.39	60	39	201	9	68	110	174	0.0	85	1		30	4	0.283		0
08-Jul-94	5.98	45	27	151	6	52	83	111	0.0	35	1		80	0	0.632		0
07-Aug-94	6.12	41	23	140	5	46	71	109	0.0	26	4	58.0	60	2			0
25-Aug-94	6.47	72	29	152	5	61	113	118	0.0	27	1		41	1			0
03-Sep-94	6.68	105	31	163	6	60	110	125	2.0	24	1	2.5	28	7	0.339	5.5	0
22-Sep-94	6.50	88	29	152	6	56	119	123	0.0	23	1		26	17	0.385	7.5	0
29-Dec-94	5.18	7	23	108	4	30	31	126	1.0	23	1		24	0	0.198	4.0	0
27-Mar-95	5.86	24	21	121	6	31	41	122	0.3	22	0	2.5	29	2	0.239	4.8	0
27-Apr-95	6.61	87	24	133	8	43	81	107	0.0	20	0	2.5	16	0	0.204	4.8	0
02-Jun-95	6.38	62	26	137	4	41	75	103	0.1	18	3	3.0	29	28	0.490	9.9	0
15-Jul-95	6.65	89	40	178	9	75	128	127	1.6	96	0	2.5	29	1	0.340	8.9	0
06-Aug-95	7.02	161	37	195	11	67	146	143	0.5	44	0		21	0	0.285	6.0	0
25-Aug-95	6.77	116	37	186	10	62	115	144	1.9	37	1	2.5	20	1	0.262	5.6	0
04-Sep-95	6.51	72	46	188	7	90	157	118	0.0	175	0	6.0	34	3	0.313	7.6	0
24-Sep-95	5.72	26	34	156	5	66	99	108	0.2	107	0		62	4	0.469	11.0	0
11-Nov-95	6.27	57	25	124	6	48	85	95	0.2	39	0	2.5	65	2	0.430	8.7	0
10-Jan-96	5.39	12	20	100	6	37	50	78	2.4	59	0	2.5	44	5	0.297	6.6	3
27-Feb-96	5.49	17	29	152	5	55	68	166	0.8	60			28	2	0.238		0
03-Apr-96	5.72	21	24	124	6	39	61	112	5.2	49	1	2.5	28	0	0.243	5.3	3
02-May-96	6.26	65	28	136	5	50	88	113	0.3	49	0	2.5	30	4	0.251	5.1	0
12-Jun-96	5.68	26	22	109	2	38	62	88	0.0	21	3	10.0	70	2	0.586	11.3	0
04-Jul-96	6.21	52	28	131	4	49	83	93	0.0	47	2	2.5	48	10	0.513	13.9	0
27-Jul-96	6.54	85	29	143	5	61	112	102	0.5	31	1	2.5	48	2	0.551	11.0	0
18-Aug-96	6.90	173	34	160	7	69	144	110	0.4	26	0	2.5	24	0	0.386	7.7	0
07-Sep-96	6.61	124	30	159	7	71	131	114	0.6	24	1	2.5	31	5	0.496	10.0	0
28-Sep-96	6.34	59	38	164	9	74	125	163	0.7	62	0	2.5	58	5	0.486	11.2	0
30-Oct-96	5.69	24	20	94	7	37	57	79	0.4	18	4		69	10	0.564	11.0	0
03-Dec-96	5.49	14	44	219	7	67	73	296	3.4	40	0	2.5	38	1	0.165	4.0	3
28-Jan-97	6.25	47	26	128	5	42	72	102	1.9	43	0	2.5	40	0	0.301	6.2	2
10-Mar-97	6.93	28	37	190	7	57	80	228	1.9	41	0						0

30-Apr-97	6.20	49	29	170	5	52	89	162	1.8	25	1	2.5	46	0	0.384	7.7	0
21-May-97	6.35	60	26	142	5	45	79	118	0.6	19	1	2.5	52	4	0.487	9.9	1
05-Jul-97	6.55	94	31	160	7	54	100	121	0.4	29	0	2.5	29	10	0.410	8.8	4
30-Jul-97	6.20	59	26	135	4	54	100	104	0.3	13	2	2.5	86	4	0.870	7.2	0
19-Aug-97	6.94	146	36	169	8	67	135	122	0.2	24	0	2.5	32	9	0.447	9.5	0
07-Sep-97	6.02	40	25	130	4	48	82	106	0.0	17	1	2.5	88	4	0.708	13.7	0
05-Oct-97	6.06	41	30	143	8	55	96	145	0.0	20	0	2.5	58	10	0.607	13.0	0
14-Nov-97	5.65	26	23	119	12	44	65	101	1.4	28	1	6.0	73	7	0.640	15.0	1
05-Jan-98	5.91	23	25	139	6	46	60	159	1.4	29	0	2.5	34	2	0.213	4.3	0
05-Feb-98	5.86	27	21	105	4	35	53	94	1.2	27	1	2.5	44	0	0.313	7.8	0
21-Mar-98	6.31	51	33	174	7	52	74	192	0.4	29	0	2.5	20	5	0.161	3.5	0
07-May-98	5.94	35	24	137	5	42	66	115	0.0	15	1	2.5	45	8	0.525	10.9	0
20-Jun-98	6.75	147	36	177	7	60	114	120	0.0	35	2	2.5	1	13	0.204	5.1	0
20-Jul-98	6.24	63	24	125	2	51	87	82	0.0	13	1	2.5	66	1	0.716	14.7	0
09-Aug-98	6.23	66	23	129	3	53	82	79	0.0	13	1	2.5	59	16	0.704	13.3	0
29-Aug-98	6.63	119	29	143	5	54	102	92	0.0	19	9	11.0	29	2	0.365	6.9	0
27-Sep-98	6.82	169	33	151	6	67	132	108	0.0	23	0	2.5	21	2		6.4	0
25-Oct-98	5.82	29	21	101	6	37	61	89	0.0	18	2						0

Appendix 2 Water chemistry for the Experimental Burn (Upper site) August 1992 - October 1998

Date	PH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4	Tot-P	Al-NL	Al-L	Abs-250	TOC	NH4
18-Sep-92	5.71	28	33	136	3	36	113	152	0.0	82	0		21	1	0.410		
30-Oct-92	6.19	58	26	130	3	32	61	128	0.0	26	0		15	0	0.270	4.4	
06-Dec-92	5.23	9	19	93	2	14	27	88	0.0	23	0		27	0	0.260	3.4	
04-Jan-93	5.43	14	19	98	2	21	31	86	0.0	35	0		12	0	0.270	3.8	
30-Mar-93	5.86	28	41	230	5	44	64	296	1.0	45	2		9	3	0.170	2.9	
03-May-93	6.42	115	37	204	7	44	95	192	1.0	29	0		5	2	0.260	4.2	
18-Jun-93	6.33	122	37	202	4	44	100	156	0.0	16	0	19.0	19	9	0.510	8.2	
10-Jul-93	6.05	66	29	164	4	35	76	139	0.0	18	3	22.0	46	1	0.700	9.5	
25-Jul-93	5.71	42	29	156	2	42	73	130	0.0	12	3		48	9	0.860	13.0	
09-Aug-93	5.93	57	29	151	4	42	76	131	0.0	8	5		54	0	0.880		
22-Aug-93	6.36	142	33	186	6	60	108	159	1.0	14	3		28	2	0.650		
04-Sep-93	6.47	213	45	210	7	68	159	171	2.0	22	1		10	2	0.410		
29-Sep-93	6.60	171	45	209	15	64	135	207	2.0	28	0		20	0			
06-Dec-93	5.29	11	21	105	3	24	26	87	0.0	39	6		24	2	0.492	6.8	
18-Feb-94	6.30	70	44	243	6	75	109	246	1.0	49	1	0.0	5	0	0.096		0
01-May-94	5.88	35	29	183	4	44	58	159	0.0	28	1	13.0	26	7	0.414	5.4	0
12-May-94	6.36	87	36	202	7	58	90	176	0.0	26	0		19	4	0.279	5.0	7
10-Jun-94	6.25	71	40	224	5	62	100	200	0.0	51	0		22	2	0.292		0
08-Jul-94	5.75	44	29	178	3	53	75	122	1.0	24	2		45	1	0.836		0
07-Aug-94	6.78	130	31	181	13	78	137	141	1.0	19	4	60.0	17	6			0
25-Aug-94	6.29	80	32	177	7	71	111	141	1.0	18	2		28	3			0
03-Sep-94	6.51	136	37	200	12	81	136	153	1.0	16	5	2.5	18	3	0.488	7.6	0
22-Sep-94	6.27	97	33	186	7	66	123	160	0.0	13	2		21	0		7.3	0
29-Dec-94	5.47	13	24	125	6	39	36	139	0.0	24	1		35	3	0.238	4.6	0
27-Mar-95	5.74	23	22	129	5	32	40	121	0.4	21	2	2.5	18	1	0.260	5.3	0
27-Apr-95	6.10	65	29	168	15	48	80	158	0.5	24	1	2.5	30	1	0.284	6.6	0
02-Jun-95	6.26	64	29	169	5	47	68	129	0.4	13	1	2.5	35	7	0.548	11.0	0
15-Jul-95	6.46	140	46	202	6	86	154	138	0.5	94	1	2.5	12	2	0.343	8.5	0
06-Aug-95	6.51	195	40	219	8	86	164	155	1.2	30	1		15	1	0.417	8.6	0
25-Aug-95	6.81	221	49	225	7	99	176	171	0.4	35	1	2.5	9	0	0.266	6.1	0
04-Sep-95	6.22	74	63	239	8	134	208	125	0.9	302	0	6.0	14	0	0.239	6.8	0
24-Sep-95	5.21	10	35	167	5	66	84	115	0.4	112	0		37	5	0.494	12.0	0
11-Nov-95	5.91	43	26	139	4	47	72	98	0.5	37	0	2.5	32	6	0.473	8.7	0
10-Jan-96	5.31	10	23	126	6	42	47	96	1.0	68	0	2.5	35	5	0.305	6.6	2
27-Feb-96	5.28	10	28	152	4	51	55	166	0.9	56			19	8	0.237		0
03-Apr-96	6.29	71	36	189	12	62	105	172	0.9	75	1	2.5	15	0	0.170	4.7	4
02-May-96	6.06	66	31	159	6	51	83	132	0.5	44	0	2.5	21	3	0.311	6.5	2
12-Jun-96	5.41	21	24	127	2	36	47	103	0.0	17	3	3.0	41	2	0.627	12.6	0
04-Jul-96	5.83	45	27	144	3	51	77	104	0.0	32	1	2.5	23	13	0.586	19.8	0
27-Jul-96	6.24	124	34	168	4	71	128	122	0.0	19	2	2.5	20	2	0.520	12.7	0
18-Aug-96	6.75	208	41	198	7	89	169	140	1.1	20	1	2.5	14	1	0.464	9.7	0
07-Sep-96	6.13	117	35	174	9	78	130	136	1.0	16	2	2.5	27	4	0.677	14.0	0
28-Sep-96	6.31	102	42	194	9	78	128	183	1.4	42	1	2.5	18	1	0.372	9.3	0
30-Oct-96	5.53	20	25	118	10	41	53	112	0.3	20	2		46	8	0.505	10.0	0
03-Dec-96	5.16	6	46	227	7	72	73	305	1.5	40	0	2.5	25	1	0.166	3.9	0
28-Jan-97	5.95	36	26	142	4	39	58	106	0.9	43	0	2.5	26	1	0.371	7.4	2
10-Mar-97	5.68	22	39	204	6	57	70	241	0.9	38	0						0

30-Apr-97	5.88	39	30	178	5	49	72	168	0.8	17	0	2.5	27	0	0.370	7.5	0
21-May-97	5.98	47	27	152	3	43	67	125	0.5	13	2	2.5	33	0	0.550	11.2	0
05-Jul-97	6.12	81	29	166	8	50	87	114	0.5	14	1	2.5	30	10	0.590	12.0	6
30-Jul-97	6.02	67	28	155	4	58	93	112	0.2	9	2	2.5	39	0	0.841	17.7	0
19-Aug-97	6.50	216	74	229	10	95	380	148	0.7	233	1	2.5	25	0	0.638	14.0	0
07-Sep-97	5.69	31	26	140	4	52	73	116	0.0	12	2	2.5	59	6	0.766	15.0	0
05-Oct-97	5.76	34	33	158	9	64	86	183	0.0	14	1	2.5	46	1	0.541	12.0	0
14-Nov-97	5.46	21	28	143	16	51	59	127	0.4	27	1	2.5	50	3	0.697	16.0	0
05-Jan-98	5.44	13	32	167	5	61	62	214	0.4	29	0	2.5	25	0	0.195	4.0	0
05-Feb-98	5.64	23	21	110	3	35	45	93	0.8	27	1	2.5	26	0	0.361	8.2	0
21-Mar-98	6.19	60	38	185	6	58	80	208	0.9	26	0	2.5	9	5	0.135	3.4	0
07-May-98	5.63	25	27	146	4	43	53	129	0.0	13	1	2.5	30	5	0.507	10.9	0
20-Jun-98	6.46	161	36	194	6	65	119	129	0.0	20	2	2.5	16	0	0.271	6.9	0
20-Jul-98	5.89	51	23	130	1	52	74	77	0.0	9	2	2.5	46	1	0.773	16.3	0
09-Aug-98	6.05	74	26	140	4	62	86	86	0.0	10	2	2.5	43	3	0.751	16.5	0
29-Aug-98	6.33	159	36	172	7	76	129	117	1.4	15	3	6.0	24	0	0.437	9.0	0
27-Sep-98	6.43	212	42	189	8	96	169	145	3.9	17	2	2.5	35	3	0.529	11.0	2
25-Oct-98	5.56	23	23	109	9	43	55	103	0.0	17	2						0

Appendix 3 Water chemistry for the Experimental Burn (Lower site) July 1995 - October 1998

Date	PH	Alk	Cond	Na	K	Mg	Ca	Cl	NO_3	SO_4	PO_4	Tot-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
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						0

Appendix 4 Water chemistry for the Allt na Riabhach na Bioraich (Lower site) July 1995 - October 1998

Date	PH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4	Tot-P	Al-NL	Al-L	Abs-250	TOC	NH4
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
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						0

Appendix 5 Biology sampling dates

Sampling year	92*	93	94	95	96	97
fish		29 Sept	27 Sept	27 Sept	24 Sept	17 Sept
macroinvertebrates		3 May	12 May	no sample	15 May	21 May
epilithic diatoms	15 Aug	29 Sept	25 Aug	25 Aug	28 Aug	23 July
aquatic macrophytes	15 Aug	29 Sept	25 Aug	25 Aug	28 Aug	23 July

* only control burn sampled in 1992