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Land-Use Experiments in the Loch Laidon Catchment:

Eighth Report on Stream Water Quality to the Rannoch Trust

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March 2004

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Cover photo: Looking west down Loch Laidon from the mouth of the Control Burn, with the mountains of Glencoe in the distance, from NN 354 534. All photos © Ewan Shilland except Figure 6. © Lord Pearson of Rannoch.

EXECUTIVE SUMMARY

1. This report presents the results from the Stream Water Quality component of the Loch Laidon catchment land-use experiment which began in 1992. The experiment was set up to examine the effects of cattle grazing on the aquatic and terrestrial habitats and biota of a moorland area of upland Scotland.

2. The catchment of a small stream, the "Experimental Burn" was fenced and cattle were introduced in a summer grazing regime whilst the neighbouring catchment and the "Control Burn" were left ungrazed by cattle.

3. Having established a seven year chemical and biological baseline the experimentally grazed area was enlarged in 2002 to include the Allt Riabhach na Bioraich Burn and cattle stocking densities were raised accordingly.

4. Multivariate statistics applied to the diatom and macroinvertebrate assemblage time series data from all three burns did not demonstrate any significant temporal changes during the period of monitoring. Similarly the fish and aquatic macrophytes do not appear to have undergone any major changes that can be identified with cattle grazing.

5. Possible increases in alkalinity and the concentrations of certain base cations in the Experimental Burn relative to the Control Burn identified in the previous report were not borne out by analysis of the more extensive dataset presented here.

6. There is slight evidence that some aspects of nutrient levels are increasing in the Experimental Burn. Prior to 1998 nitrate levels were generally higher in the Control Burn; subsequently this has changed to levels being more elevated in the Experimental Burn. During the same time period summer peaks in soluble reactive phosphorus have shown a tendency to increase in the Experimental Burn relative to the Control Burn.

7. The physical poaching by cattle of the banks of the grazed burns continues to affect the Experimental Burn and, since it was included in the experimentally grazed area, is now also readily apparent on the Allt Riabhach na Bioraich Burn.

1 INTRODUCTION

This report presents and summarises data from the Stream Water Quality project instigated by the Rannoch Trust in 1992. Results for the period January 2002 to December 2003 are discussed in the context of the longer time series. 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 (Monteith *et al.* 1995; Monteith *et al.* 1996; Monteith *et al.* 1997; Monteith *et al.* 1999; Shilland *et al.* 2001; Shilland *et al.* 2003) have provided ongoing updates of the accumulating biological and chemical datasets.

2 METHODOLOGY

Sampling methodologies follow those of Allott *et al.* (1994). The sampling area is shown in Figure 1. Water chemistry spot samples have been collected at approximately monthly intervals from sites on the Control Burn and Experimental Burn since 1992 (Figure 2, Sites 1 & 2). Biological surveys of fish, aquatic macroinvertebrates, epilithic diatoms and aquatic macrophytes have been undertaken annually at these sites over the same period. A total of 33 cattle (1 bull, 16 cows and 16 calves) were introduced within the fenced experimental plot (see Figure 2) from mid July to late September 1993 and a similar grazing period has been observed in subsequent years. Stocking levels were reduced by one cow and one calf in 1994.

In the report of Monteith *et al.* (1996) concerns were raised that:

(a) insufficient pre-impact assessment of the Experimental Burn had been carried out before cattle had been introduced,
(b) the Experimental burn lacked sufficient similarity to the Control Burn for rigorous comparisons to be made,
(c) the upper station on the Experimental Burn might be too far up the catchment to be sensitive to any change in grazing regime.

In response to points (a) and (b) chemical monitoring began in summer 1995 on a second experimental system, the Allt Riabhach na Bioraich Burn, approximately 500 m further to the east and with physical characteristics closer in similarity to the Control. At this time the Allt Riabhach na Bioraich Burn was outwith the fenced area. Simultaneously, in response to point (c) a second chemistry sampling site was adopted on the original Experimental Burn, while, due to the long term interest in the acidity status of Loch Laidon and its predicted recovery from acidification, a further sampling site was established on the loch outflow. The additional sampling sites, numbered according to Figure 2, are therefore as follows:

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

One further spot water chemistry sampling point, number seven, 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 Burn. 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.

In 2002, having established a seven year pre-impact baseline, the experimentally fenced area was enlarged to include the Allt Riabhach na Bioraich Burn. Accordingly, stocking densities were increased to 40 cattle in 2002 and 36 cattle in 2003. An area of approximately fifteen hectares in the North West corner of the enlarged experimentally fenced area was burnt in 2002. Aquatic macroinvertebrates were not surveyed in 1995 nor aquatic macrophytes in 2000. Biological sampling dates are provided in Appendix 5. Photographs of the current survey stretches are shown in Figures 3 to 5 and the area of grazing can be seen clearly in Figure 6.

3 DATA ANALYSIS AND PRESENTATION

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

Selected water chemistry variables are presented as time series with values for two or three burns superimposed. Where appropriate time series ratios between the values for the Experimental and Control Burns are also overlaid. These allow common (natural) variability to be controlled for, thus providing an important tool for the assessment of the impact of grazing

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.
BMWP 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. Macroinvertebrate species occurring with a minimum abundance of at least 1.5% are presented whereas the diatom graphs show species with a minimum abundance of at least 1%.

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; Detrended Canonical Correspondence Analysis (DCCA) was used to measure the

time-constrained gradient lengths of species so that the most appropriate subsequent analysis could be determined. As this demonstrated very little turnover in species composition, the linear methods of Principal Components Analysis (PCA) and Redundancy Analysis (RDA) were selected. 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, "time", coded as the year of sampling was applied as the single explanatory variable. 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 and Smilauer 1998). For a fuller explanation of the statistical methodologies see Patrick *et al.* (1995).

4 RESULTS

4.1 CHEMISTRY

Summaries of the chemical data are presented in Appendix 1. Full chemistry is shown in Appendices 2 to 8. The assessment below concentrates primarily on evidence for a temporal departure in the relationship between the chemistry of the Control and Experimental sites.

4.1.1 COMPARISON OF THE CONTROL AND UPPER EXPERIMENTAL BURN

Although the upper station Experimental Burn may be situated rather too high in the catchment to adequately capture grazing effects, its dataset represents the longest time series available. The relationship between the Control and Upper Experimental Burn concentrations of key chemical determinands are provided in Figures 8 to 12.

The alkalinity and conductivity for the two stations continue to show the same seasonal relationship discussed in earlier reports. While values are very similar between sites for much of the year summer peak values still tend to be higher in the Experimental Burn than the Control Burn, reflecting either a stronger ground-water influence on the former or a difference in the chemistry of ground-water in these two catchments. This observation is supported by the relationship in the ratio between Experimental Burn/Control Burn alkalinity and stage board height (Figure 12). Alkalinity is normally higher in the Experimental Burn when the stage board reading is below circa 0.25 m but lower when the reading is higher than this.

Concentrations of nitrate continue to show the strong seasonality which typifies these upland systems. Seasonality is particularly marked in the Control Burn where peak

values are usually recorded toward the end of each winter. Nitrate peaks have been consistently higher in the upper Experimental Burn relative to the Control Burn over the last two years. Peak levels of soluble reactive phosphorus have been slightly higher in the Experimental Burn over the same time period when compared to earlier monitoring, although the largest peak was seen in the Control Burn in summer 2003

4.1.2 COMPARISON OF THE CONTROL AND LOWER EXPERIMENTAL BURN

Although slightly shorter in duration the lower station on the Experimental Burn might be expected to be more sensitive to changes within the catchment. Figures 13 to 20 illustrate the relationships of selected chemical determinands between the Control Burn and the Lower Experimental Burn.

In the last report (Shilland *et al.* 2003) the ratio of alkalinity between these two sites appeared to show a slight upward trend since the beginning of 1997, thereby indicating that alkalinity in the Experimental Burn was increasing relative to the Control Burn. Calcium, magnesium and potassium also seemed to show a similar trend but after controlling for hydrology no statistical significance was found. The same exercise has been repeated for the extended dataset, controlling for the influence of hydrology by regressing the ratios of various chemical determinands between the streams against stage board height. Time series of the residuals from these regressions are presented in Figures 21 to 24. The only determinand ratio to show a significant relationship with stage board height ($p<0.05$) was calcium but the subsequent residual plot indicates that there has been no trend through time. It would thus appear that trends hinted at in the data at the time of the last report have not persisted and are most likely to have resulted from short term variability. Conductivity, and calcium, potassium and magnesium concentrations have continued in general to be slightly higher in the Lower Experimental Burn than in the Control Burn.

Time series graphs (Figures 13 and 14) of the ratio and difference between nitrate at these two stations demonstrate two distinct periods during monitoring. Prior to the summer of 1998 concentrations were generally higher in the Control Burn, more recently however levels have generally been greater in the Lower Experimental Burn. No similar trend was observed in the ammonia data but in-stream nitrification often tends to be rapid and ammonia is quickly immobilised in soils.

Soluble reactive phosphorus peaks have been larger in the Lower Experimental Burn in late summer for the three most recent years, and whilst this pattern of slightly elevated levels relative to earlier monitoring is also repeated in the Control Burn, the ratio shown in Figure 20 demonstrates that through time the difference between the summer peaks in the two streams has been growing as concentrations increase slightly in the Experimental Burn.

4.1.3 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 25 to 29.

The chemical determinands have continued to show marked seasonal effects in the Allt Riabhach na Bioraich, Burn, similar to the other study burns. The Lower Experimental Burn persisted in having generally higher summer peak values of conductivity, alkalinity and total organic carbon than the other two burns, though in 2003 peak alkalinity and in 2002 peak total organic carbon were higher in the Control Burn, both for the first time. Generally the Allt Riabhach na Bioraich Burn and the Control Burn have had much more similar values of measured chemical variables than the Experimental Burn. Soluble reactive phosphorus has been slightly elevated in the Allt Riabhach na Bioraich Burn over the last three years relative to earlier monitoring, echoing the trend in the other two burns and suggesting that the pattern observed in the Experimental Burn is probably not an effect attributable to cattle grazing. Peak winter nitrate concentrations have been slightly higher in 2002 and 2003 in the Allt Riabhach na Bioraich Burn than in the other burns.

4.2 BIOLOGY

4.2.1 EPILITHIC DIATOMS

The data for epilithic diatoms are provided graphically in Figures 30, 31 and 32 and trend test statistics are shown in Table 1. Due to the time required for diatom analysis results discussed here are from 2001 and 2002.

The three main diatom species in the Control Burn in 2001 were *Tabellaria flocculosa*, *Synedra minuscula* and *Brachysira vitrea*. In 2002 *S. minuscula* increased substantially in relative abundance whilst the other two decreased less markedly. This pattern of variability is also apparent earlier in the monitoring whereby *S. minuscula* has exhibited large swings but *T. flocculosa* and *B. vitrea* have remained more stable.

The Experimental Burn diatom assemblage has been the most variable of any of the study burns. Six taxa have tended to predominate, although with much inter annual variation: *Brachysira vitrea, Peronia fibula, Tabellaria flocculosa, Eunotia naegelii*, *Eunotia incisa* and *Frustulia rhomboides* var. *saxonica.* These species have continued to constitute much of the two most recent samples despite the slightly greater diversity of taxa since 2001.

The relatively impoverished diatom flora of the Allt Riabhach na Bioraich Burn has remained stable throughout the monitoring period and consistently dominated by *Tabellaria flocculosa. Brachysira vitrea* has been the second most abundant species with the 2001 and 2002 samples maintaining this trend.

Detrended Canonical Correspondence Analysis on the diatom data from the three burns established that the datasets had short, time constrained, gradient lengths of less than 3 standard deviation units and were therefore appropriate for linear analysis i.e. Principal Components Analysis. The PCA first axis eigenvalues (λ_1^{PCA}) are provided in Table 1. These provide the maximum proportion of total between-year variance that can be explained by a single hypothetical linear variable. Table 1 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. As with similar statistics performed in the previous report (Shilland *et al.* 2003) this result implies that cattle grazing is not having a measurable effect on the diatom 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	0.07	0.20	0.10
Experimental Burn	0.27	0.09	0.33	0.35
Allt Riabhach na Bioraich Burn	0.55	0.07	0.13	0.21

4.2.2 MACROINVERTEBRATES

Macroinvertebrate data are provided in Appendix 9 and Figures 33, 34 and 35. Appendices 10 to 12 and Figures 36, 37 and 38 detail macroinvertebrate summary statistics.

In the Control Burn the acid sensitive mayfly *Baetis rhodani*, which was very uncommon at the start of monitoring, maintained its more recent abundance in 2002 and 2003. Stoneflies continued to constitute a large proportion of the assemblage with *Amphinemura sulcicollis* especially abundant in 2003, but the predatory species *Isoperla grammatica* and *Siphonoperla torrentium* were less abundant than previously. The beetle *Limnius volckmari* was also characteristic of the assemblage. Summary statistics show that the total number of taxa have reduced from a peak in 2001 although the diversity and water quality indices have remained relatively stable.

In 2002 and 2003 the non biting midge family Chironomidae continued to dominate the species assemblage of the Experimental Burn. Caddis fly larvae, including

Plectrocnemia conspersa, *Polycentropus flavomaculatus*, Hydroptilidae and Limnephilidae were also common, although the latter did not reach the abundances seen in the late 1990s. Mayflies and stoneflies were less common than in samples from some previous years but the beetle *Oulimnius* sp. increased. Water quality indicator statistics were lower in the Experimental Burn on the most recent sampling occasion and there was a drop in the total number of taxa found but the species diversity scores remained within previous limits.

The aquatic macrofauna of the Allt Riabhach na Bioraich Burn, similar to that of the Control Burn, was dominated by stoneflies in 2002 and 2003 with the species *Amphinemura sulcicollis* and *Isoperla grammatica* especially abundant. During the same period the mayfly *Baetis rhodani* increased relative to former years. The beetles *Limnius volckmari* and *Oulimnius* sp. were also present alongside low numbers of the caddis flies *Plectrocnemia conspersa* and *Polycentropus flavomaculatus.* Whilst the total number of species were the same in 2003 as in 2001 Hill's diversity indices have increased and water quality scores slightly decreased over the same period. Similar to the other two burns no overall trends are apparent in the summary statistics during the monitoring period.

Results from the statistical analysis on the macroinvertebrate data are presented in Table 2. The gradient lengths obtained using Detrended Canonical Correspondence Analysis on the macroinvertebrate data from three study burns confirmed their suitability for Principal Components Analysis. In all three 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 do not seem to have had a detectable effect on the macroinvertebrate fauna of the Experimental Burn or the Allt Riabhach Na Bioraich Burn.

Table 2 Macroinvertebrate trend test statistics

	λ_1^{PCA}	λ_1^{RDA}	$\lambda_1^{RDA}/\lambda_1^{PCA}$	**Restricted P Value**
Control Burn	0.32	0.25	0.78	0.10
Experimental Burn	0.37	0.22	0.59	0.10
Allt Riabhach na Bioraich Burn	0.35	0.22	0.62	0.12

4.2.3 AQUATIC MACROPHYTES

Appendices 13, 14 and 15 summarise aquatic macrophyte data for the three study burns and Figures 3 to 5 illustrate the survey stretches. Due to time constraints surveys were not performed in 2000. Sampling of the Experimental Burn in 2001 was abandoned due to physical erosion of the survey stretch and surveys have subsequently ceased. The aquatic macroflora of both burns studied continued to be

dominated by bryophytes. In the Control Burn levels of all species present, the liverworts *Marsupella emarginata* var. *aquatica* and *Scapania undulata* and the moss *Racomitrium aciculare*, increased in 2002 and 2003 relative to 2001. Since monitoring began there appears to have been a shift from dominance of M. *emarginata* var. *aquatica* to *S. undulata* and this has continued during the last two years of survey. In the Allt Riabhach na Bioraich Burn in 2002 cover levels of *S. undulata* and *R. aciculare* were low, similar to previous years. In 2003 total macrophyte cover halved, almost certainly as a result of physical scouring due to a major storm that occurred about ten days prior to the survey.

4.2.4 FISH

Data for the fish populations in the three study burns are presented in Figures 39 to 41 and Appendix 16. Recruitment occurred in all three burns in 2002 and 2003 but numbers of young 0+ fish dropped in both the Control and Experimental Burns over the same period to some of the lowest levels recorded since the project started, in 2003. In the Allt Riabhach na Bioraich Burn the highest numbers of 0+ fish recorded since monitoring began were found in 2002 but dropped sharply in 2003, possibly as a result of a combination of flushing due to an extreme storm event in late summer that year and the prolonged dry spell in 2003 reducing available fry habitat. In this and the Control Burn, as in previous years, mature fish were less abundant than the 0+ cohort. However, in the Experimental Burn in 2003, the 0+ fish dropped to densities below those of the more mature fish. Although there is some sign of increasing densities, relative to previous years, of >0+ fish in the Experimental Burn, levels are still not as high as in 1994 and overall the data would not appear to show consistently rising or falling trout densities in either age class in any of the three burns.

5 DISCUSSION

Multivariate statistical analysis performed on the biological data failed to identify any significant time trends and there is therefore no evidence that the diatoms or macroinvertebrates are being affected by the long term grazing in the Experimental Burn's catchment or the more recent grazing in the Allt Riabhach na Bioraich Burn catchment. The change in aquatic macrophyte cover observed since the last report in the Allt Riabhach na Bioraich Burn can probably be attributed to the physical scouring produced by extreme flows after the major storm event that occurred in the late summer of 2003.

The possibility of incipient trends within the water chemistry data identified in the last report failed to persist within the more extensive dataset analysed here. Although, through the three-weekly addition of cattle salt licks within the experimental catchments, certain base cations such as calcium, magnesium and potassium might be

expected to have increased this has not been detectable in the water samples with any statistical significance.

Slight increases in concentrations of soluble reactive phosphorus (SRP) have been observed over the past three summers in all streams, including the Control Burn, and this would tend to suggest that cattle are not the potential cause. However increases, identified for the first time, in the difference between summer SRP peaks in the Control and the Lower Experimental Burn and the switch of higher nitrate concentrations from the former to the latter burn in 1998 hint that cattle may be having some measurable effects on nutrients. Increases in stream nutrient levels have been recorded as associated with cattle grazing elsewhere (Hooda *et al* 1997a, Hooda *et al* 1997b, Lemly 1982, Scrimgeour and Kendall 2002). This interesting observation will be investigated in future reports to see whether the biology is exhibiting any trophic response, for instance by applying the Trophic Diatom Index (Kelly. and Whitton 1995).

An area in the North West of the expanded experimental area was subjected to burning in 2002. An unforeseen consequence of this is that the cattle have subsequently shown a slight preference for this area (Thexton, pers. comm.), which falls within the catchment of the original Experimental Burn.

Riparian poaching by cattle continues to be apparent at the Experimental Burn and is now also visible along the Allt Riabhach na Bioraich Burn (see Figure 7), the banks of which the cattle use as a path for accessing Loch Laidon from the higher ground (Thexton, pers. comm.). This effect of cattle is well reported in the literature (Belsky, Matzke, and Uselman 1999; Scrimgeour and Kendall 2002; Sovell *et al.* 2000; Wohl and Carline 1996) and whilst usually seen as negative, Knapp *et al* (1998) found that stream sections subject to grazing actually increased the available spawning habitat for the endangered California Golden Trout.

With the long pre-grazing baseline of chemical and biological data available for the Allt Riabhach na Bioraich Burn, recommended as key to good grazing experimental design in the review paper by Larsen *et al.* (1998), and the new experimental stream's greater similarity to the Control Burn, the methodological power of the study is much improved now that the area of grazing has been increased. This is especially true given the paucity of other studies performed within Scotland on the effects of upland cattle grazing on freshwater rather than terrestrial habitats.

6 ACKNOWLEDGEMENTS

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

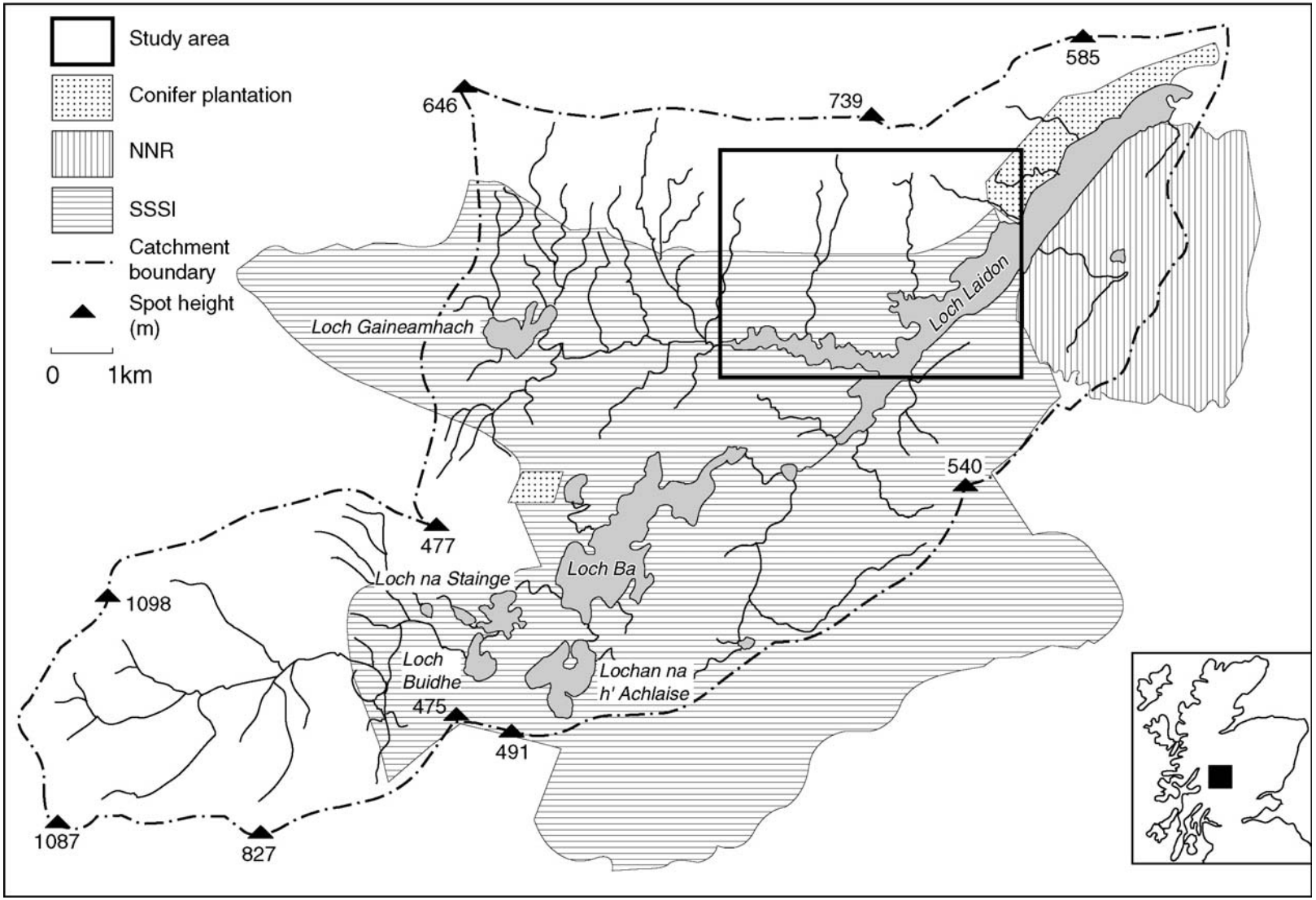


Figure 2 Loch Laidon study area.

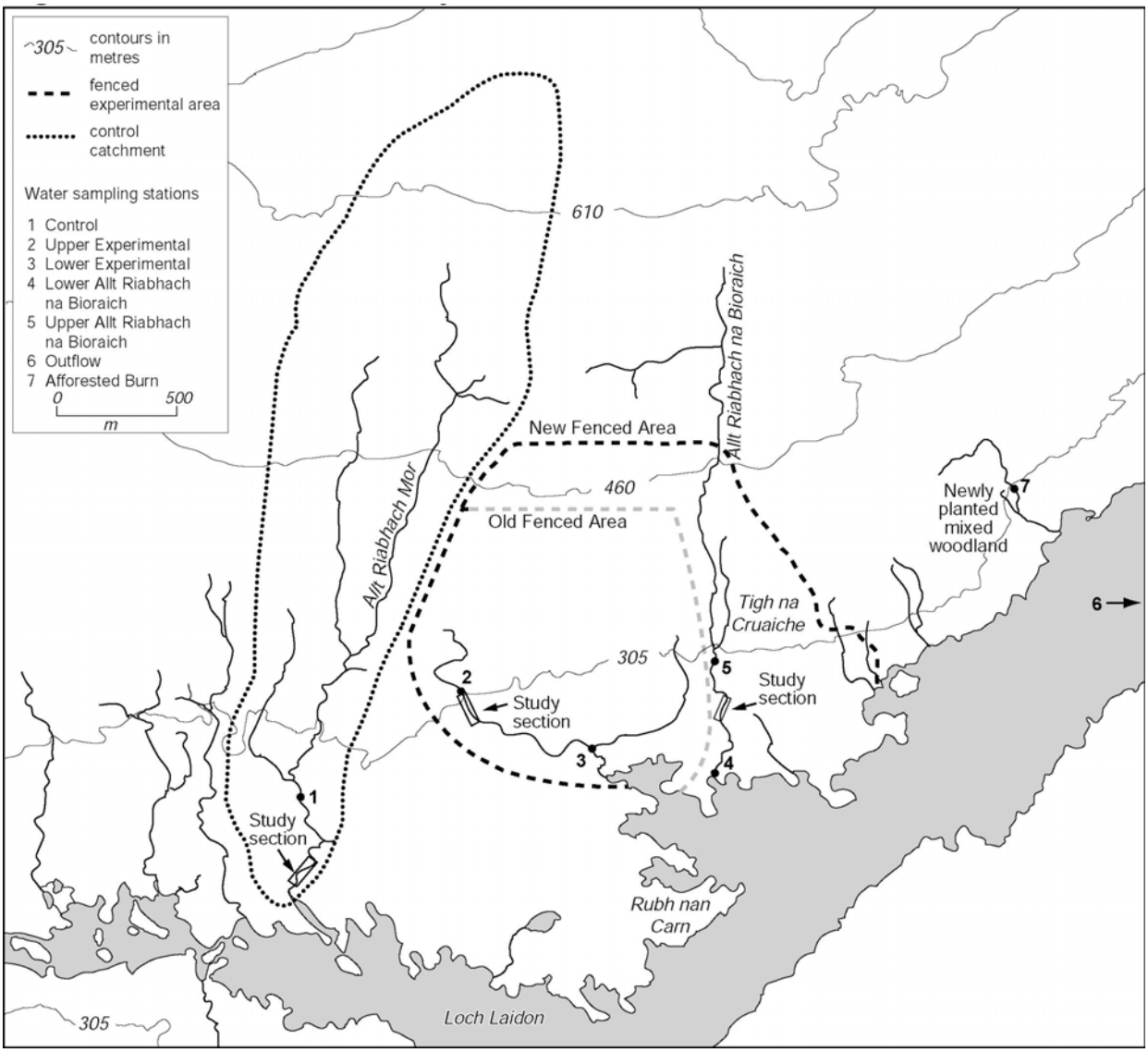


Figure 3 Control Burn, 2003

Figure 4 Experimental Burn, 2003

Figure 5 Allt Riabhach na Bioraich Burn, 2003

Figure 6 The experimentally grazed area

Figure 7 Cattle erosion of the bank of the Allt Riabhach na Bioraich Burn

Figure 8 The ratio of alkalinity and its temporal variability in spot samples between the Experimental and Control Burns, August 1992 – December 2003.

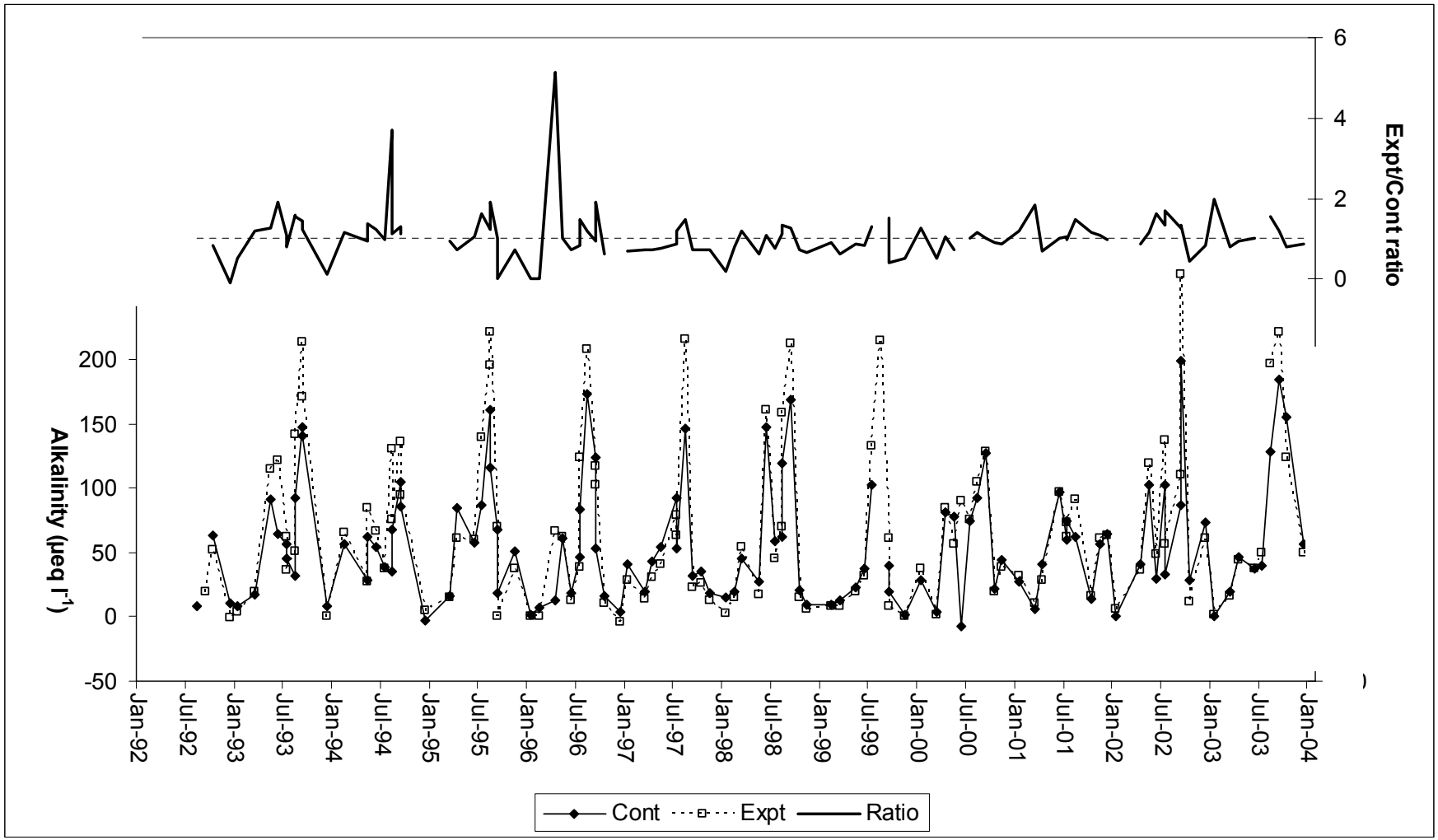


Figure 9 The ratio of conductivity and its temporal variability in spot samples between the Experimental and Control Burns, August 1992 – December 2003.

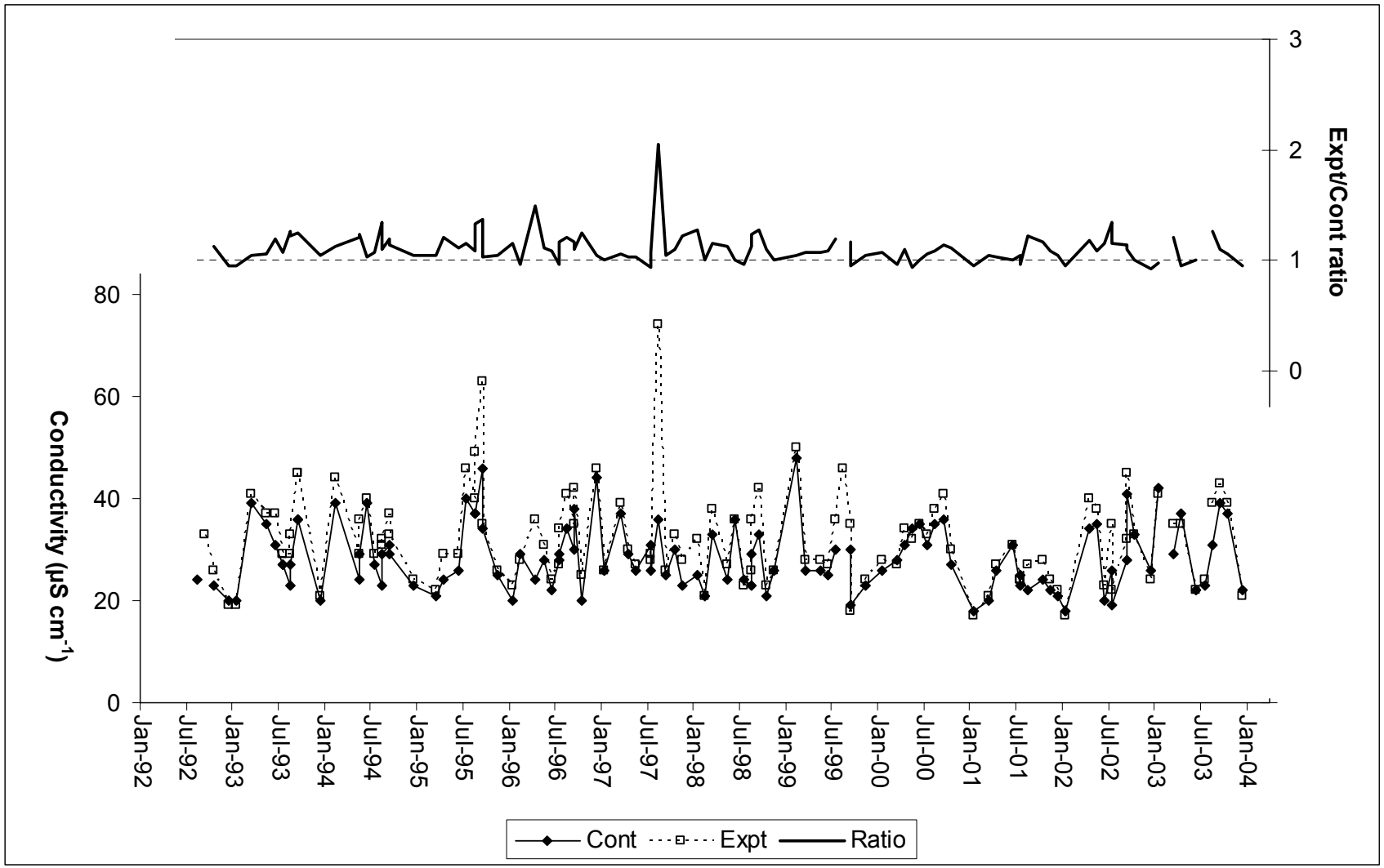


Figure 10 Temporal variability of nitrate in spot samples from the Experimental and Control Burns, August 1992-December 2003.

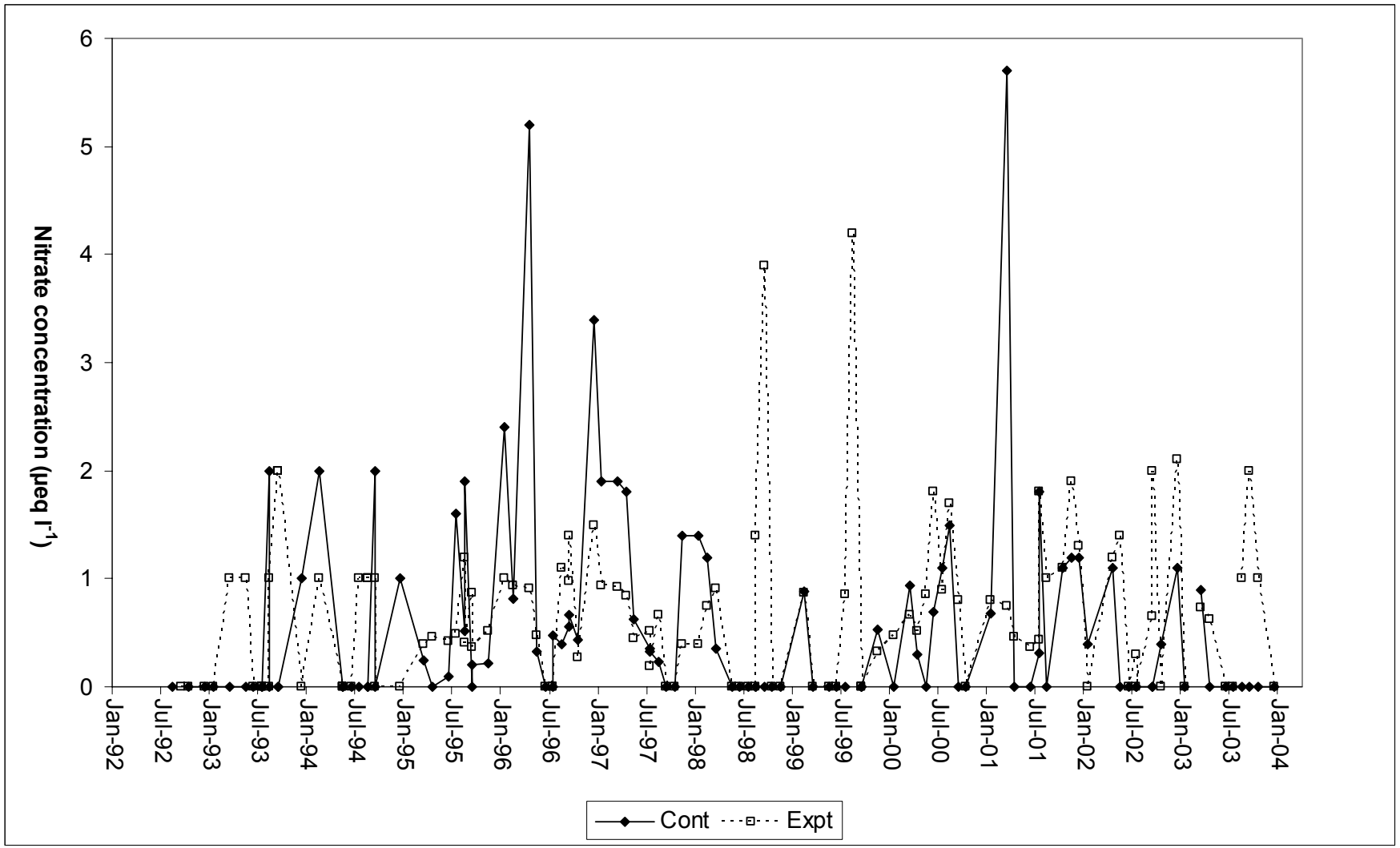


Figure 11 Temporal variability of soluble reactive phosphorus in spot samples from the Experimental and Control Burns, August 1992- December 2003

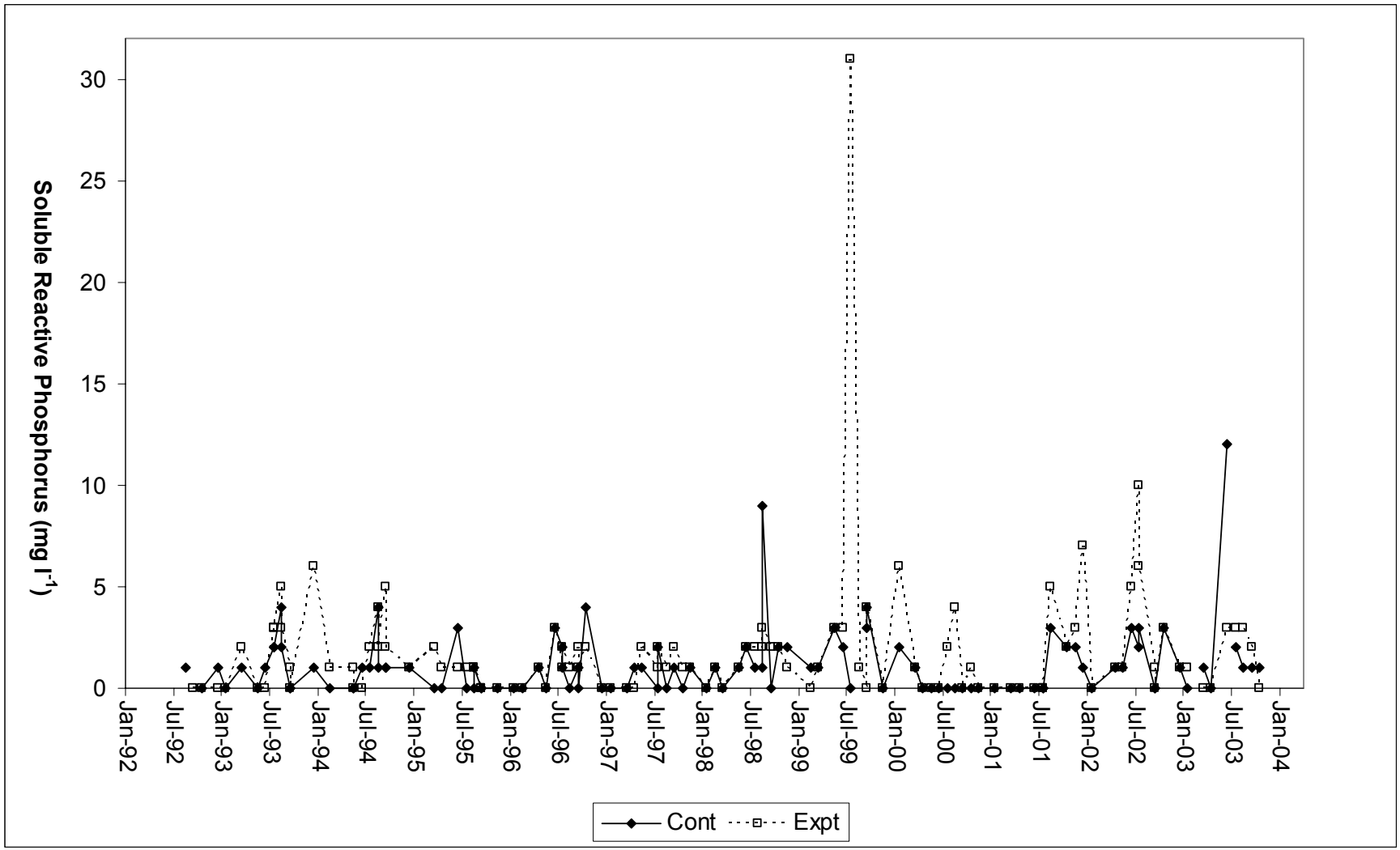


Figure 12 The relationship between the ratio of alkalinity in spot samples from the Experimental and Control Burns and the stage board height of the Control Burn over the period August 1992 – December 2003.

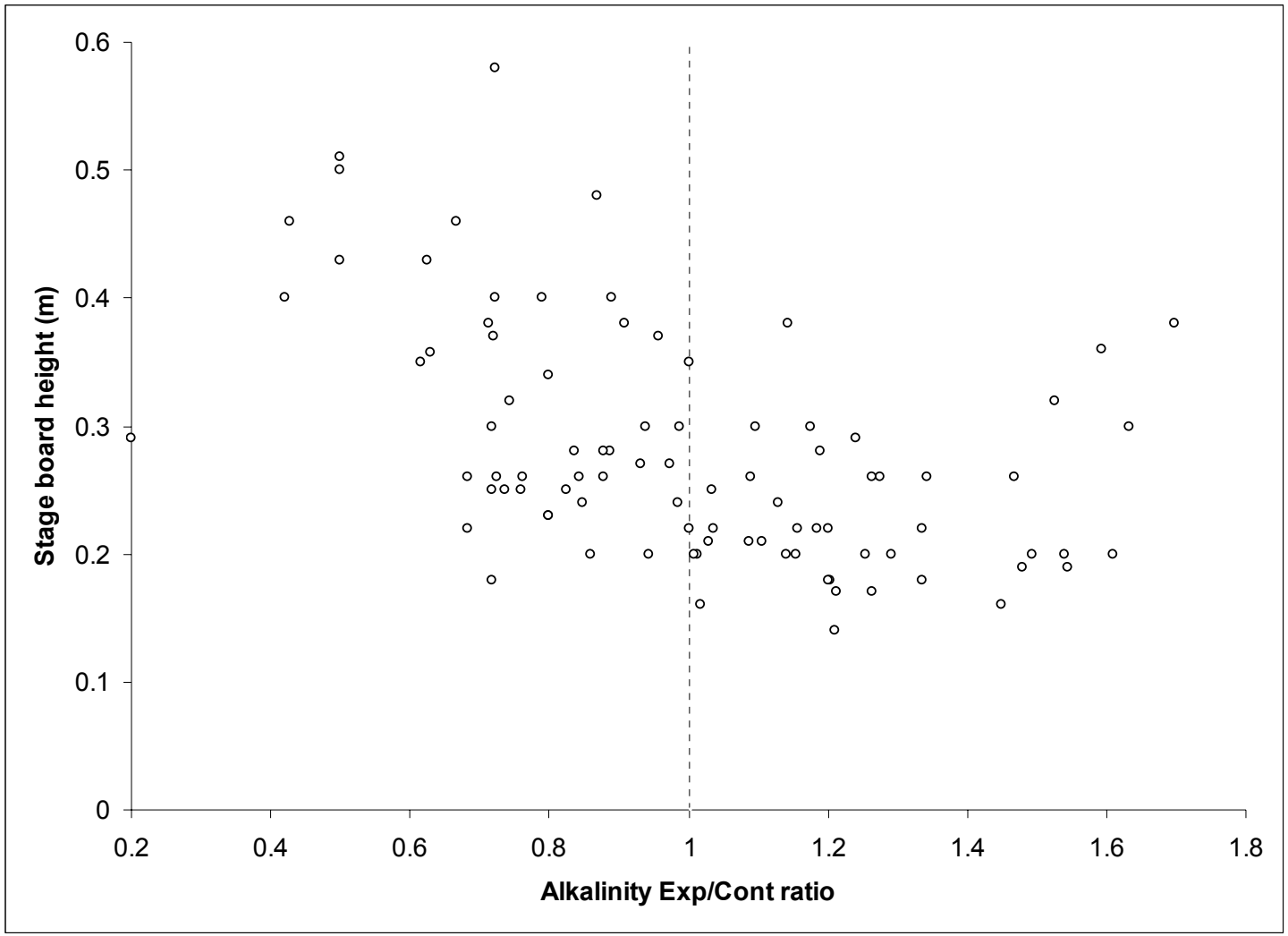
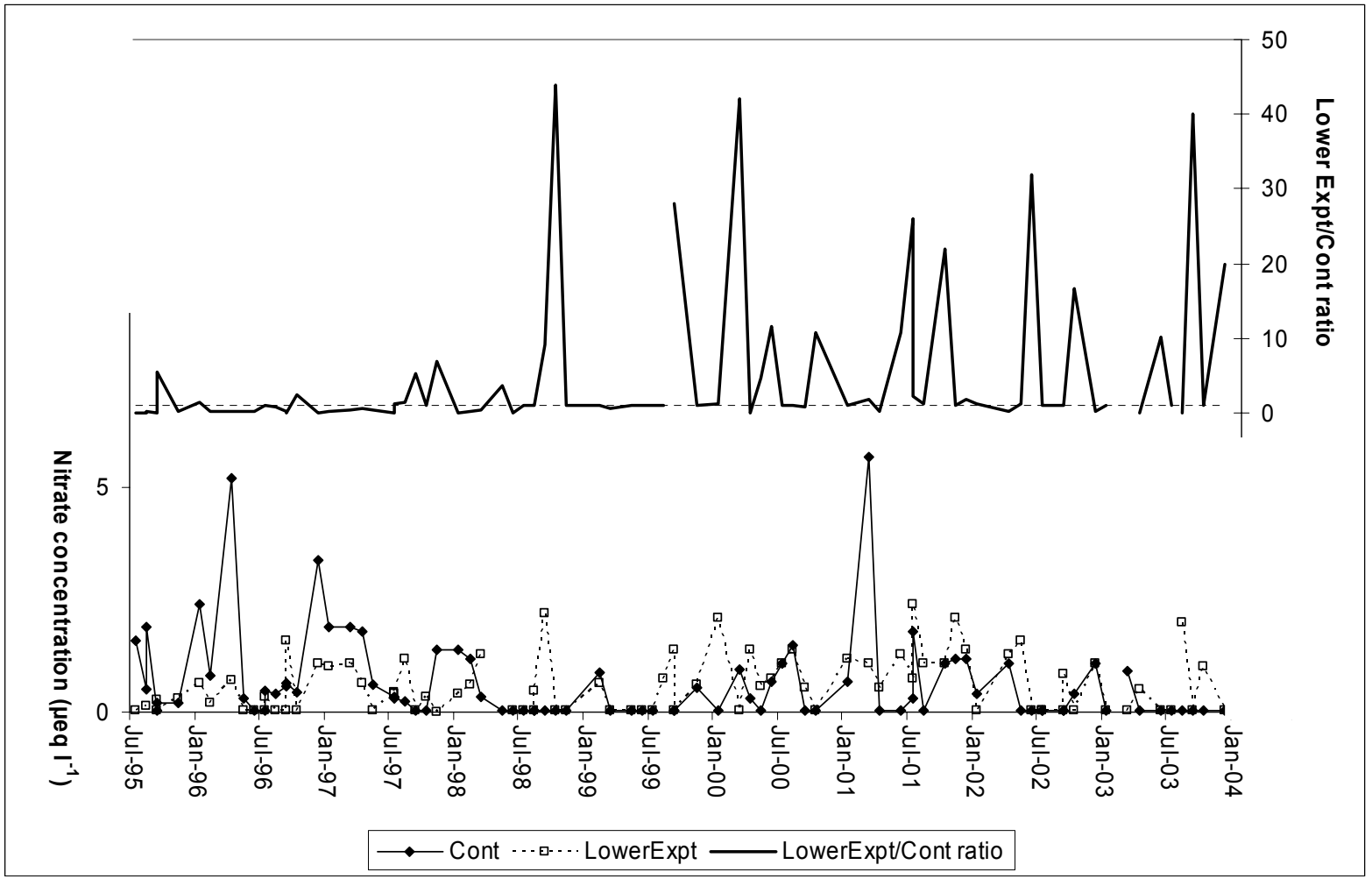


Figure 13 The ratio of nitrate and its temporal variability in spot samples between the Control and Experimental Burn (Lower site) June 1995 – December 2003.



N.B. 0 values converted to half nitrate detection limit for ratio calculations.

Figure 14 The temporal variability of nitrate in spot samples and the difference between the Control and Experimental Burn (Lower site) June 1995 – December 2003.

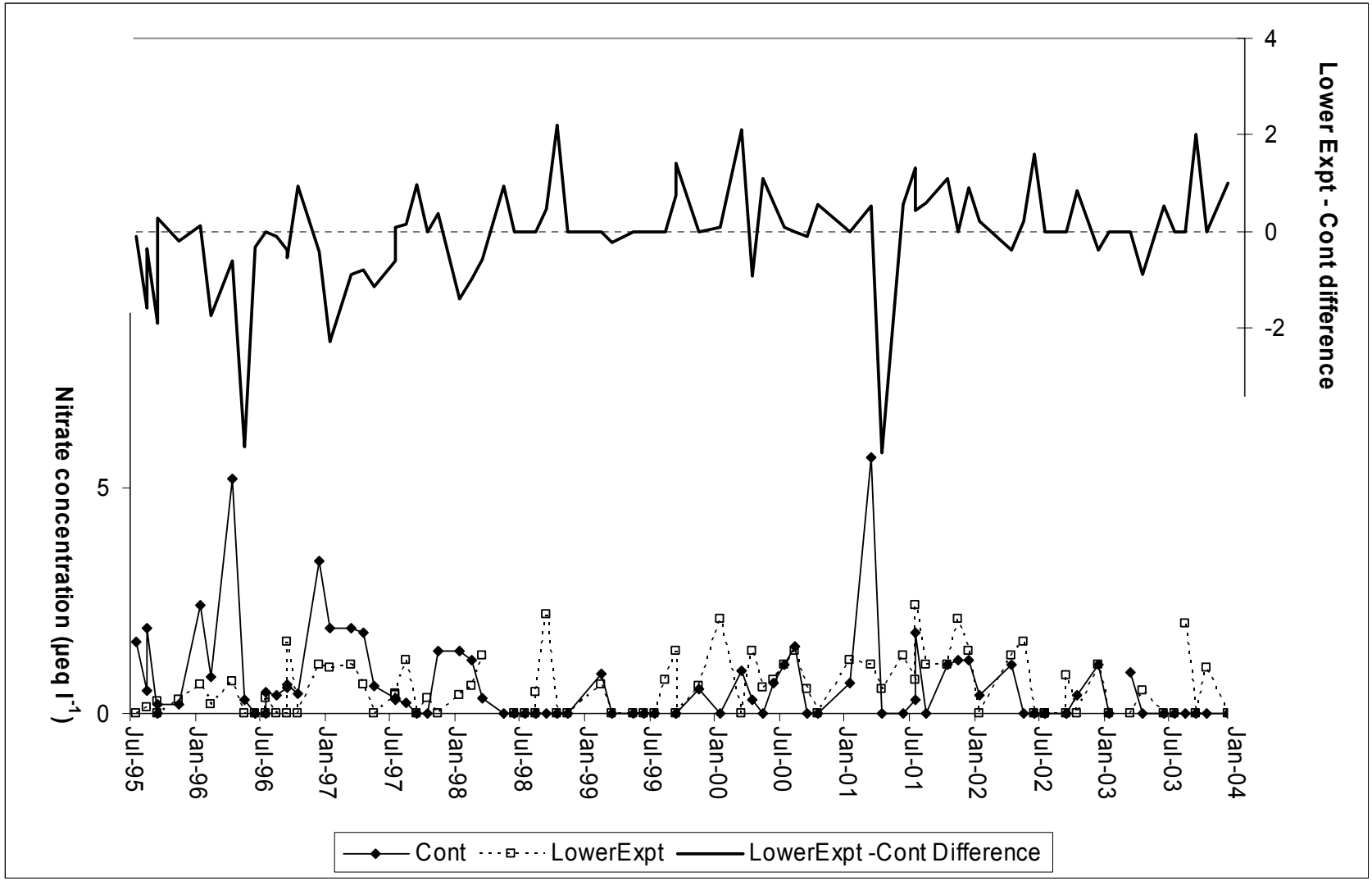


Figure 15 The ratio of alkalinity and its temporal variability in spot samples between the Control and Experimental Burn (Lower site) June 1995 – December 2003.

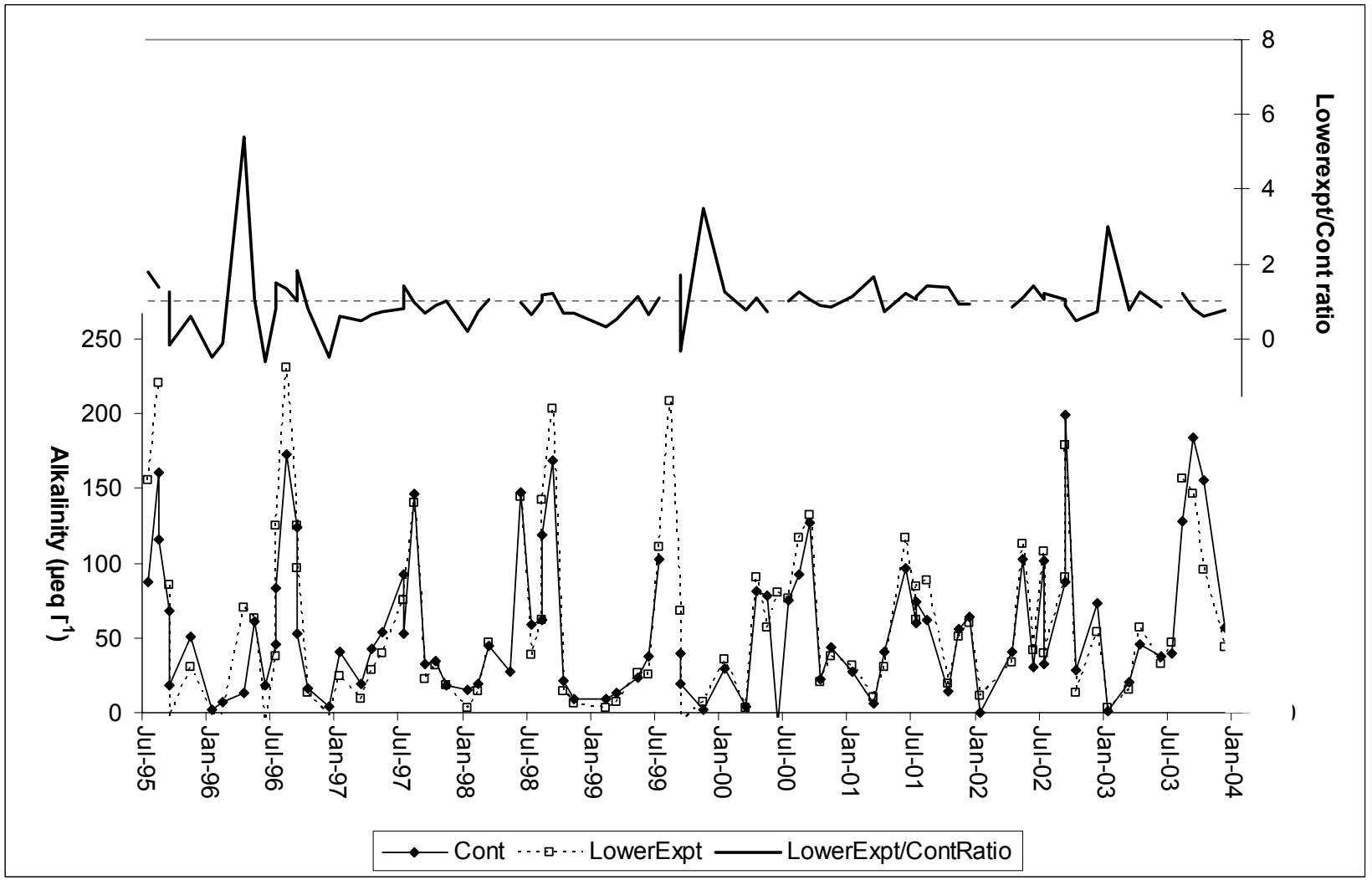


Figure 16 The ratio of calcium and its temporal variability in spot samples between the Control and Experimental Burn (Lower site) June 1995 – December 2003.

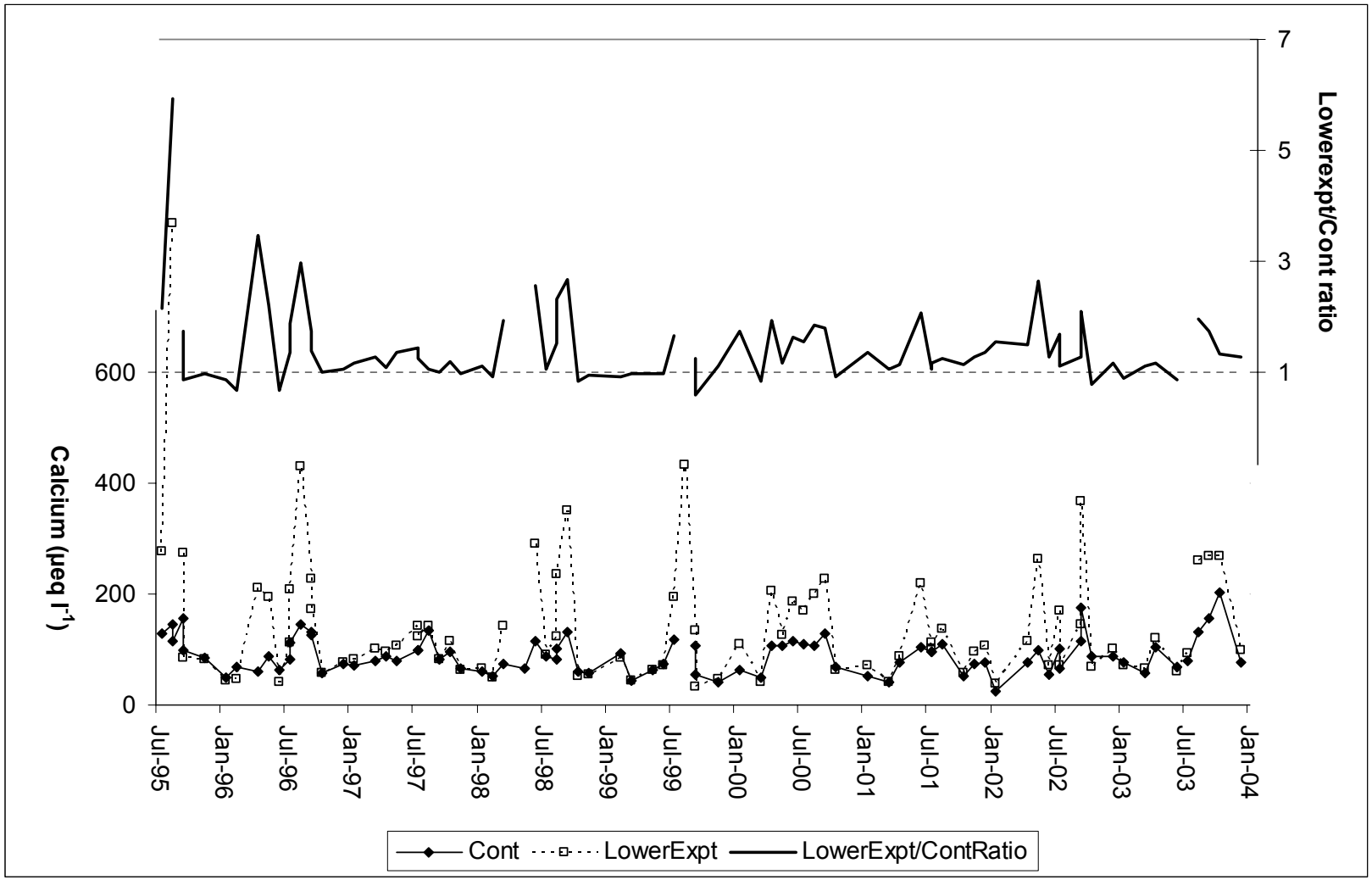


Figure 17 The ratio of magnesium and its temporal variability in spot samples between the Control and Experimental Burn (Lower site) June 1995 – December 2003.

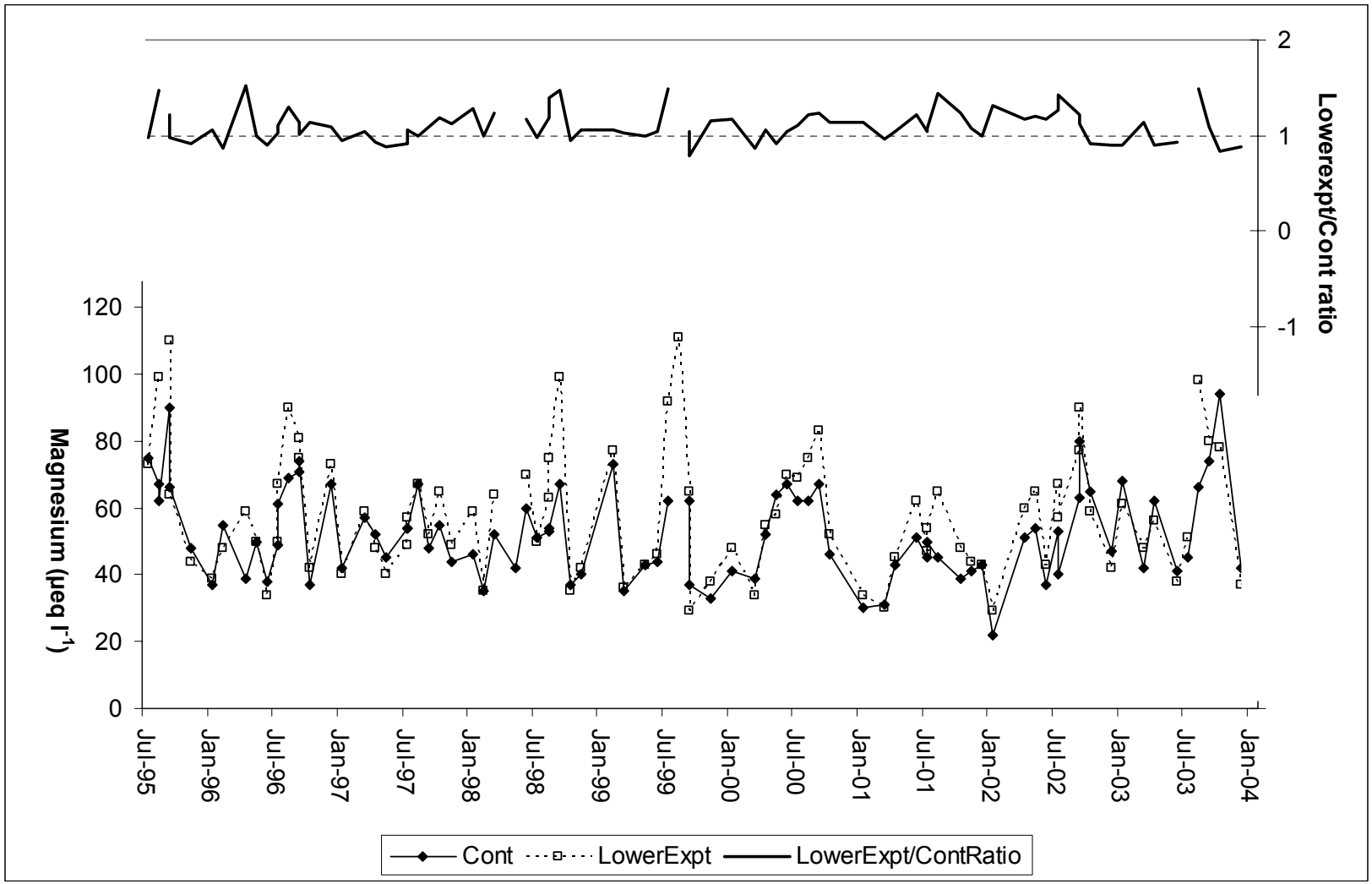


Figure 18 The ratio of potassium and its temporal variability in spot samples between the Control and Experimental Burn (Lower site) June 1995 – December 2003.

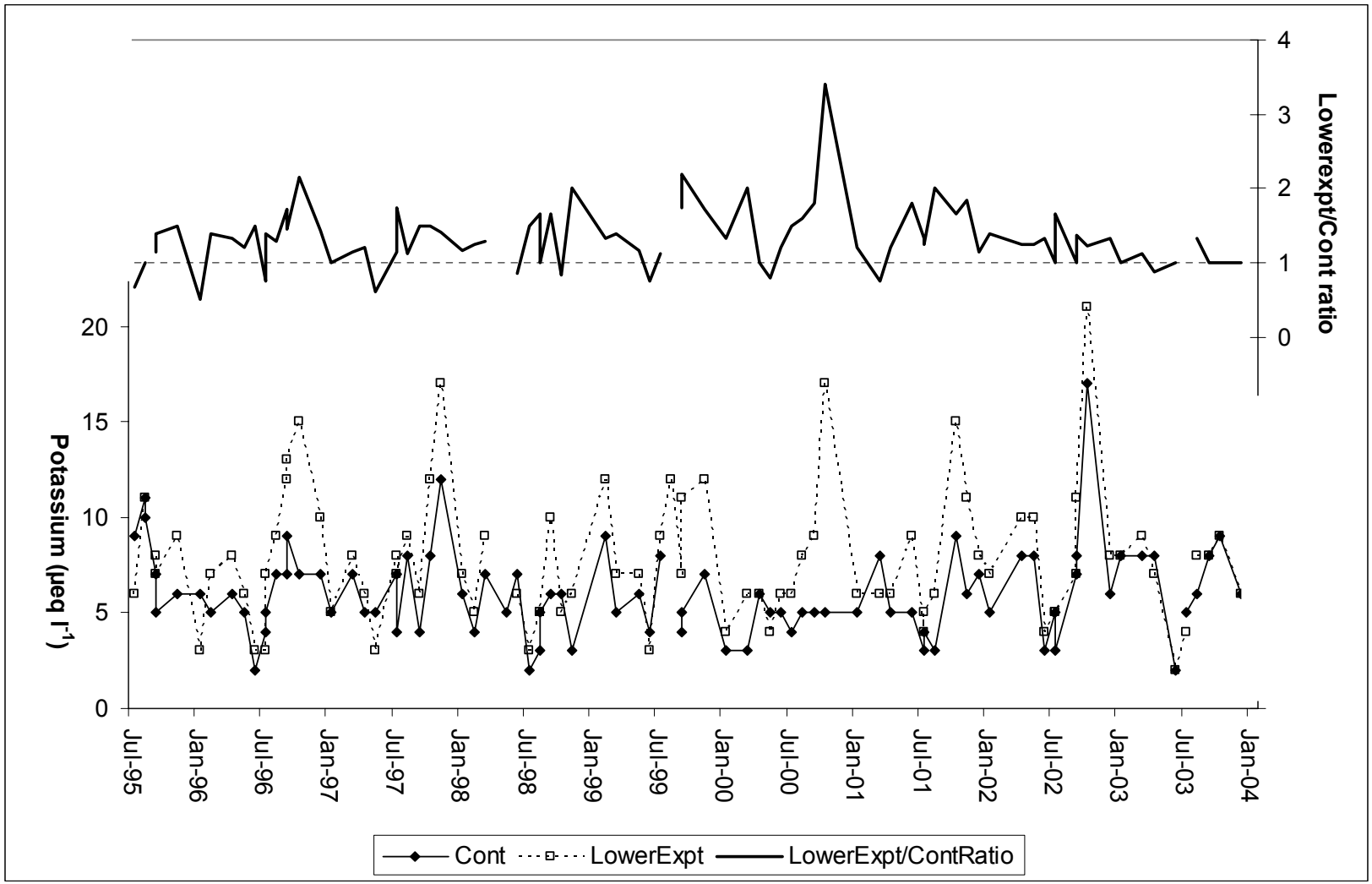


Figure 19 The ratio of conductivity and its temporal variability in spot samples between the Control and Experimental Burn (Lower site) June 1995 – December 2003

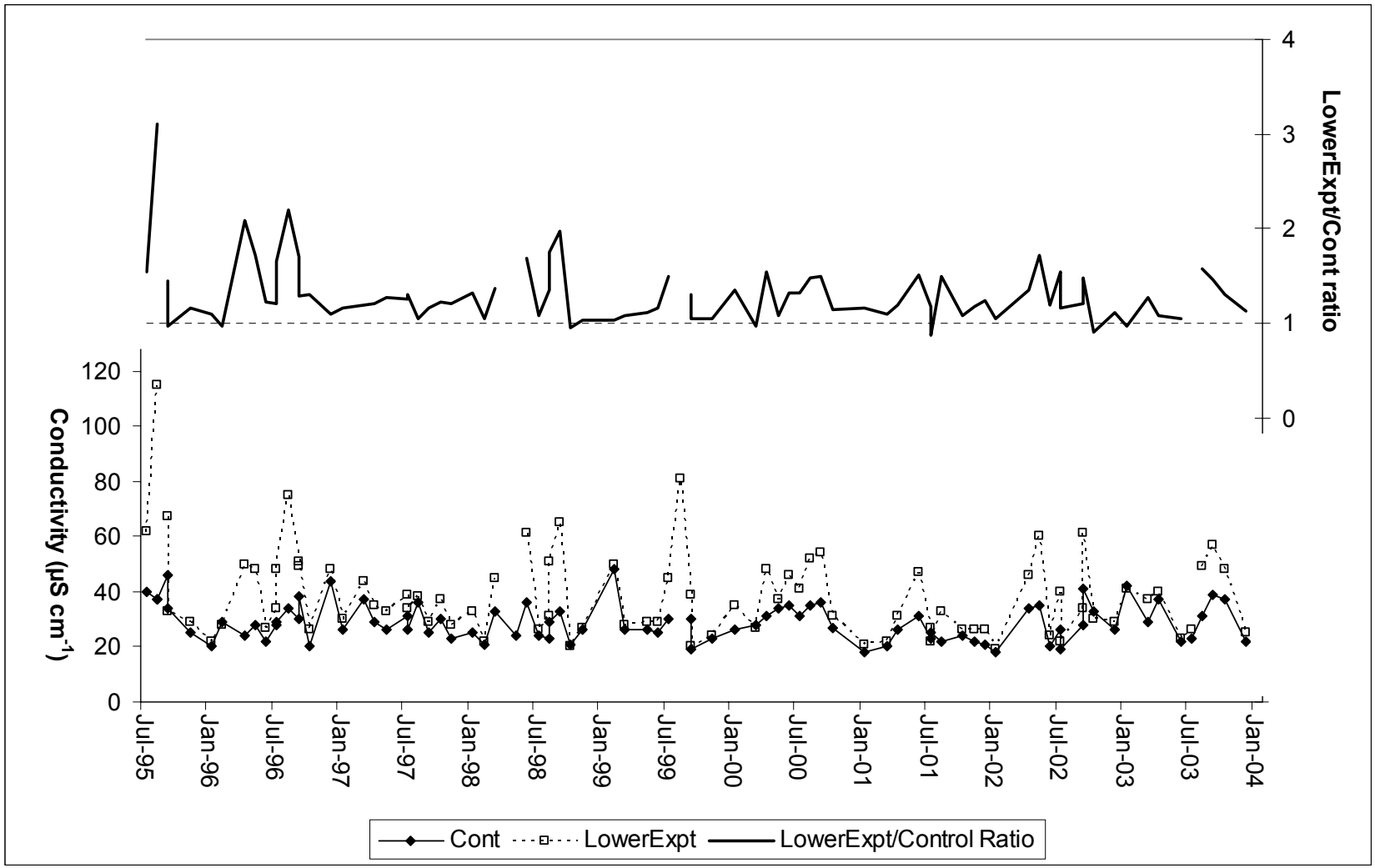
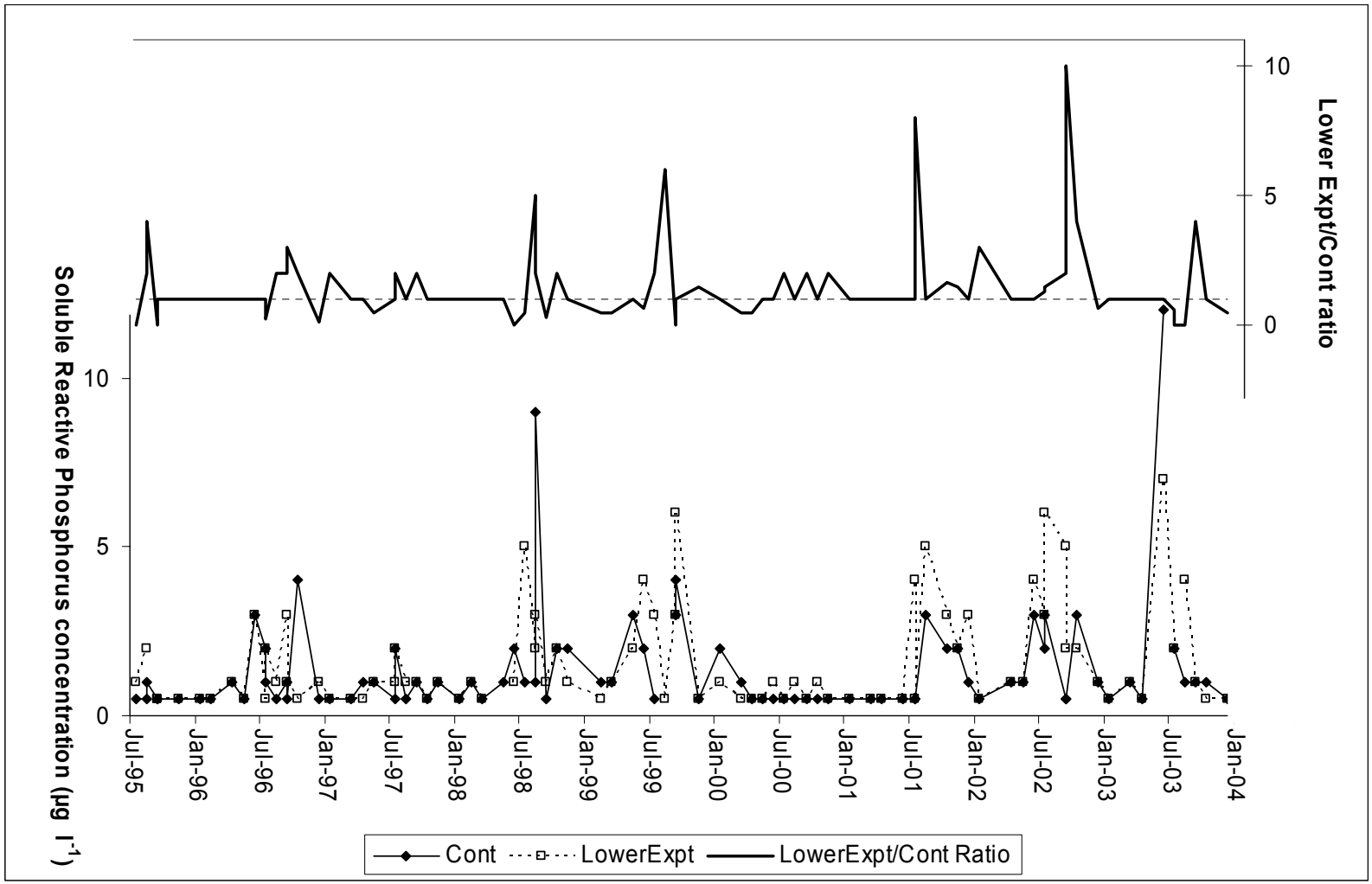


Figure 20 The ratio of soluble reactive phosphorus and its temporal variability in spot samples between the Control and Experimental Burn (Lower site) June 1995 – December 2003.



N.B. 0 values converted to half SRP detection limit for ratio calculations.

Figure 21 Residuals for Lower Experimental-Control alkalinity once the effect of 'hydrology' has been removed.

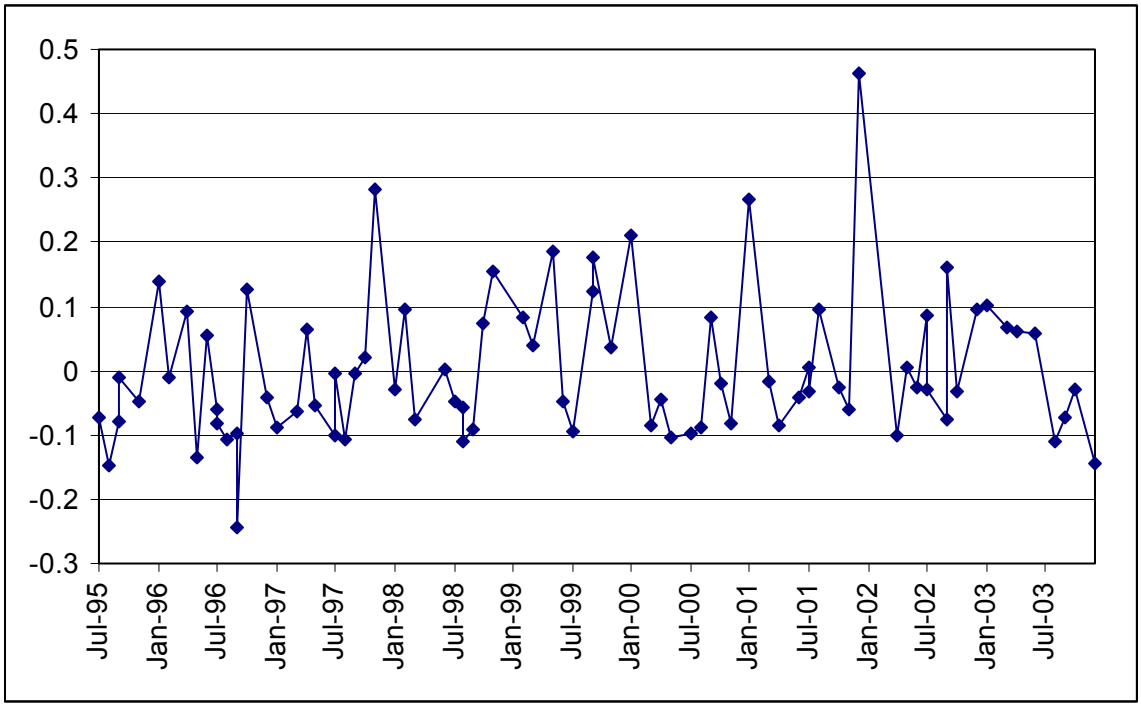


Figure 22 Residuals for Lower Experimental-Control calcium once the effect of 'hydrology' has been removed

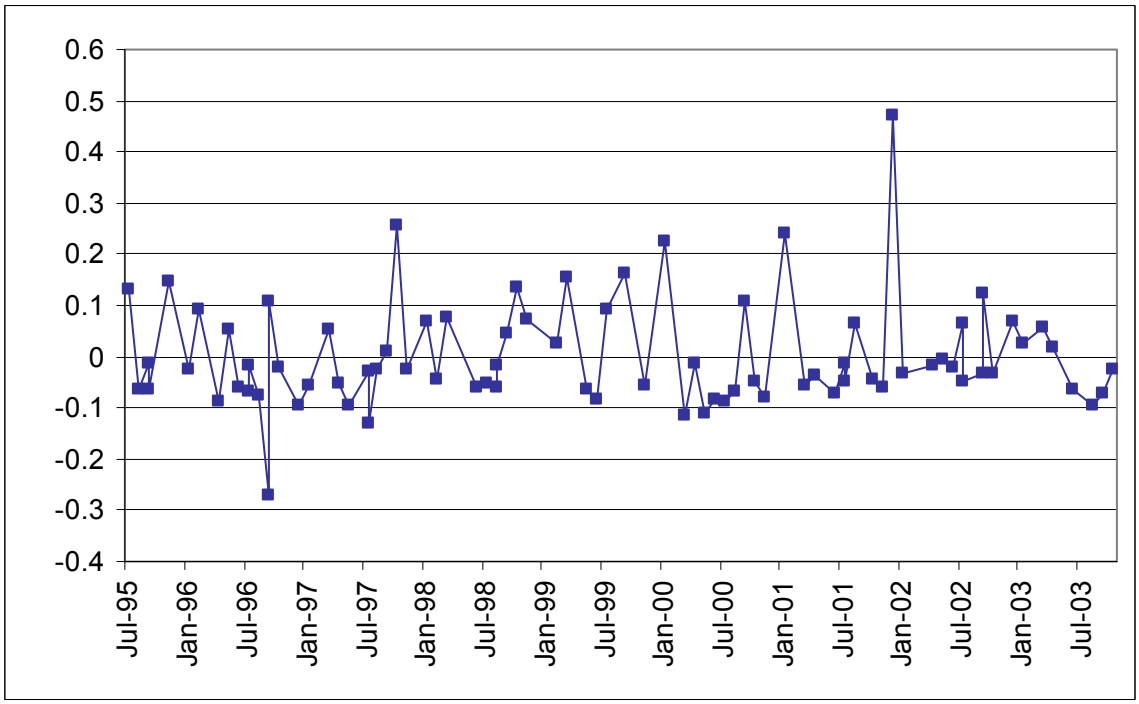


Figure 23 Residuals for Lower Experimental-Control magnesium once the effect of 'hydrology' has been removed

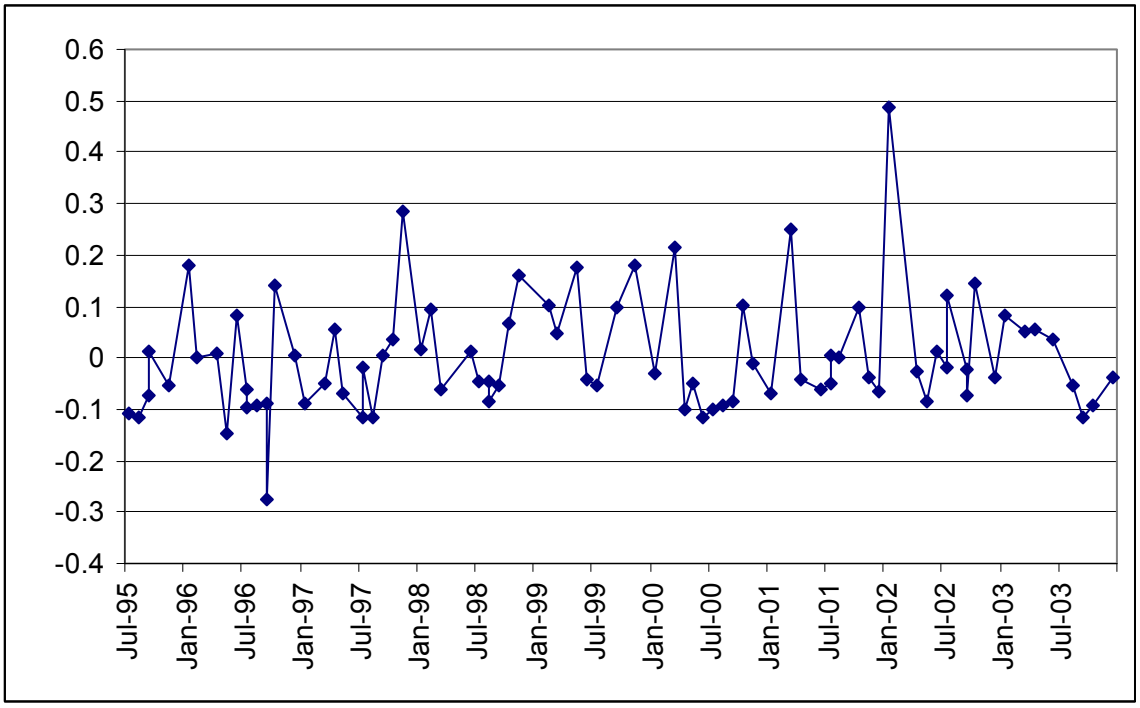


Figure 24 Residuals for Lower Experimental-Control potassium once the effect of 'hydrology' has been removed

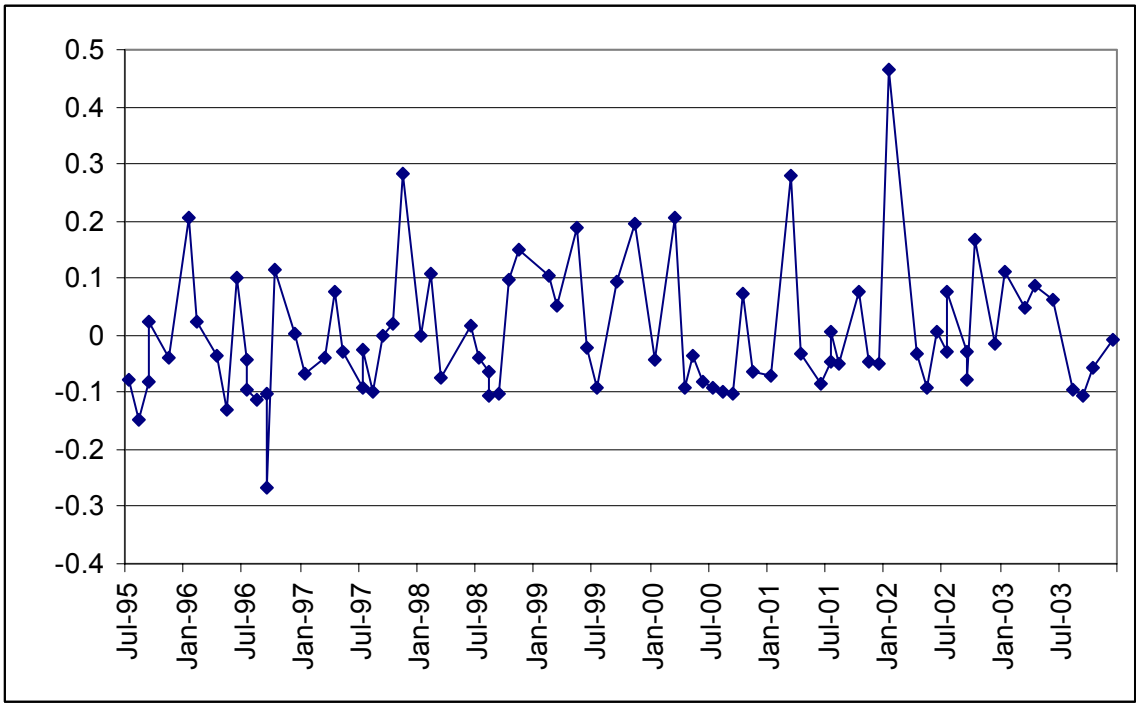


Figure 25 A comparison of alkalinity in spot samples from the Control Burn, Experimental Burn (Lower site) and the Allt Riabhach na Bioraich, June 1995 – December 2003.

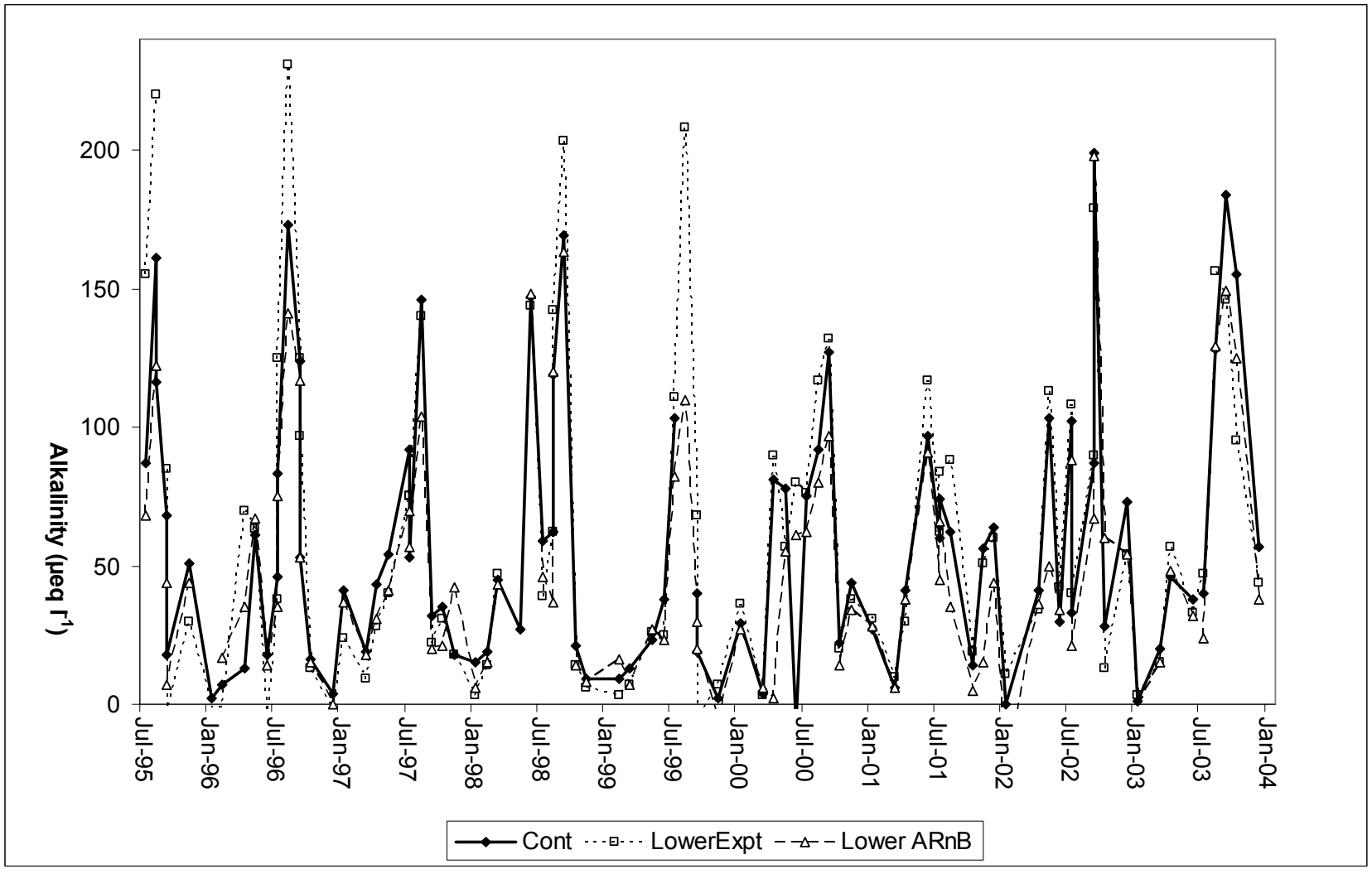


Figure 26 A comparison of conductivity of spot samples from the Control Burn, Experimental Burn (Lower site) and the Allt Riabhach na Bioraich, June 1995 – December 2003.

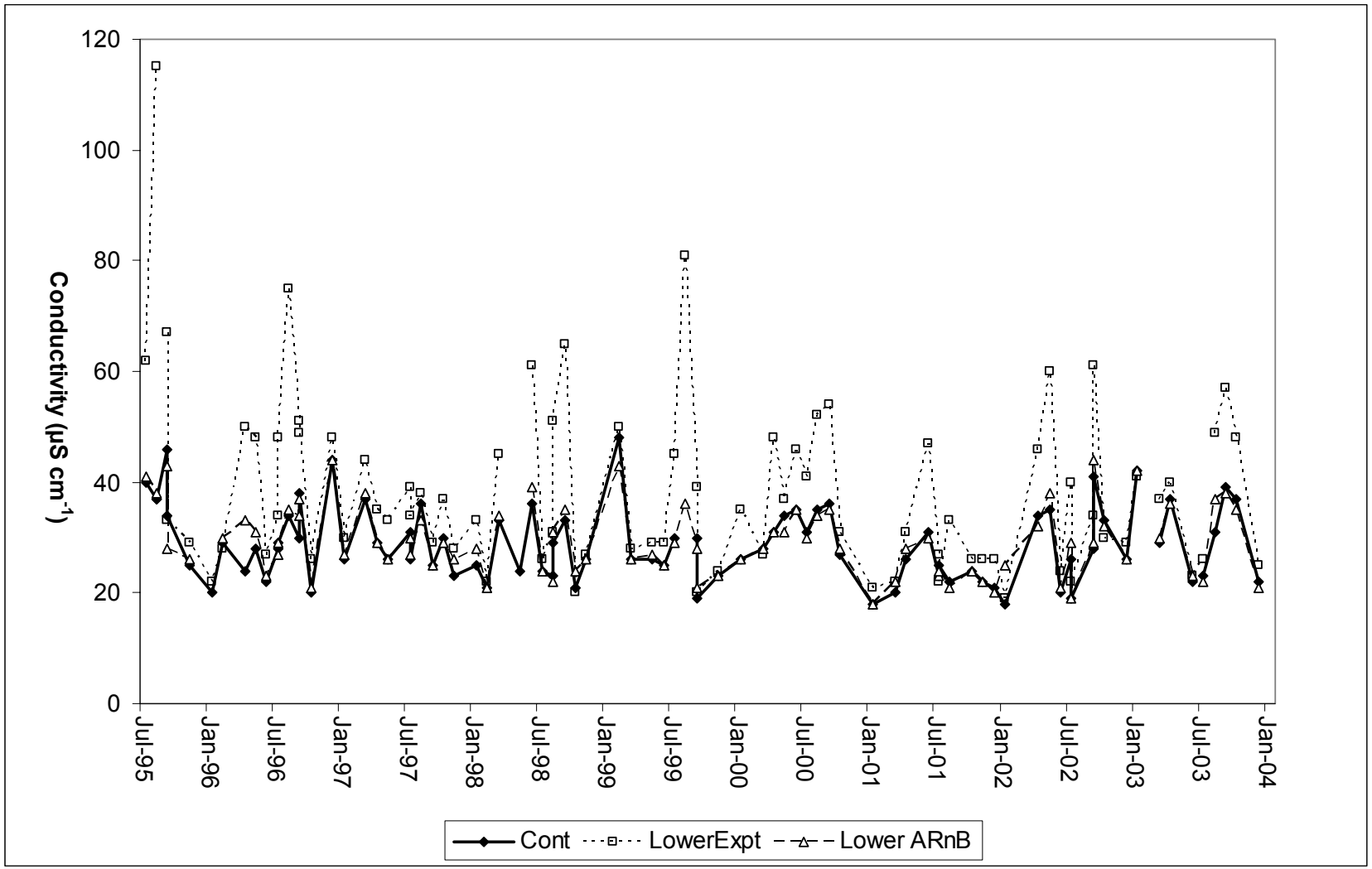


Figure 27 A comparison of nitrate concentrations of spot samples from the Control Burn, Experimental Burn (Lower site) and the Allt Riabhach na Bioraich, June 1995 – December 2003.

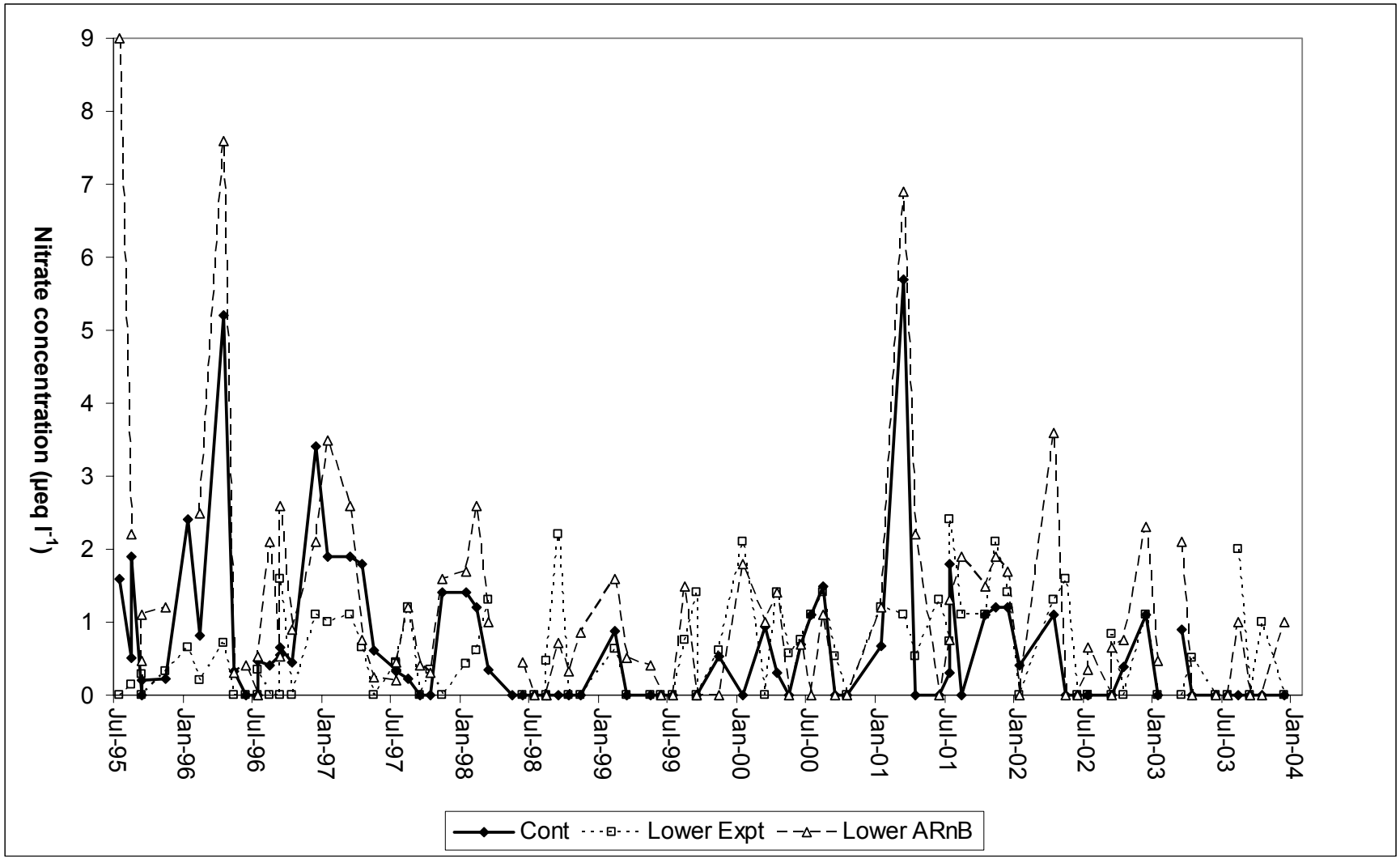


Figure 28 A comparison of soluble reactive phosphorus concentrations of spot samples from the Control Burn, Experimental Burn (Lower site) and the Allt Riabhach na Bioraich, June 1995 – December 2003.

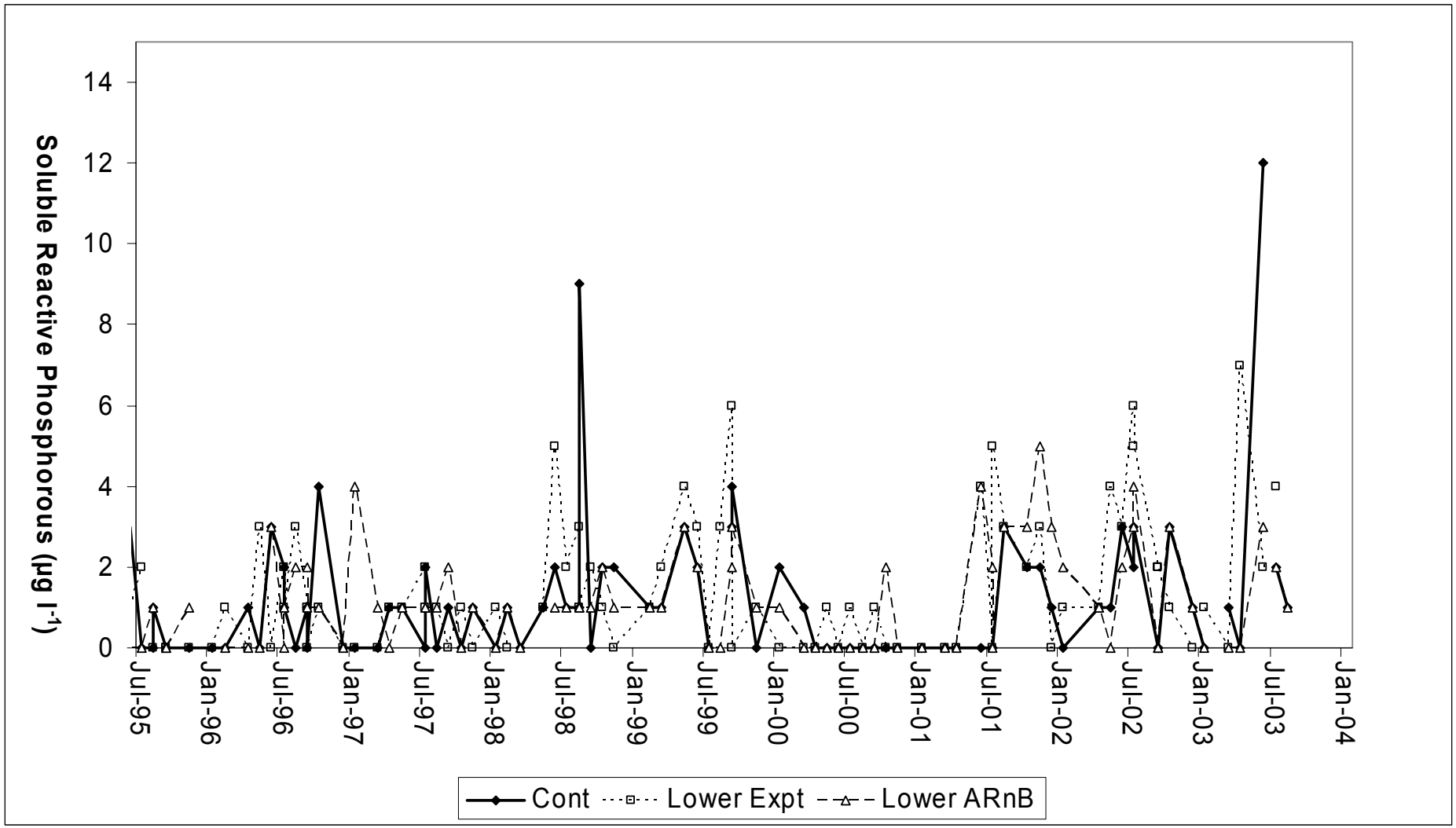


Figure 29 A comparison of total organic carbon concentrations of spot samples from the Control Burn, Experimental Burn (Lower site) and the Allt Riabhach na Bioraich, June 1995 – November 2003.

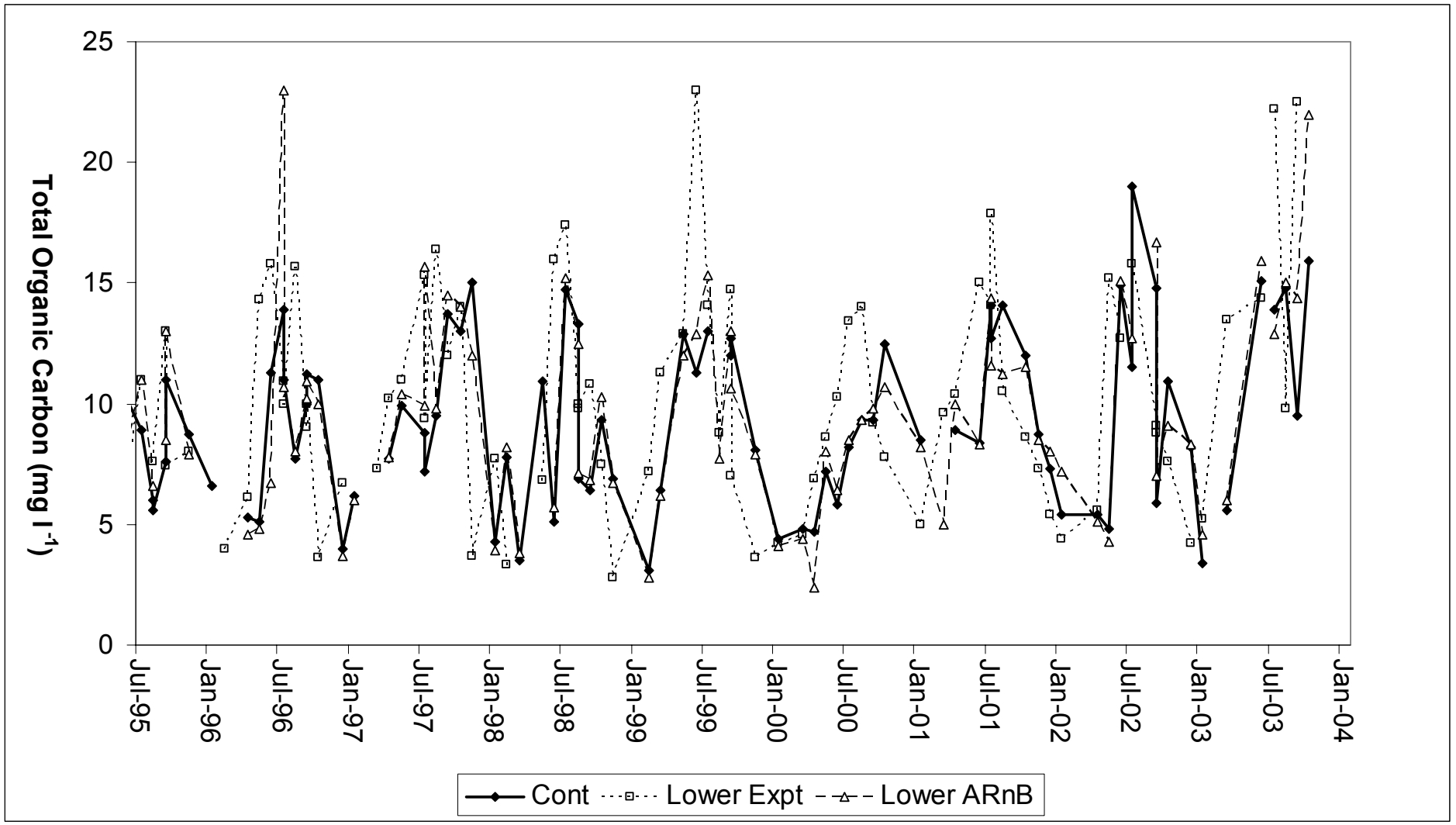


Figure 30 Control Burn diatom percentage abundances

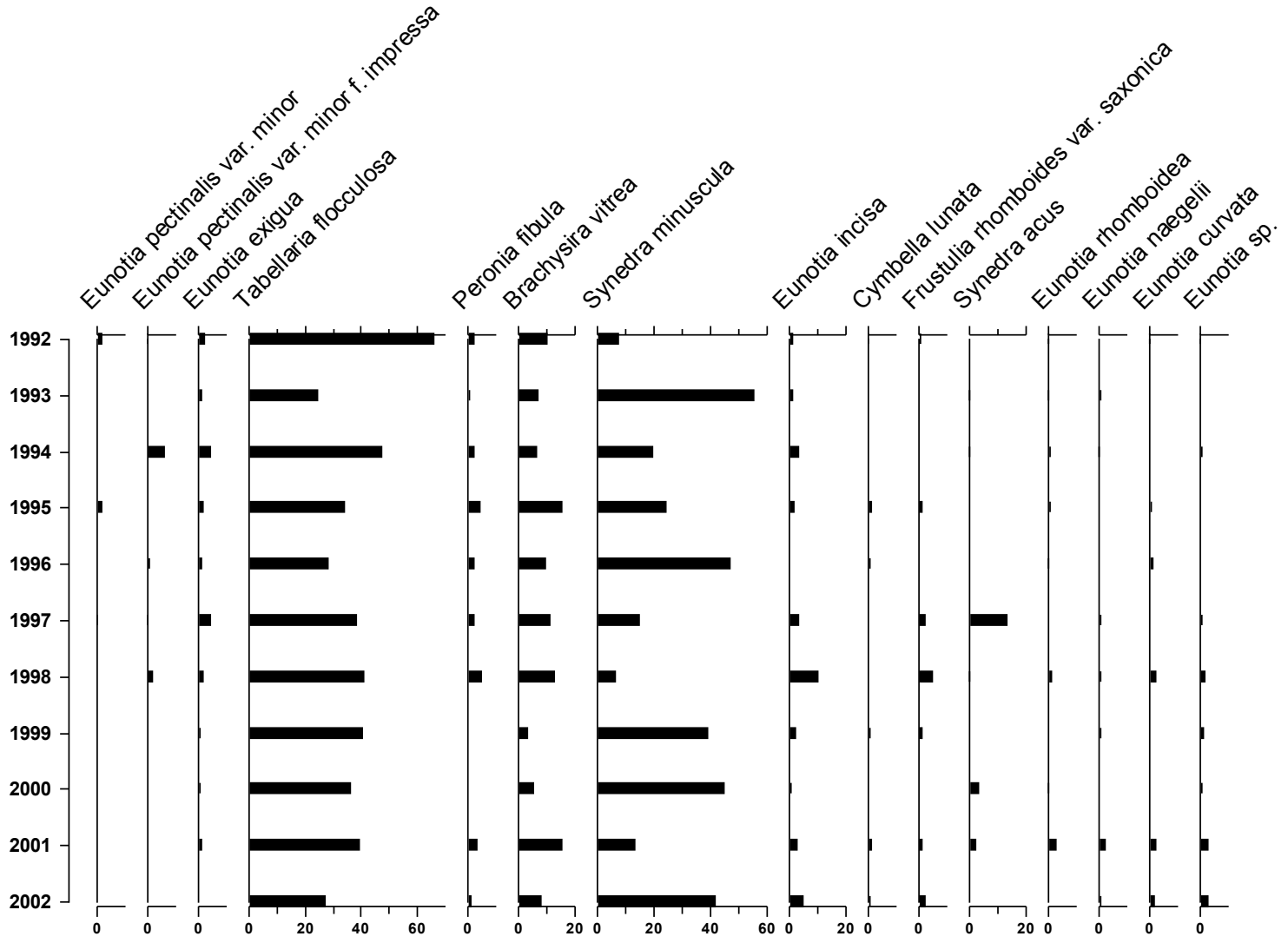


Figure 31 Experimental Burn diatom percentage abundances

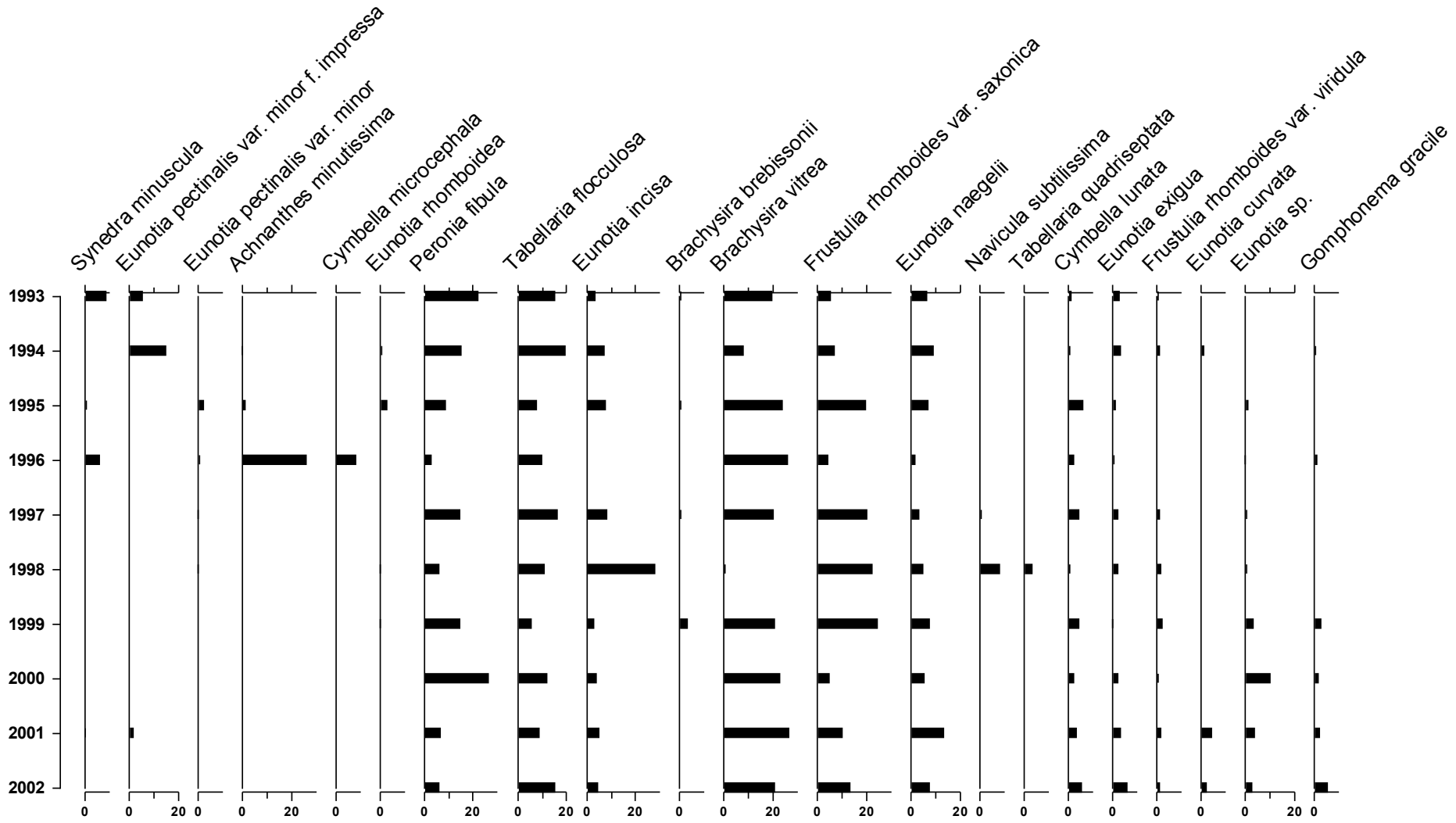


Figure 32 Allt Riabhach na Bioraich diatom percentage abundances

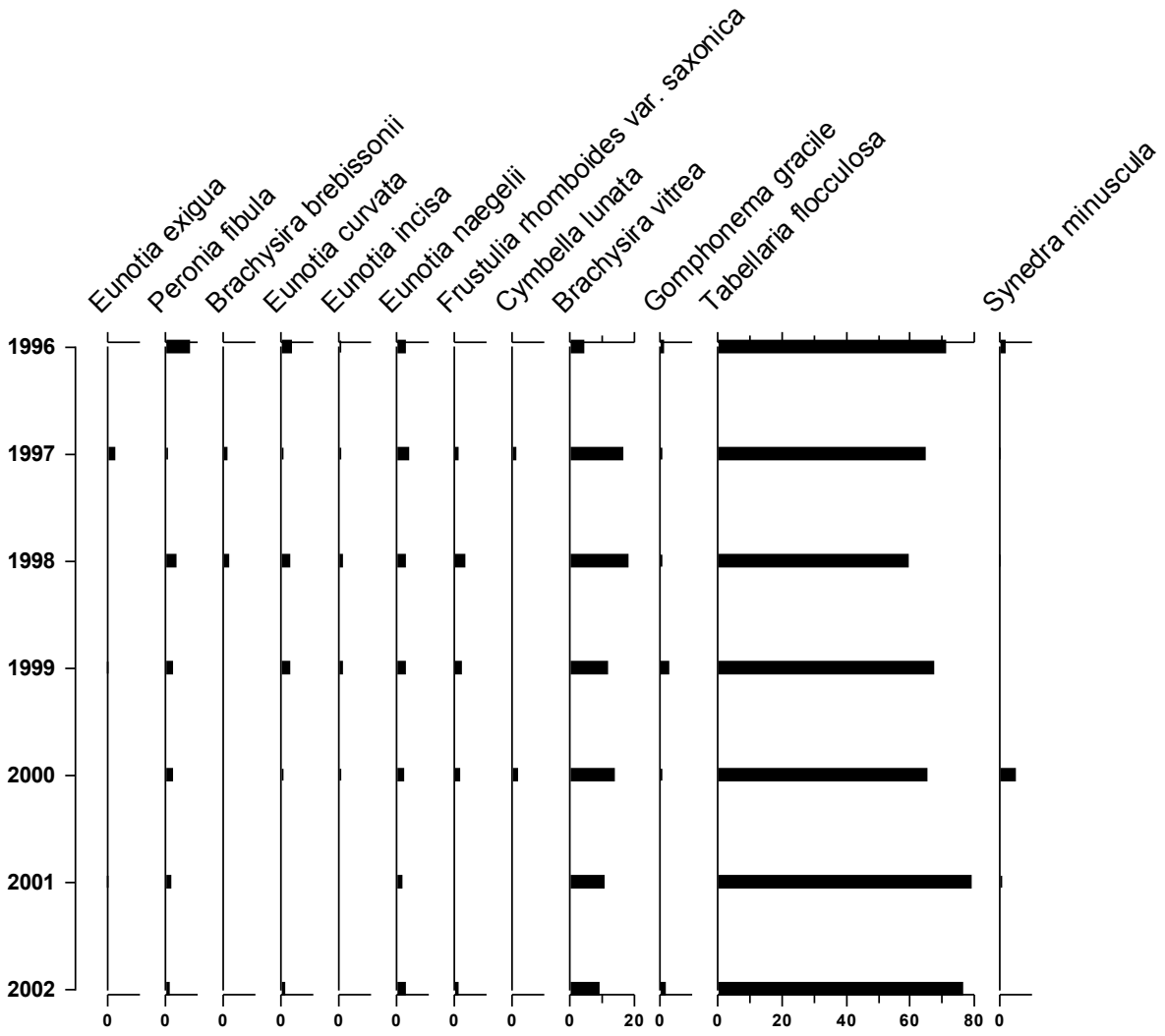


Figure 33 Control Burn macroinvertebrate percentage abundances

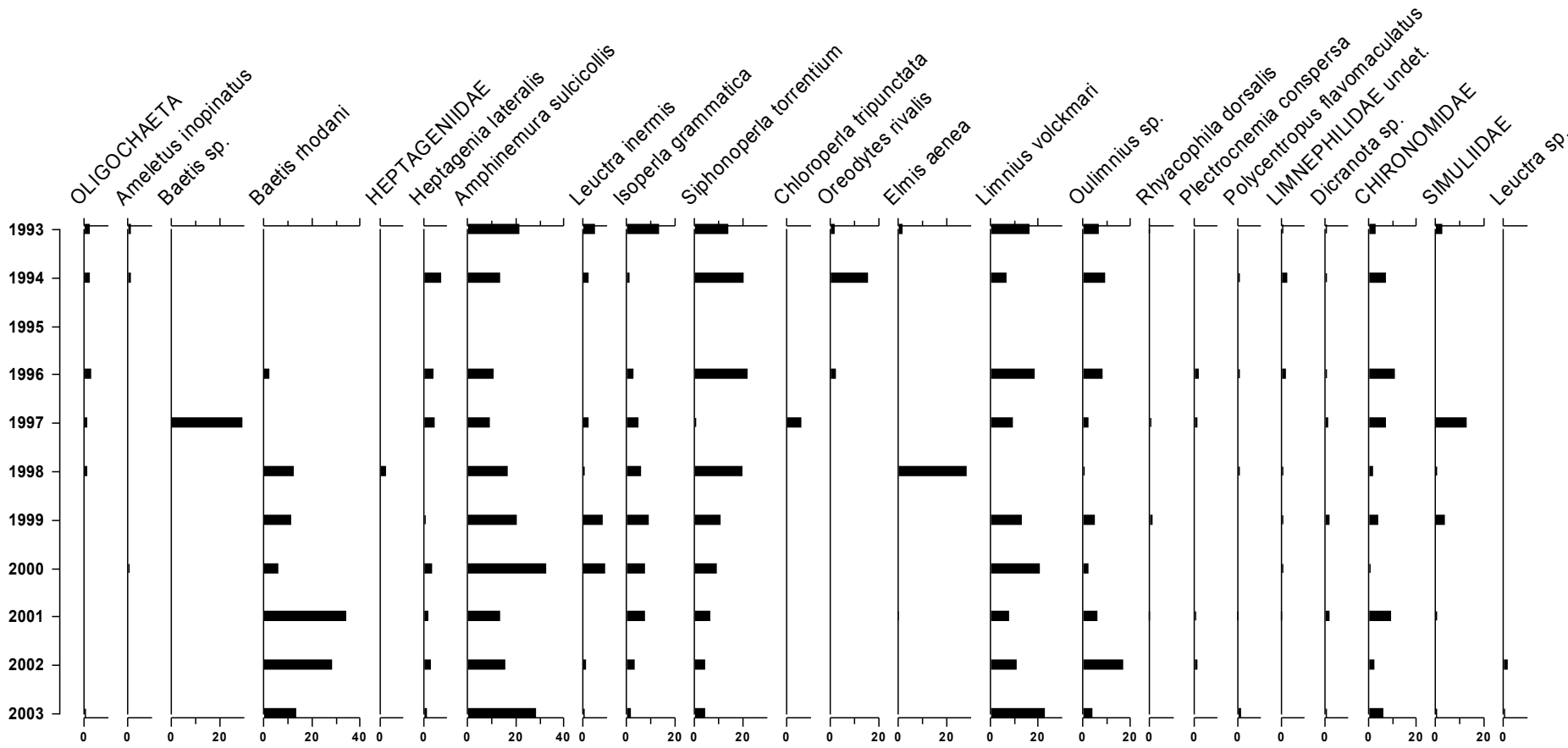


Figure 34 Experimental Burn macroinvertebrate percentage abundances

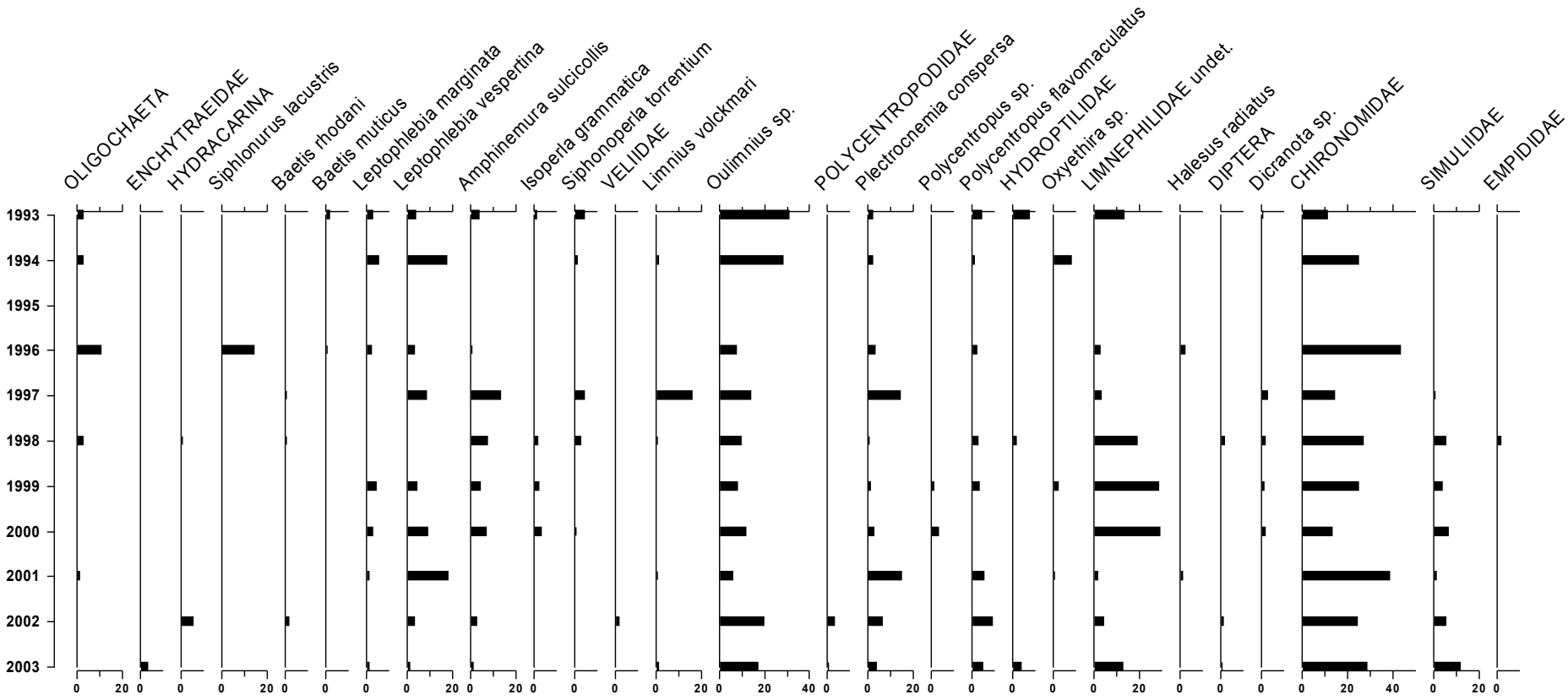


Figure 35 Allt Riabhach na Bioraich Burn macroinvertebrate percentage abundances

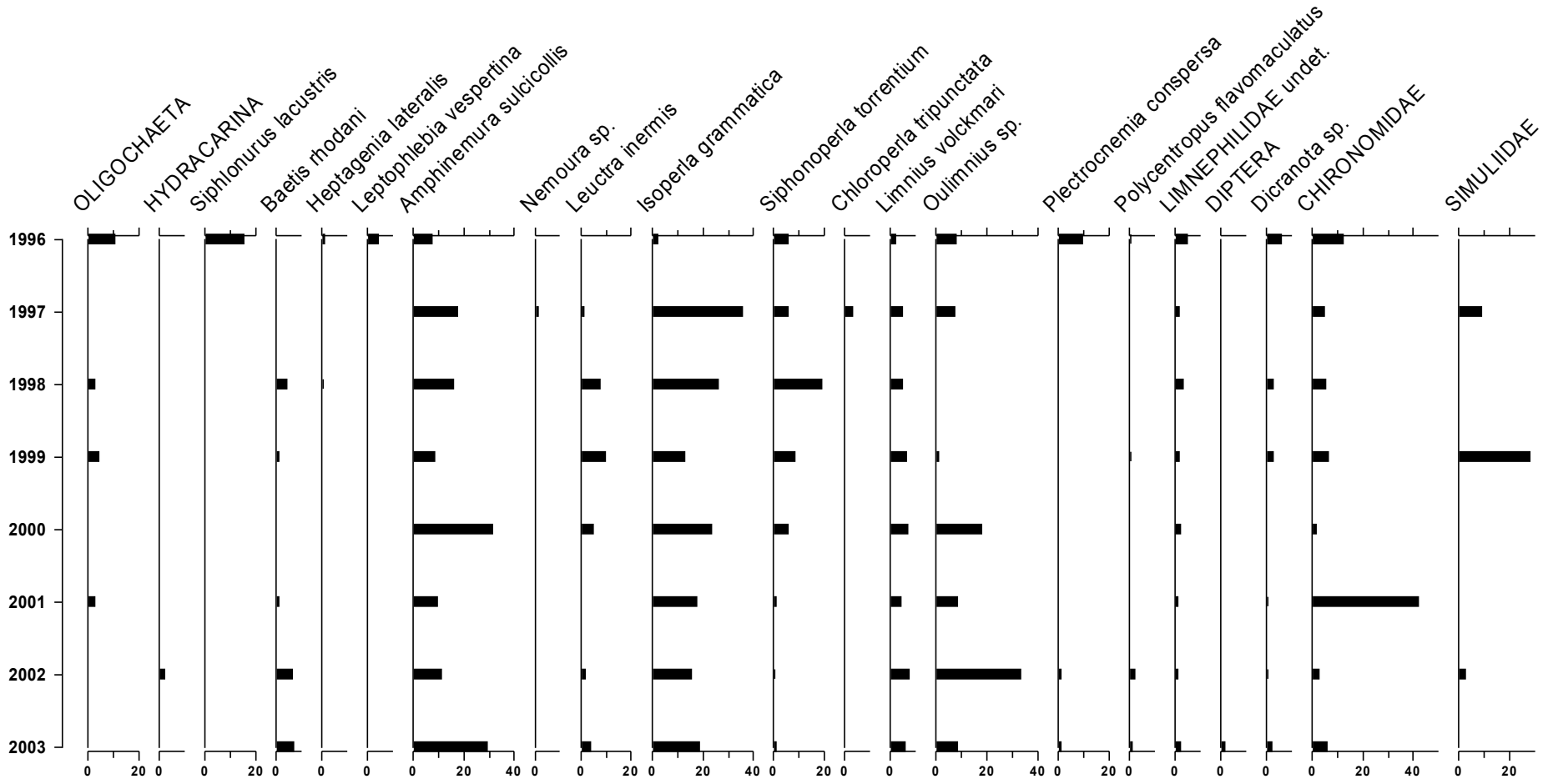


Figure 36 Selected Control Burn macroinvertebrate summary statistics

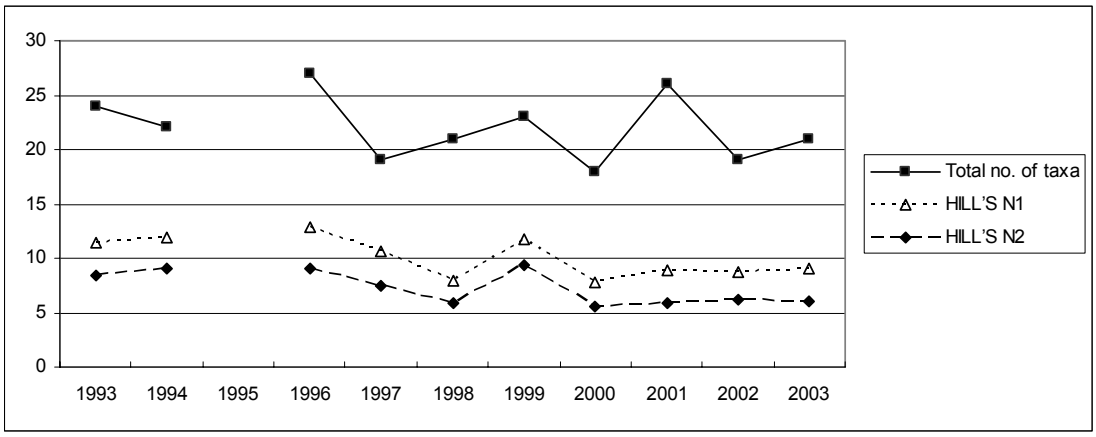


Figure 37 Selected Experimental Burn macroinvertebrate summary statistics

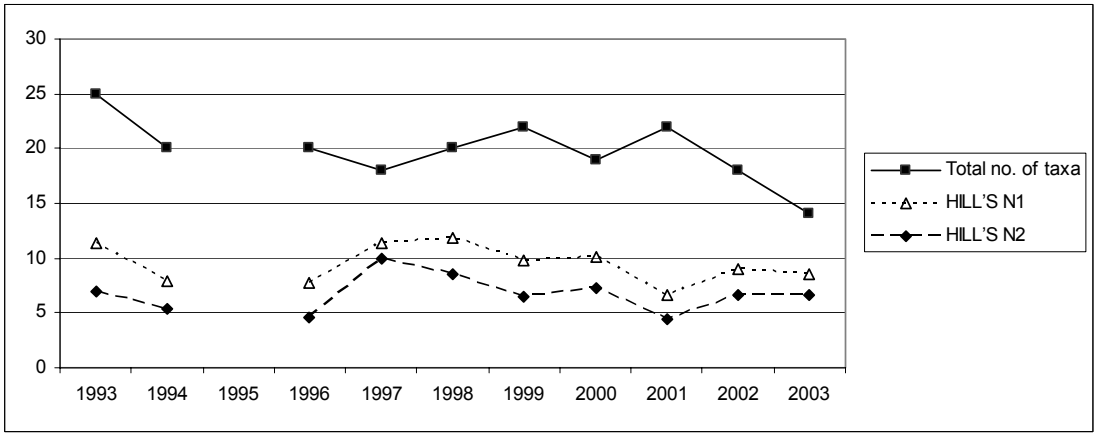


Figure 38 Selected Allt Riabhach na Bioraich macroinvertebrate summary statistics

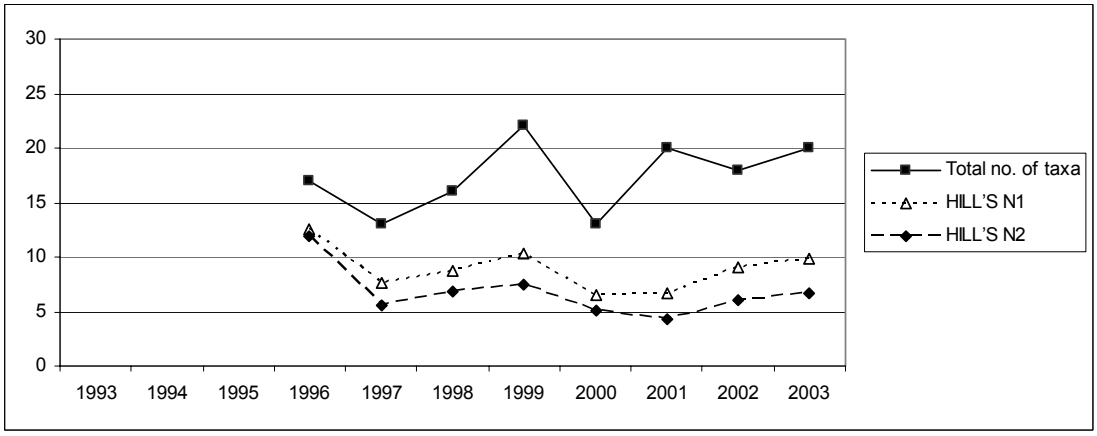


Figure 39 Control Burn fish densities

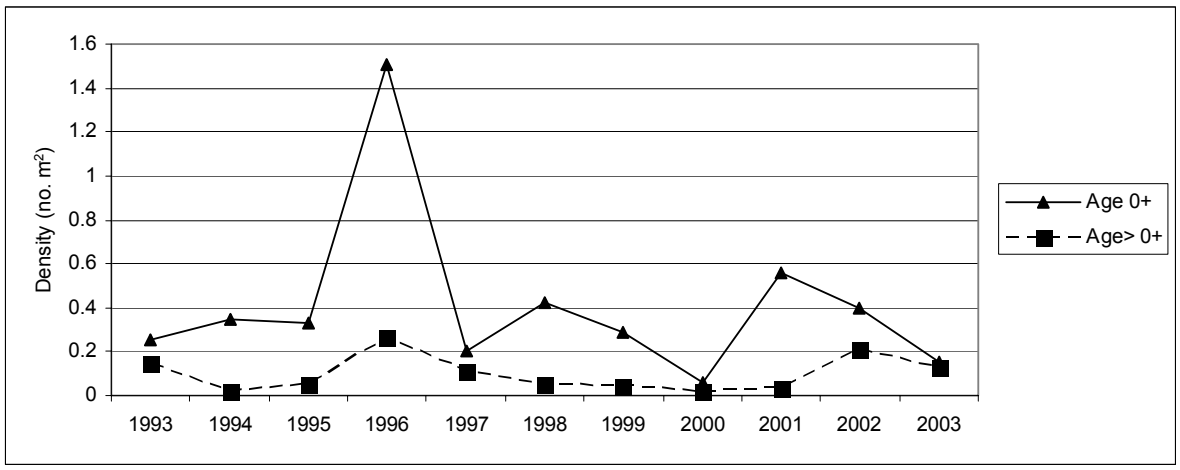


Figure 40 Experimental Burn fish densities

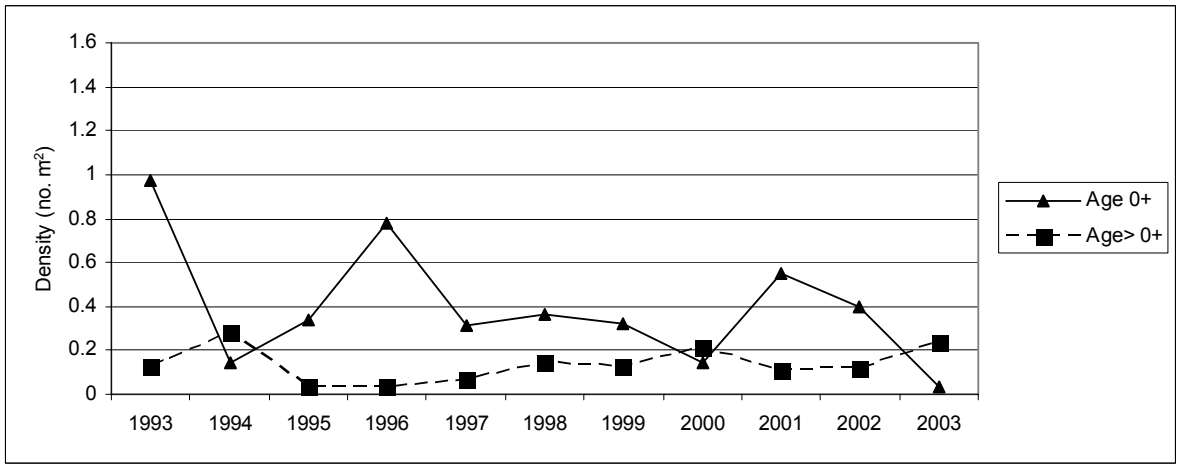
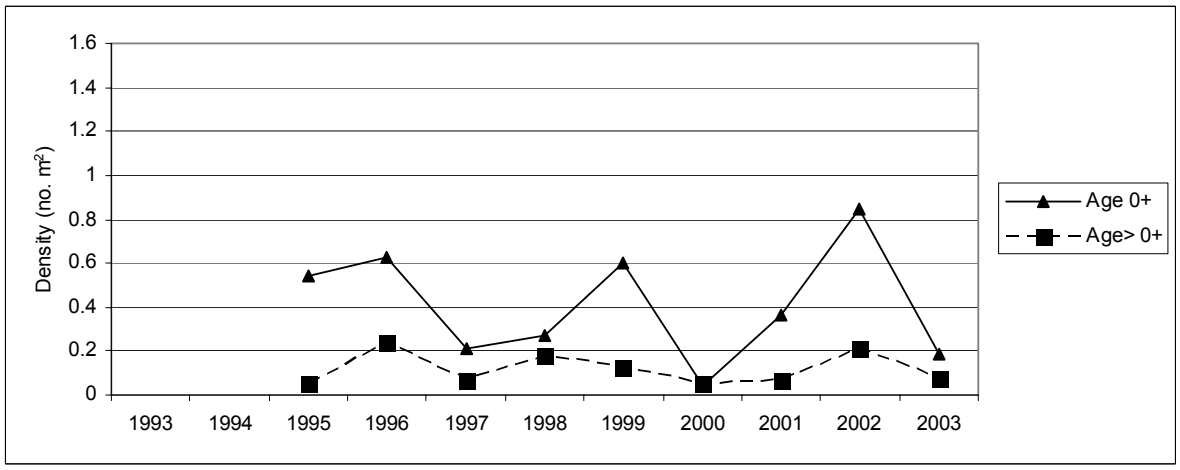


Figure 41 Allt Riabhach na Bioraich fish densities



8 APPENDICES

Appendix 1 Summary statistics of selected chemical determinands for individual years at all sampling stations

Site name	Year	pH			Alkalinity (μeq l^{-1})			Conductivity (μS cm^{-1})			Nitrate (μeq l^{-1})			Sulphate (μeq l^{-1})			Total Phosphorous (μg l^{-1})			Labile Aluminium (μeq l^{-1})		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
CONTROL	1992	5.87	5.44	6.46	27	8	63	22	20	24	0	0	0	26	25	28				8	2	18
CONTROL	1993	6.23	5.59	6.91	64	8	147	29	20	39	0	0	2	28	11	44	22.5	19.0	26.0	6	0	29
CONTROL	1994	6.22	5.18	6.68	53	-3	105	29	23	39	1	0	2	34	23	85	18.9	2.5	58.0	4	0	17
CONTROL	1995	6.42	5.72	7.02	73	16	161	32	21	46	1	0	2	62	18	175	3.1	2.5	6.0	5	0	28
CONTROL	1996	6.03	5.39	6.9	50	2	173	29	20	44	1	0	5	41	18	62	3.3	2.5	10.0	4	0	10
CONTROL	1997	6.32	5.65	6.94	53	18	146	29	23	37	1	0	2	26	13	43	2.9	2.5	6.0	5	0	10
CONTROL	1998	6.19	5.61	6.82	63	9	169	27	21	36	0	0	1	22	13	35	3.3	2.5	11.0	5	0	16
CONTROL	1999	5.86	5.29	6.53	31	2	103	28	19	48	0	0	1	25	10	54	5.0	2.5	6.0	4	2	7
CONTROL	2000	6.33	5.46	6.75	55	-7	127	31	24	36	1	0	2	28	16	59	2.9	2.5	6.0	5	0	13
CONTROL	2001	6.18	5.56	6.63	50	6	97	23	18	31	1	0	6	22	13	34	6.9	2.5	21.0	9	1	24
CONTROL	2002	6.22	5.32	6.84	70	0	199	28	18	41	0	0	1	21	9	33	10.5	2.5	27.0	3	0	21
CONTROL	2003	6.24	5.34	6.93	74	1	184	31	22	42	0	0	1	31	11	63	11.6	6.0	19.0	3	0	10
UPPER EXPT	1992	5.71	5.23	6.19	24	-1	52	26	19	33	0	0	0	44	23	82				0	0	1
UPPER EXPT	1993	6.04	5.29	6.6	85	1	213	33	19	45	1	0	2	24	8	45	20.5	19.0	22.0	3	0	9
UPPER EXPT	1994	6.19	5.47	6.78	73	5	136	34	24	44	1	0	1	27	13	51	18.9	0.0	60.0	3	0	7
UPPER EXPT	1995	6.14	5.21	6.81	89	0	221	38	22	63	0	0	1	74	13	302	3.0	2.5	6.0	3	0	7
UPPER EXPT	1996	5.86	5.16	6.75	62	-4	208	33	23	46	1	0	2	37	16	75	2.6	2.5	3.0	4	0	13
UPPER EXPT	1997	5.90	5.46	6.5	53	13	216	34	26	74	1	0	1	42	9	233	2.5	2.5	2.5	2	0	10
UPPER EXPT	1998	5.92	5.44	6.46	69	3	212	30	21	42	1	0	4	19	9	29	2.8	2.5	6.0	2	0	5
UPPER EXPT	1999	5.79	5.29	6.49	54	1	215	32	18	50	1	0	4	21	7	46	4.7	2.5	6.0	3	0	10
UPPER EXPT	2000	6.09	5.33	6.43	64	2	128	32	25	41	1	0	2	21	10	32	4.3	2.5	6.0	5	0	9
UPPER EXPT	2001	6.03	5.58	6.31	53	11	97	25	17	31	1	0	2	19	10	39	6.4	2.5	11.0	4	0	12
UPPER EXPT	2002	6.08	5.5	6.51	85	6	266	31	17	45	1	0	2	17	6	26	12.2	2.5	21.0	4	0	10
UPPER EXPT	2003	6.06	5.36	6.6	82	2	221	33	21	43	1	0	2	25	10	48	14.5	6.0	35.0	2	0	5
LOWER EXPT	1995	6.13	5.13	6.77	97	-3	220	61	29	115	0	0	0	291	55	749	5.3	2.5	11.0	2	0	4
LOWER EXPT	1996	5.82	4.98	6.67	62	-11	231	42	22	75	0	0	2	105	21	278	3.1	2.5	6.0	5	0	12
LOWER EXPT	1997	5.91	5.54	6.67	46	9	140	35	28	44	0	0	1	52	28	80	5.6	2.5	17.0	2	0	7
LOWER EXPT	1998	5.85	5.44	6.34	67	3	203	38	20	65	0	0	2	88	20	232	3.2	2.5	6.0	8	0	42
LOWER EXPT	1999	5.70	4.97	6.29	50	-6	208	38	20	81	0	0	1	67	10	312	5.4	2.5	8.0	4	0	9
LOWER EXPT	2000	6.15	5.63	6.39	65	3	132	40	27	54	1	0	2	78	18	128	4.3	2.5	6.0	4	0	13
LOWER EXPT	2001	6.03	5.6	6.37	55	10	117	28	21	47	1	1	2	52	19	133	5.3	2.5	6.0	5	0	16
LOWER EXPT	2002	6.02	5.65	6.37	68	11	179	37	19	61	1	0	2	73	13	199	12.4	2.5	24.0	3	0	11
LOWER EXPT	2003	5.92	5.4	6.21	66	3	156	38	23	57	0	0	2	78	20	178	11.9	6.0	18.0	6	0	16
LOWER ARnB	1995	6.16	5.41	6.8	55	7	122	34	25	43	2	0	9	84	26	156	3.4	2.5	6.0	3	0	8
LOWER ARnB	1996	5.97	5.26	6.69	52	0	141	31	21	44	2	0	8	47	22	88	2.7	2.5	4.0	7	1	29
LOWER ARnB	1997	6.02	5.64	6.63	44	18	104	29	25	38	1	0	4	31	20	49	2.9	2.5	6.0	4	0	10
LOWER ARnB	1998	5.95	5.46	6.52	60	6	163	28	21	39	1	0	3	33	18	62	2.5	2.5	2.5	3	0	12
LOWER ARnB	1999	5.79	5.02	6.56	34	-6	110	29	21	43	1	0	2	29	14	51	3.8	2.5	6.0	4	0	20
LOWER ARnB	2000	6.02	5.47	6.59	44	2	97	30	24	35	1	0	2	32	20	47	4.3	2.5	6.0	6	2	15
LOWER ARnB	2001	5.97	5.3	6.45	37	5	91	23	18	30	2	0	7	27	18	37	5.2	2.5	6.0	7	0	15
LOWER ARnB	2002	5.97	4.59	6.6	58	-24	198	30	19	44	1	0	4	28	10	45	12.8	2.5	25.0	6	0	22
LOWER ARnB	2003	5.99	5.25	6.62	62	-1	149	32	21	42	0	0	2	39	14	59	11.3	5.0	19.0	15	2	76
UPPER ARnB	1995	6.19	5.56	6.59	44	9	84	31	23	41	3	0	8	77	20	158	3.4	2.5	6.0	2	0	8
UPPER ARnB	1996	5.94	5.28	6.67	38	-1	114	28	20	43	2	0	7	43	21	82	2.8	2.5	4.0	5	1	11
UPPER ARnB	1997	6.05	5.63	6.51	49	7	202	29	24	46	1	0	4	26	17	44	2.9	2.5	6.0	7	0	28
UPPER ARnB	1998	6.02	5.54	6.68	44	6	130	25	20	32	1	0	2	23	14	33	3.1	2.5	6.0	7	0	27
UPPER ARnB	1999	5.82	5.22	6.46	27	-2	85	28	19	45	0	0	2	25	15	39	4.1	1.0	10.0	4	0	13
UPPER ARnB	2000	6.14	5.54	6.51	40	5	79	28	23	32	1	0	2	27	17	46	4.3	2.5	6.0	2	0	6
UPPER ARnB	2001	6.02	5.44	6.38	37	4	71	22	18	27	2	0	7	23	14	36	9.7	2.5	35.0	9	0	22
UPPER ARnB	2002	6.13	5.32	6.91	53	0	152	26	17	36	1	0	3	20	10	33	12.9	2.5	28.0	6	0	14
UPPER ARnB	2003	6.03	5.23	6.57	49	-2	119	29	20	41	0	0	2	29	14	55	13.8	6.0	25.0	6	1	18
LAIDONOFLOW	1995	5.93	5.71	6.15	19	14	24	24	23	24	2	2	2	39	35	43	2.5	2.5	2.5	1	0	2
LAIDONOFLOW	1996	5.92	5.52	6.27	19	6	35	26	18	32	4	2	6	49	34	91	3.1	2.5	6.0	2	0	7
LAIDONOFLOW	1997	5.91	5.51	6.31	15	2	26	29	25	33	2	1	5	31	27	34	3.4	2.5	10.0	2	0	8
LAIDONOFLOW	1998	5.93	5.63	6.15	19	10	28	25	22	28	2	1	3	29	24	34	4.3	2.5	17.0	3	1	6
LAIDONOFLOW	1999	5.87	5.48	6.09	17	2	23	28	24	36	1	0	3	25	12	31	4.3	2.5	6.0	2	0	12
LAIDONOFLOW	2000	5.86	5.3	6.11	14	-1	23	31	25	39	1	1	2	29	22	34	5.0	2.5	17.0	2	0	5
LAIDONOFLOW	2001	6.02	5.67	6.31	25	10	34	22	20	24	4	2	8	28	22	32	6.7	2.5	14.0	2	0	3
LAIDONOFLOW	2002	5.96	5.64	6.27	20	10	33	30	21	41	1	0	3	29	25	37	9.6	2.5	25.0	4	0	9
LAIDONOFLOW	2003	5.99	5.83	6.28	21	12	36	27	24	30	2	1	3	31	29	34	10.8	6.0	20.0	2	0	6
FOREST	2000	6.29	5.72	7.27	124	19	330	36	22	58	1	0	2	26	14	45	5.7	2.5	12.0	14	0	33
FOREST	2001	5.78	5.4	6	28	9	47	21	16	25	1	0	2	19	10	36	7.1	2.5	17.0	8	0	34
FOREST	2002	5.82	5.48	6.1	43	5	111	27	17	36	0	0	1	17	8	31	11.0	2.5	26.0	15	1	51
FOREST	2003	5.70	5.42	6	45	4	126	28	18	41	0	0	2	24	7	45	12.4	7.0	17.0	7	1	16

Appendix 2 Water chemistry for the Control Burn August 1992 – December 2003

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
12/08/1992	5.44	8	24	106	3	34	68	94	0	26	1		70	18	0.74		
30/10/1992	6.46	63	23	112	4	32	68	99	0	28	0		29	4	0.32	5	
06/12/1992	5.7	10	20	104	3	17	43	103	0	25	1		33	2	0.25	3.5	
04/01/1993	5.63	8	20	105	4	25	41	101	0	44	0		21	3	0.27	3.8	
30/03/1993	5.91	17	39	203	5	44	67	278	0	41	1		20	3	0.17	3.1	
03/05/1993	6.57	91	35	177	6	42	97	186	0	35	0		9	5	0.17	3.3	
18/06/1993	6.38	64	31	145	4	39	88	130	0	30	1	19	15	29	0.55	9.4	
10/07/1993	6.31	57	27	141	4	33	77	129	0	19	2	26	71	1	0.61	9.1	
25/07/1993	6.06	45	27	134	3	38	92	117	0	16	2		72	0	0.78	11	
09/08/1993	5.91	32	23	114	3	33	72	98	2	11	4		92	13	0.88		
22/08/1993	6.54	92	27	148	4	42	91	141	0	18	2		39	4	0.48		
04/09/1993	6.76	147	36	168	7	46	111	151	0	26	0		17	1	0.29		
29/09/1993	6.91	141	36	161	6	47	114	155	0	31	0		26	5			
06/12/1993	5.59	8	20	99	4	25	32	86	1	38	1		37	5	0.459	6.7	
18/02/1994	6.34	57	39	210	6	66	101	211	2	41	0	5	14	0	0.132		0
01/05/1994	6.03	29	24	141	9	34	56	123	0	25	0	10	36	8	0.309	4.4	0
12/05/1994	6.48	62	29	161	6	48	82	143	0	30	0		22	5	0.213	3.2	0
10/06/1994	6.39	54	39	201	9	68	110	174	0	85	1		30	4	0.283		0
08/07/1994	5.98	39	27	151	6	52	83	111	0	35	1		80	0	0.632		0
07/08/1994	6.12	35	23	140	5	46	71	109	0	26	4	58	60	2			0
25/08/1994	6.47	68	29	152	5	61	113	118	0	27	1		41	1			0
03/09/1994	6.68	105	31	163	6	60	110	125	2	24	1	2.5	28	7	0.339	5.5	0
22/09/1994	6.5	86	29	152	6	56	119	123	0	23	1		26	17	0.385	7.5	0
29/12/1994	5.18	-3	23	108	4	30	31	126	1	23	1		24	0	0.198	4	0
27/03/1995	5.86	16	21	121	6	31	41	122	0	22	0	2.5	29	2	0.239	4.8	0
27/04/1995	6.61	85	24	133	8	43	81	107	0	20	0	2.5	16	0	0.204	4.8	0
02/06/1995	6.38	58	26	137	4	41	75	103	0	18	3	3	29	28	0.49	9.9	0
15/07/1995	6.65	87	40	178	9	75	128	127	2	96	0	2.5	29	1	0.34	8.9	0
06/08/1995	7.02	161	37	195	11	67	146	143	1	44	0		21	0	0.285	6	0
25/08/1995	6.77	116	37	186	10	62	115	144	2	37	1	2.5	20	1	0.262	5.6	0
04/09/1995	6.51	68	46	188	7	90	157	118	0	175	0	6	34	3	0.313	7.6	0
24/09/1995	5.72	18	34	156	5	66	99	108	0	107	0		62	4	0.469	11	0
11/11/1995	6.27	51	25	124	6	48	85	95	0	39	0	2.5	65	2	0.43	8.7	0
10/01/1996	5.39	2	20	100	6	37	50	78	2	59	0	2.5	44	5	0.297	6.6	3
27/02/1996	5.49	7	29	152	5	55	68	166	1	60			28	2	0.238		0
03/04/1996	5.72	13	24	124	6	39	61	112	5	49	1	2.5	28	0	0.243	5.3	3
02/05/1996	6.26	61	28	136	5	50	88	113	0	49	0	2.5	30	4	0.251	5.1	0
12/06/1996	5.68	18	22	109	2	38	62	88	0	21	3	10	70	2	0.586	11.3	0
04/07/1996	6.21	46	28	131	4	49	83	93	0	47	2	2.5	48	10	0.513	13.9	0
27/07/1996	6.54	83	29	143	5	61	112	102	0	31	1	2.5	48	2	0.551	11	0
18/08/1996	6.9	173	34	160	7	69	144	110	0	26	0	2.5	24	0	0.386	7.7	0
07/09/1996	6.61	124	30	159	7	71	131	114	1	24	1	2.5	31	5	0.496	10	0
28/09/1996	6.34	53	38	164	9	74	125	163	1	62	0	2.5	58	5	0.486	11.2	0
30/10/1996	5.69	16	20	94	7	37	57	79	0	18	4		69	10	0.564	11	0
03/12/1996	5.49	4	44	219	7	67	73	296	3	40	0	2.5	38	1	0.165	4	3
28/01/1997	6.25	41	26	128	5	42	72	102	2	43	0	2.5	40	0	0.301	6.2	2
10/03/1997	6.93	19	37	190	7	57	80	228	2	41	0						0
30/04/1997	6.2	43	29	170	5	52	89	162	2	25	1	2.5	46	0	0.384	7.7	0
21/05/1997	6.35	54	26	142	5	45	79	118	1	19	1	2.5	52	4	0.487	9.9	1
05/07/1997	6.55	92	31	160	7	54	100	121	0	29	0	2.5	29	10	0.41	8.8	4
30/07/1997	6.2	53	26	135	4	54	100	104	0	13	2	2.5	86	4	0.87	7.2	0
19/08/1997	6.94	146	36	169	8	67	135	122	0	24	0	2.5	32	9	0.447	9.5	0
07/09/1997	6.02	32	25	130	4	48	82	106	0	17	1	2.5	88	4	0.708	13.7	0

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
05/10/1997	6.06	35	30	143	8	55	96	145	0	20	0	2.5	58	10	0.607	13	0
14/11/1997	5.65	18	23	119	12	44	65	101	1	28	1	6	73	7	0.64	15	1
05/01/1998	5.91	15	25	139	6	46	60	159	1	29	0	2.5	34	2	0.213	4.3	0
05/02/1998	5.86	19	21	105	4	35	53	94	1	27	1	2.5	44	0	0.313	7.8	0
21/03/1998	6.31	45	33	174	7	52	74	192	0	29	0	2.5	20	5	0.161	3.5	0
07/05/1998	5.94	27	24	137	5	42	66	115	0	15	1	2.5	45	8	0.525	10.9	0
20/06/1998	6.75	147	36	177	7	60	114	120	0	35	2	2.5	1	13	0.204	5.1	0
20/07/1998	6.24	59	24	125	2	51	87	82	0	13	1	2.5	66	1	0.716	14.7	0
09/08/1998	6.23	62	23	129	3	53	82	79	0	13	1	2.5	59	16	0.704	13.3	0
29/08/1998	6.63	119	29	143	5	54	102	92	0	19	9	11	29	2	0.365	6.9	0
27/09/1998	6.82	169	33	151	6	67	132	108	0	23	0	2.5	21	2		6.4	0
25/10/1998	5.82	21	21	101	6	37	61	89	0	18	2	2.5	51	3	0.49	9.3	0
25/11/1998	5.61	9	26	129	3	40	57	146	0	24	2	2.5	34	2	0.327	6.9	0
12/02/1999	5.76	9	48	258	9	73	92	337	1	37	1	6	15	2	0.112	3.1	0
25/03/1999	5.74	13	26	147	5	35	45	161	0	20	1	2.5	28	4	0.289	6.4	1
10/05/1999	5.81	23	26	149	6	43	64	133	0	27	3	6	53	4	0.58	12.9	0
17/06/1999	6.09	38	25	146	4	44	73	134	0	10	2	6	63	4	0.552	11.3	0
12/07/1999	6.53	103	30	168	8	62	118	127	0	18	0		57	2	0.617	13	0
01/09/1999	6.04	40	30	146	4	62	106	120	0	54	3	6	59	7	0.581	12	0
26/09/1999	5.62	19	19	104	5	37	54	81	0	16	4	6	50	3	0.612	12.7	0
06/11/1999	5.29	2	23	115	7	33	42	126	1	21	0	2.5	30	6	0.357	8.1	0
20/01/2000	6.11	29	26	141	3	41	63	145	0	26	2	2.5	33	0	0.197	4.4	0
05/03/2000	5.46	4	28	168	3	39	48	185	1	27	1	2.5	26	1	0.192	4.8	0
14/04/2000	6.59	81	31	166	6	52	106	158	0	21	0	2.5	16	7	0.209	4.7	0
31/05/2000	6.53	78	34	188	5	64	108	149	0	59	0	2.5	26	13	0.336	7.2	0
17/06/2000	6.56	-7	35	190	5	67	114	181	1	31	0	2.5	32	0	0.25	5.8	0
12/07/2000	6.7	75	31	169	4	62	110	147	1	26	0	2.5	25	11	0.354	8.2	0
05/08/2000	6.6	92	35	175	5	62	108	146	2	38	0	2.5	30	3	0.391	9.3	2
04/09/2000	6.75	127	36	170	5	67	128	154	0	18	0	6	20	6	0.425	9.3	0
08/10/2000	5.75	22	27	142	5	46	68	144	0	16	0	2.5	67	9	0.613	12.5	0
21/11/2000	6.24	44	24	132	3	43	71	116	1	19	0	2.5	44	0	0.407	8.2	0
09/01/2001	6.01	27	18	102	5	30	52	75	1	22	0	21	50	1	0.413	8.5	0
08/03/2001	5.56	6	20	95	8	31	40	92	6	32	0	10	41	1	0.227		1
26/04/2001	6.23	41	26	130	5	43	77	115	0	32	0	6	26	24	0.416	8.9	1
06/06/2001	6.63	97	31	150	5	51	105	103	0	34	0	2.5	18	9	0.387	8.4	0
03/07/2001	6.3	60	23	125	3	45	96	75	0	17	0	6	86	4	0.769	14.1	0
23/07/2001	6.39	74	25	123	4	50	97	90	2	15	0	2.5	40	14	0.645	12.7	3
19/08/2001	6.31	62	22	108	3	45	110	70	0	13	3	6	37	23	0.725	14.1	0
07/10/2001	5.58	14	24	111	9	39	51	112	1	15	2	6	44	9	0.548	12	0
14/11/2001	6.32	56	22	107	6	41	75	88	1	19	2	2.5	32	3	0.379	8.7	0
10/12/2001	6.42	64	21	113	7	43	78	86	1	22	1	6	33	4	0.356	7.3	0
22/01/2002	5.32	0	18	94	5	22	24	99	0	15	0	2.5	25	0	0.237	5.4	0
04/04/2002	6.25	41	34	201	8	51	77	215	1	32	1	2.5	16	0	0.252	5.4	0
07/05/2002	6.65	103	35	194	8	54	99	164	0	26	1	6	11	0	0.204	4.8	0
12/06/2002	5.87	30	20	121	3	37	56	78	0	13	3	6	64	0	0.755	14.9	0
14/07/2002	6.56	102	26	144	5	53	101	100	0	13	2	11	22	8	0.541	11.5	0
31/07/2002	5.81	33	19	99	3	40	65	57	0	9	3	17	53	21	0.933	19	0
01/09/2002	6.49	87	28	148	7	63	114	116	0	17	0	27			0.635	14.8	0
29/09/2002	6.84	199	41	170	8	80	174	126	0	21	0	6	17	0	0.276	5.9	0
21/10/2002	5.94	28	33	141	17	65	87	182	0	33	3	6	25	1	0.42	10.9	0
08/12/2002	6.42	73	26	122	6	47	88	99	1	28	1	21	30	1	0.375	8.2	0
26/01/2003	5.34	1	42	203	8	68	78	272	0	36	0	17	28	0	0.184	3.4	0
03/03/2003	5.99	20	29	154	8	42	58	157	1	46	1	6	32	5	0.261	5.6	2
28/04/2003	6.31	46	37	191	8	62	103	183	0	63	0	10	30	2	0.368		4
11/06/2003	5.95	38	22	118	2	41	69	85	0	11	12	19	47	10	0.792	15.1	0
24/07/2003	5.9	40	23	122	5	45	79	89	0	24	2	11	51	3	0.621	13.9	2

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
10/08/2003	6.69	128	31	161	6	66	132	116	0	21	1	9	27	1	0.472	14.8	0
08/09/2003	6.93	184	39	170	8	74	155	128	0	27	1	13	12	1	0.249	9.5	0
27/10/2003	6.74	155	37	174	9	94	202	159	0	24	1	8	7	2	0.191	15.9	0
16/12/2003	6.35	57	22	119	6	42	77	97	0	25	0		26	2	0.298		0

Appendix 3 Water chemistry for the Experimental Burn (Upper site) September 1992 - December 2003

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
18/09/1992	5.71	20	33	136	3	36	113	152	0	82	0		21	1	0.41		
30/10/1992	6.19	52	26	130	3	32	61	128	0	26	0		15	0	0.27	4.4	
06/12/1992	5.23	-1	19	93	2	14	27	88	0	23	0		27	0	0.26	3.4	
04/01/1993	5.43	4	19	98	2	21	31	86	0	35	0		12	0	0.27	3.8	
30/03/1993	5.86	20	41	230	5	44	64	296	1	45	2		9	3	0.17	2.9	
03/05/1993	6.42	115	37	204	7	44	95	192	1	29	0		5	2	0.26	4.2	
18/06/1993	6.33	122	37	202	4	44	100	156	0	16	0	19	19	9	0.51	8.2	
10/07/1993	6.05	62	29	164	4	35	76	139	0	18	3	22	46	1	0.7	9.5	
25/07/1993	5.71	36	29	156	2	42	73	130	0	12	3		48	9	0.86	13	
09/08/1993	5.93	51	29	151	4	42	76	131	0	8	5		54	0	0.88		
22/08/1993	6.36	142	33	186	6	60	108	159	1	14	3		28	2	0.65		
04/09/1993	6.47	213	45	210	7	68	159	171	2	22	1		10	2	0.41		
29/09/1993	6.6	171	45	209	15	64	135	207	2	28	0		20	0			
06/12/1993	5.29	1	21	105	3	24	26	87	0	39	6		24	2	0.492	6.8	
18/02/1994	6.3	66	44	243	6	75	109	246	1	49	1	0	5	0	0.096		0
01/05/1994	5.88	27	29	183	4	44	58	159	0	28	1	13	26	7	0.414	5.4	0
12/05/1994	6.36	85	36	202	7	58	90	176	0	26	0		19	4	0.279	5	7
10/06/1994	6.25	67	40	224	5	62	100	200	0	51	0		22	2	0.292		0
08/07/1994	5.75	38	29	178	3	53	75	122	1	24	2		45	1	0.836		0
07/08/1994	6.78	130	31	181	13	78	137	141	1	19	4	60	17	6			0
25/08/1994	6.29	76	32	177	7	71	111	141	1	18	2		28	3			0
03/09/1994	6.51	136	37	200	12	81	136	153	1	16	5	2.5	18	3	0.488	7.6	0
22/09/1994	6.27	95	33	186	7	66	123	160	0	13	2		21	0		7.3	0
29/12/1994	5.47	5	24	125	6	39	36	139	0	24	1		35	3	0.238	4.6	0
27/03/1995	5.74	15	22	129	5	32	40	121	0	21	2	2.5	18	1	0.26	5.3	0
27/04/1995	6.1	61	29	168	15	48	80	158	0	24	1	2.5	30	1	0.284	6.6	0
02/06/1995	6.26	60	29	169	5	47	68	129	0	13	1	2.5	35	7	0.548	11	0
15/07/1995	6.46	140	46	202	6	86	154	138	0	94	1	2.5	12	2	0.343	8.5	0
06/08/1995	6.51	195	40	219	8	86	164	155	1	30	1		15	1	0.417	8.6	0
25/08/1995	6.81	221	49	225	7	99	176	171	0	35	1	2.5	9	0	0.266	6.1	0
04/09/1995	6.22	70	63	239	8	134	208	125	1	302	0	6	14	0	0.239	6.8	0
24/09/1995	5.21	0	35	167	5	66	84	115	0	112	0		37	5	0.494	12	0
11/11/1995	5.91	37	26	139	4	47	72	98	1	37	0	2.5	32	6	0.473	8.7	0
10/01/1996	5.31	0	23	126	6	42	47	96	1	68	0	2.5	35	5	0.305	6.6	2
27/02/1996	5.28	0	28	152	4	51	55	166	1	56			19	8	0.237		0
03/04/1996	6.29	67	36	189	12	62	105	172	1	75	1	2.5	15	0	0.17	4.7	4
02/05/1996	6.06	62	31	159	6	51	83	132	0	44	0	2.5	21	3	0.311	6.5	2
12/06/1996	5.41	13	24	127	2	36	47	103	0	17	3	3	41	2	0.627	12.6	0
04/07/1996	5.83	39	27	144	3	51	77	104	0	32	1	2.5	23	13	0.586	19.8	0
27/07/1996	6.24	124	34	168	4	71	128	122	0	19	2	2.5	20	2	0.52	12.7	0
18/08/1996	6.75	208	41	198	7	89	169	140	1	20	1	2.5	14	1	0.464	9.7	0
07/09/1996	6.13	117	35	174	9	78	130	136	1	16	2	2.5	27	4	0.677	14	0
28/09/1996	6.31	102	42	194	9	78	128	183	1	42	1	2.5	18	1	0.372	9.3	0
30/10/1996	5.53	10	25	118	10	41	53	112	0	20	2		46	8	0.505	10	0
03/12/1996	5.16	-4	46	227	7	72	73	305	2	40	0	2.5	25	1	0.166	3.9	0
28/01/1997	5.95	28	26	142	4	39	58	106	1	43	0	2.5	26	1	0.371	7.4	2
10/03/1997	5.68	14	39	204	6	57	70	241	1	38	0						0
30/04/1997	5.88	31	30	178	5	49	72	168	1	17	0	2.5	27	0	0.37	7.5	0
21/05/1997	5.98	41	27	152	3	43	67	125	0	13	2	2.5	33	0	0.55	11.2	0
05/07/1997	6.12	79	29	166	8	50	87	114	1	14	1	2.5	30	10	0.59	12	6
30/07/1997	6.02	63	28	155	4	58	93	112	0	9	2	2.5	39	0	0.841	17.7	0
19/08/1997	6.5	216	74	229	10	95	380	148	1	233	1	2.5	25	0	0.638	14	0

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
07/09/1997	5.69	23	26	140	4	52	73	116	0	12	2	2.5	59	6	0.766	15	0
05/10/1997	5.76	26	33	158	9	64	86	183	0	14	1	2.5	46	1	0.541	12	0
14/11/1997	5.46	13	28	143	16	51	59	127	0	27	1	2.5	50	3	0.697	16	0
05/01/1998	5.44	3	32	167	5	61	62	214	0	29	0	2.5	25	0	0.195	4	0
05/02/1998	5.64	15	21	110	3	35	45	93	1	27	1	2.5	26	0	0.361	8.2	0
21/03/1998	6.19	54	38	185	6	58	80	208	1	26	0	2.5	9	5	0.135	3.4	0
07/05/1998	5.63	17	27	146	4	43	53	129	0	13	1	2.5	30	5	0.507	10.9	0
20/06/1998	6.46	161	36	194	6	65	119	129	0	20	2	2.5	16	0	0.271	6.9	0
20/07/1998	5.89	45	23	130	1	52	74	77	0	9	2	2.5	46	1	0.773	16.3	0
09/08/1998	6.05	70	26	140	4	62	86	86	0	10	2	2.5	43	3	0.751	16.5	0
29/08/1998	6.33	159	36	172	7	76	129	117	1	15	3	6	24	0	0.437	9	0
27/09/1998	6.43	212	42	189	8	96	169	145	4	17	2	2.5	35	3	0.529	11	2
25/10/1998	5.56	15	23	109	9	43	55	103	0	17	2	2.5	38	0	0.522	9.8	0
25/11/1998	5.46	6	26	136	4	42	52	144	0	22	1	2.5	39	4	0.371	7.9	0
12/02/1999	5.7	8	50	278	7	83	93	363	1	36	0	6	13	2	0.119	3.7	0
25/03/1999	5.56	8	28	167	5	37	42	177	0	20	1	2.5	29	0	0.358	7.9	2
10/05/1999	5.67	20	28	168	6	44	55	153	0	18	3	6	49	1	0.608	14.3	0
17/06/1999	5.84	32	27	164	2	46	60	143	0	7	3	6	47	1	0.613	12.3	0
12/07/1999	6.21	133	36	196	6	87	129	138	1	11	31		50	5	0.93	19.3	0
03/08/1999	6.49	215	46	222	10	100	167	158	4	20	1	6	34	10	0.639	13.3	0
01/09/1999	6.07	61	35	173	5	70	109	157	0	46	0	2.5	18	2	0.431	9.7	0
26/09/1999	5.32	8	18	92	9	33	41	75	0	10	4	6	30	6	0.624	13.7	0
06/11/1999	5.29	1	24	129	10	36	45	134	0	22	0	2.5	22	1	0.354	5.9	0
20/01/2000	6.01	37	28	167	3	47	70	167	0	32	6	6	13	0	0.171	3.9	0
05/03/2000	5.33	2	27	161	5	35	40	171	1	25	1	2.5	19	0	0.19	4.5	0
14/04/2000	6.31	84	34	191	6	54	104	182	1	19	0	2.5	7	3	0.186	4.7	0
31/05/2000	6.16	56	32	193	3	56	84	155	1	30	0	2.5	24	9	0.444	9.6	0
17/06/2000	6.43	90	35	207	5	68	100	177	2	18	0	2.5	15	9	0.347	8.1	0
12/07/2000	6.36	76	33	189	4	67	104	158	1	19	2	6	23	6	0.503	12	0
05/08/2000	6.3	105	38	194	5	73	110	154	2	26	4	6	23	1	0.546	13.6	2
04/09/2000	6.34	128	41	200	7	83	129	182	1	10	0	6	22	9	0.624	13	0
08/10/2000	5.62	20	30	160	13	54	64	171	0	13	1	2.5	37	7	0.628	11.9	0
21/11/2000	6.01	39	25	139	5	42	56	125	1	18	0	6	21	6	0.406	8.3	0
09/01/2001	5.98	32	17	100	4	31	49	69	1	18	0	6	22	2	0.383	7.9	0
08/03/2001	5.58	11	21	109	5	31	40	100	1	39	0	2.5	29	0	0.327		1
26/04/2001	5.96	28	27	147	5	45	65	135	0	28	0	6	21	10	0.414	9.7	2
06/06/2001	6.3	97	31	164	4	53	95	119	0	16	0	6	12	4	0.388	9.2	1
03/07/2001	5.98	62	24	137	3	48	78	84	0	12	0	11	54	0	0.792	15.1	0
23/07/2001	6.22	73	24	135	4	54	78	90	2	11	0	6	35	3	0.69	14.3	2
19/08/2001	6.12	91	27	127	5	64	93	90	1	10	5	6	13	12	0.693	15.5	1
07/10/2001	5.6	16	28	112	15	48	51	137	1	15	2	6	30	0	0.488	11.5	0
14/11/2001	6.31	61	24	119	11	48	76	107	2	17	3	6	16	4	0.361	10	0
10/12/2001	6.28	63	22	114	8	46	72	94	1	21	7	8	12	5	0.338	7.6	0
22/01/2002	5.5	6	17	106	6	28	32	111	0	16	0	6	21	2	0.246	5.9	0
04/04/2002	6	36	40	252	9	58	76	288	1	26	1	2.5	13	0	0.215	4.9	0
07/05/2002	6.38	119	38	227	9	61	104	190	1	20	1	6	10	0	0.24	4.8	0
12/06/2002	5.99	49	23	148	4	46	61	86	0	8	5	11	28	0	0.752	15.9	0
14/07/2002	6.36	137	35	168	5	75	115	115	0	12	10	13	7	10	0.625	14	0
31/07/2002	5.9	56	22	116	4	62	78	67	0	6	6	21	29	8	0.94	20	0
01/09/2002	6.34	110	32	159	6	83	122	138	1	11	1	2.5	23	0	0.669	16.6	0
29/09/2002	6.51	266	45	200	9	96	173	163	2	16	0	19	4	6	0.289	8.5	0
21/10/2002	5.55	12	33	148	23	68	73	199	0	26	3	21	11	8	0.448	12	0
08/12/2002	6.22	61	24	132	6	45	73	102	2	24	1	20	22	3	0.362	8.4	0
26/01/2003	5.36	2	41	198	5	61	61	259	0	35	1	18	17	5	0.176	4.5	0
03/03/2003	5.95	16	35	184	7	47	55	192	1	48	0	6	31	3	0.239	5.3	2
28/04/2003	6.05	44	35	202	6	54	77	193	1	37	0	13	16	4	0.357		3

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
11/06/2003	5.8	38	22	135	1	40	55	81	0	10	3	35	23	1	0.8	14.5	0
21/07/2003	5.86	50	24	132	4	51	77	87	0	18	3	12	20	0	0.674	14.4	2
10/08/2003	6.45	197	39	189	7	102	174	127	1	14	3	11	18	1	0.645	15.7	0
08/09/2003	6.6	221	43	197	7	89	171	156	2	18	2	13	6	0	0.278	8.9	0
27/10/2003	6.32	124	39	196	9	93	181	209	1	22	0	8	2	1	0.117	14.6	5
16/12/2003	6.15	50	21	118	4	39	67	89	0	24	0		15	1	0.33		0

Appendix 4 Water chemistry for the Experimental Burn (Lower site) July 1995 - December 2003

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
15/07/1995	6.63	155	62	210	6	73	276	148	0	206	1	2.5	12	0	0.348	7.7	0
06/08/1995	6.77	220	115	287	11	99	868	154	0	749	2		18	2	0.524	11	0
04/09/1995	6.36	85	67	245	8	110	275	144	0	337	0	11	16	0	0.28	7.6	0
24/09/1995	5.13	-3	33	165	7	64	86	120	0	109	0		33	4	0.514	13	0
11/11/1995	5.76	30	29	139	9	44	82	113	0	55	0	2.5	51	3	0.384	7.4	0
10/01/1996	5.26	-1	22	119	3	39	43	82	1	69	0	2.5	40	2	0.369	8	2
27/02/1996	5.28	-1	28	148	7	48	46	165	0	51			19	12	0.167		0
03/04/1996	6.31	70	50	185	8	59	211	168	1	188	1	2.5	11	0	0.149	4	0
02/05/1996	6.03	63	48	167	6	50	195	134	0	175	0	2.5	18	3	0.299	6.1	0
12/06/1996	4.98	-11	27	128	3	34	41	109	0	21	3	4	36	2	0.7	14.3	0
04/07/1996	5.89	38	34	151	3	50	113	111	0	79	0	2.5	26	6	0.538	15.8	0
27/07/1996	6.15	125	48	184	7	67	209	140	0	111	2	6	18	6	0.488	10.9	3
18/08/1996	6.67	231	75	227	9	90	430	148	0	278	1	2.5	14	1	0.477	10	0
07/09/1996	6.02	125	51	193	12	81	228	147	0	118	3	3.5	41	2	0.75	15.7	0
28/09/1996	6.3	97	49	206	13	75	172	199	2	94	1	2.5	12	1	0.35	9	0
30/10/1996	5.49	13	26	122	15	42	57	113	0	27	0		49	10	0.479	10	0
03/12/1996	5.41	-2	48	230	10	73	77	309	1	50	1	2.5	22	10	0.155	3.6	3
28/01/1997	5.87	24	30	145	5	40	83	114	1	75	0	2.5	24	1	0.328	6.7	2
10/03/1997	5.54	9	44	207	8	59	101	243	1	77	0						0
30/04/1997	5.77	28	35	179	6	48	96	174	1	48	0	2.5	25	1	0.344	7.3	2
21/05/1997	6.11	40	33	154	3	40	107	128	0	65	1	2.5	31	0	0.474	10.2	0
05/07/1997	6.08	75	39	176	8	49	143	127	0	80	1	2.5	21	7	0.502	11	3
30/07/1997	6.02	75	34	169	7	57	124	135	0	38	2	16	29	3	0.731	15.3	3
19/08/1997	6.67	140	38	173	9	67	142	124	1	39	1	2.5	29	0	0.445	9.4	3
07/09/1997	5.72	22	29	149	6	52	81	125	0	28	1	2.5	64	4	0.766	16.4	3
05/10/1997	5.74	31	37	171	12	65	115	194	0	39	0	2.5	36	2	0.519	12	0
14/11/1997	5.55	18	28	144	17	49	63	134	0	29	1	17	43	4	0.613	14	0
05/01/1998	5.44	3	33	170	7	59	67	215	0	36	0	2.5	20	0	0.176	3.7	0
05/02/1998	5.64	14	22	115	5	35	48	100	1	32	1	2.5	28	2	0.323	7.7	0
21/03/1998	6	47	45	210	9	64	142	241	1	95	0	2.5	13	4	0.131	3.3	2
20/06/1998	6.26	144	61	209	6	70	291	132	0	232	1	2.5	4	13	0.27	6.8	0
20/07/1998	5.75	39	26	137	3	50	91	86	0	29	5	6	42	42	0.759	16	0
09/08/1998	5.85	62	31	143	5	63	124	85	0	51	2	2.5	50	2	0.808	17.4	0
29/08/1998	6.21	142	51	178	5	75	235	118	0	145	3	6	31	0	0.47	9.8	0
27/09/1998	6.34	203	65	207	10	99	351	149	2	218	1	2.5	32	2	0.482	10	3
25/10/1998	5.58	14	20	100	5	35	51	89	0	20	2	2.5	57	6	0.496	10.8	0
25/11/1998	5.44	6	27	143	6	42	54	151	0	26	1	2.5	31	4	0.351	7.5	0
12/02/1999	5.47	3	50	255	12	77	84	336	1	36	0	6	15	1	0.082	2.8	0
25/03/1999	5.51	7	28	163	7	36	44	174	0	24	1	2.5	28	4	0.32	7.2	1
10/05/1999	5.75	26	29	168	7	43	63	161	0	30	2	6	40	1	0.474	11.3	0
17/06/1999	5.71	25	29	169	3	46	72	155	0	26	4	6	31	9	0.607	12.9	0
12/07/1999	5.87	111	45	207	9	92	195	150	0	75	3		109	7	1.195	23	0
03/08/1999	6.25	208	81	246	12	111	432	156	1	312	0	2.5	31	3	0.684	14.1	0
01/09/1999	6.29	68	39	175	7	65	133	164	1	67	3	6	19	0	0.38	8.8	0
26/09/1999	4.97	-6	20	88	11	29	32	74	0	10	6	8	30	8	0.691	14.7	0
06/11/1999	5.46	7	24	131	12	38	47	137	1	23	0	6	34	5	0.352	7	0
20/01/2000	5.99	36	35	168	4	48	110	171	2	71	1	6	11	2	0.149	3.6	0
05/03/2000	6.39	3	27	158	6	34	40	171	0	27	0	2.5	22	0	0.161	4.2	0
14/04/2000	6.38	90	48	200	6	55	205	184	1	128	0	2.5	7	3	0.191	4.6	0
31/05/2000	6.11	57	37	200	4	58	127	165	1	78	0	2.5	22	13	0.31	6.9	0
17/06/2000	6.2	80	46	217	6	70	185	186	1	105	1	2.5	31	1	0.356	8.6	0
12/07/2000	6.37	76	41	200	6	69	170	169	1	86	0	6	15	9	0.468	10.3	0

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
05/08/2000	6.23	117	52	215	8	75	201	178	1	114	1	6	24	6	0.535	13.4	2
04/09/2000	6.27	132	54	217	9	83	228	189	1	114	0	6	31	2	0.64	14	2
08/10/2000	5.63	20	31	161	17	52	63	170	0	18	1	2.5	52	1	0.58	9.2	0
21/11/2000	5.93	38	28	142	7	43	77	130	1	37	0	6	24	2	0.374	8	0
09/01/2001	5.95	31	21	103	6	34	71	76	1	41	0	6	37	2	0.347	7.8	0
08/03/2001	5.61	10	22	107	6	30	42	100	1	39	0	6	21	2	0.235	5	1
26/04/2001	5.95	30	31	149	6	45	88	137	1	51	0	2.5	21	8	0.421	9.6	0
06/06/2001	6.31	117	47	199	9	62	218	140	1	133	0	6	22	0	0.4	10.4	5
03/07/2001	5.95	62	27	137	4	47	101	83	1	41	4	6	42	16	0.791	15	0
23/07/2001	6.26	84	22	144	5	54	112	96	2	41	0	6	16	7	0.632	14.1	3
19/08/2001	6.04	88	33	126	6	65	137	90	1	52	5	6	15	12	0.73	17.9	1
07/10/2001	5.6	19	26	117	15	48	58	130	1	19	3	6	31	6	0.49	10.5	2
14/11/2001	6.37	51	26	114	11	44	95	103	2	46	2	2.5	19	1	0.334	8.6	0
10/12/2001	6.21	60	26	119	8	43	106	97	1	61	3	6	13	0	0.338	7.3	0
22/01/2002	5.71	11	19	112	7	29	37	117	0	18	0	2.5	21	0	0.227	5.4	0
04/04/2002	5.96	34	46	249	10	60	115	282	1	73	1	2.5	14	0	0.185	4.4	0
07/05/2002	6.37	113	60	239	10	65	263	193	2	199	1	6	10	0	0.234	5.6	0
12/06/2002	5.89	42	24	145	4	43	71	93	0	23	4	6	30	0	0.712	15.2	0
14/07/2002	6.23	108	40	168	5	67	169	120	0	81	3	12	11	11	0.598	12.7	0
31/07/2002	5.65	40	22	117	5	57	72	69	0	13	6	22	50	6	0.949		0
01/09/2002	6.19	90	34	160	7	77	144	143	0	50	5	6	28	5	0.663	15.8	0
29/09/2002	6.31	179	61	201	11	90	367	153	1	181	2	22	16	8	0.362	9.1	0
21/10/2002	5.78	13	30	141	21	59	69	181	0	30	2	21	20	1	0.329	8.8	0
08/12/2002	6.09	54	29	137	8	42	102	112	1	57	1	24	22	1	0.326	7.6	0
26/01/2003	5.4	3	41	202	8	61	70	254	0	39	0	18	24	4	0.165	4.2	0
03/03/2003	5.7	15	37	187	9	48	65	200	0	63	1	6	20	3	0.2	5.2	2
28/04/2003	6.16	57	40	201	7	56	120	195	1	67	0	13	14	0	0.324		0
11/06/2003	5.68	33	23	126	2	38	60	88	0	20	7	16	26	9	0.733	13.5	0
21/07/2003	5.81	47	26	131	4	51	94	94	0	36	2	9	26	9	0.643	14.4	2
10/08/2003	5.99	156	49	198	8	98	259	135	2	117	4	12	101	16	1.215	22.2	2
08/09/2003	6.21	146	57	196	8	80	268	157	0	178	1	13	19	7	0.373	9.8	0
27/10/2003	6.08	95	48	195	9	78	269	204	1	126	0	8	3	10	0.115	22.5	0
16/12/2003	6.21	44	25	121	6	37	99	95	0	58	0		19	0	0.305		0

Appendix 5 Water chemistry for the Allt Riabhach na Bioraich (Lower site) June 1995 - December 2003

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
02/06/1995	6.15	42	25	137	5	41	68	109	1	26	0	2.5	53	0	0.431	8.8	0
15/07/1995	6.35	68	41	175	9	76	128	121	9	104	0	2.5	30	8	0.436	11	0
06/08/1995	6.8	122	38	207	13	65	142	148	2	80	1		15	3	0.287	6.6	0
04/09/1995	6.19	44	43	182	9	84	132	118	0	156	0	6	39	0	0.347	8.5	0
24/09/1995	5.41	7	28	150	6	63	85	107	1	96	0		66	8	0.517	13	0
11/11/1995	6.03	44	26	130	6	47	81	94	1	43	1	2.5	65	0	0.411	7.9	0
27/02/1996	5.68	17	30	155	5	55	74	166	2	64			29	1	0.213		1
03/04/1996	6.07	35	33	153	12	59	100	135	8	88	0	2.5	29	2	0.194	4.6	6
02/05/1996	5.98	67	31	139	6	48	98	115	0	60	0	2.5	32	2	0.241	4.8	0
12/06/1996	5.52	14	23	115	3	37	51	91	0	23	3	4	40	29	0.563	6.7	0
04/07/1996	5.92	35	27	130	4	49	85	96	0	46	0	2.5	47	14	0.553	23	0
27/07/1996	6.36	75	29	140	5	57	117	100	1	34	1	2.5	42	4	0.532	10.7	0
18/08/1996	6.69	141	35	158	7	62	144	108	2	39	2	2.5	24	2	0.398	8	0
07/09/1996	6.34	117	34	162	11	65	137	117	1	40	2	2.5	35	4	0.485	10.2	0
28/09/1996	6.21	53	37	169	10	74	120	174	3	57	1	2.5	46	9	0.484	10.9	0
30/10/1996	5.61	15	21	97	7	36	53	80	1	22	1		90	7	0.525	10	0
03/12/1996	5.26	0	44	218	8	71	75	293	2	42	0	2.5	35	7	0.16	3.7	0
28/01/1997	6.09	37	27	129	6	41	73	104	4	49	4	6	45	0	0.305	6	2
10/03/1997	5.64	18	38	184	9	56	77	218	3	46	1						0
30/04/1997	5.92	31	29	154	5	48	79	149	1	27	0	2.5	43	1	0.382	7.8	0
21/05/1997	6.09	41	26	144	5	45	76	120	0	25	1	2.5	52	7	0.501	10.4	4
05/07/1997	6.23	70	30	148	7	51	97	108	0	35	1	2.5	55	0	0.48	9.9	3
30/07/1997	6.18	57	27	136	5	54	97	104	0	27	1	2.5	70	8	0.769	15.7	0
19/08/1997	6.63	104	33	163	8	60	112	120	1	22	1	2.5	32	0	0.478	9.8	0
07/09/1997	5.68	20	25	125	4	47	71	103	0	20	2	2.5	89	10	0.74	14.5	0
05/10/1997	5.75	21	29	143	7	57	84	145	0	24	0	2.5	82	5	0.644	14	0
14/11/1997	6.02	42	26	139	8	50	76	114	2	30	1	2.5	57	5	0.561	12	0
05/01/1998	5.46	6	28	146	6	49	55	168	2	31	0	2.5	31	0	0.209	3.9	1
05/02/1998	5.72	15	21	115	7	36	53	102	3	30	1	2.5	47	1	0.346	8.2	3
21/03/1998	6.05	43	34	171	8	50	77	183	1	40	0	2.5	24	2	0.149	3.8	2
20/06/1998	6.48	148	39	180	9	60	138	120	0	62	1	2.5	23	0	0.228	5.7	0
20/07/1998	5.94	46	24	129	4	48	77	81	0	18	1	2.5	85	3	0.735	15.2	0
09/08/1998	5.89	37	22	123	4	44	71	82	0	20	1	2.5	55	9	0.634	12.5	0
29/08/1998	6.36	120	31	156	8	51	106	101	0	34	1	2.5	27	1	0.35	7.1	0
27/09/1998	6.52	163	35	159	8	66	159	109	1	51	1	2.5	21	0	0.312	6.8	0
25/10/1998	5.49	14	24	109	12	43	51	107	0	20	2	2.5	49	12	0.513	10.3	0
25/11/1998	5.56	8	26	134	5	40	55	145	1	26	1	2.5	45	4	0.318	6.7	0
12/02/1999	5.8	16	43	238	8	69	89	299	2	38	1	2.5	16	0	0.098	2.8	0
25/03/1999	5.56	7	26	142	6	35	42	158	1	23	1	2.5	39	0	0.274	6.2	0
10/05/1999	5.89	27	27	149	9	45	68	139	0	28	3	6	51	0	0.558	12	0
17/06/1999	5.74	23	25	142	2	42	61	129	0	14	2	2.5	52	20	0.617	12.9	0
12/07/1999	6.2	82	29	168	7	57	105	124	0	27	0		82	2	0.752	15.3	0
03/08/1999	6.56	110	36	179	9	59	138	145	2	51	0	6	24	0	0.372	7.7	0
01/09/1999	5.83	30	28	136	5	54	78	110	0	40	2	2.5	61	10	0.647	13	0
26/09/1999	5.5	20	21	108	5	36	52	88	0	21	3	6	68	5	0.563	10.6	0
06/11/1999	5.02	-6	23	110	6	35	31	119	0	22	1	2.5	18	2	0.303	7.9	0
20/01/2000	5.86	27	26	140	4	40	71	140	2	33	1	2.5	31	2	0.19	4.1	0
05/03/2000	5.47	6	28	163	4	39	52	182	1	29	0	2.5	24	2	0.188	4.4	0
14/04/2000	5.47	2	31	188	3	43	57	215	1	27	0	2.5	10	5	0.108	2.4	0
31/05/2000	6.31	55	31	174	5	57	95	145	0	47	0	2.5	34	15	0.364	8	0
17/06/2000	6.27	61	35	187	6	61	100	179	1	40	0	2.5	34	3	0.269	6.4	0
12/07/2000	6.33	62	30	163	5	59	109	139	0	31	0	6	29	12	0.397	8.5	0

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
05/08/2000	6.48	80	34	174	6	58	104	143	1	45	0	6	26	3	0.389	9.3	3
04/09/2000	6.59	97	35	169	6	62	118	152	0	27	0	6	24	4	0.439	9.8	0
08/10/2000	5.47	14	28	144	6	46	62	146	0	20	2	6	83	9	0.636	10.7	0
21/11/2000	5.92	34	24	127	4	40	66	117	1	25	0	6	40	3	0.414	8.3	0
09/01/2001	5.92	28	18	97	4	31	55	73	1	25	0	6	47	0	0.372	8.2	0
08/03/2001	5.51	6	22	98	8	32	41	97	7	36	0	6	21	8	0.222	5	2
26/04/2001	6.03	38	28	141	9	43	76	123	2	37	0	2.5	35	11	0.47	10	3
06/06/2001	6.45	91	30	151	6	53	98	108	0	36	4	6	23	4	0.371	8.3	2
03/07/2001	5.95	45	23	125	3	43	77	79	1	22	2	2.5	95	14	0.788	14.4	1
23/07/2001	6.32	66	24	126	4	47	80	86	1	20	0	5	46	2	0.563	11.6	2
19/08/2001	6.06	35	21	108	3	35	64	82	2	23	3	6	24	15	0.474	11.2	1
07/10/2001	5.3	5	24	99	10	40	46	107	2	18	3	6	51	6	0.541	11.5	0
14/11/2001	6.04	15	22	108	8	39	67	88	2	25	5	6	34	4	0.379	8.5	0
10/12/2001	6.07	44	20	109	8	39	68	86	2	29	3	6	22	9	0.371	8	0
22/01/2002	4.59	-24	25	101	5	22	15	112	0	17	2	6	15	0	0.314	7.2	0
04/04/2002	6.01	36	32	191	10	47	68	200	4	36	1	2.5	18	5	0.237	5.1	3
07/05/2002	6.27	50	38	215	8	54	91	217	0	42	0	6	9	0	0.176	4.3	0
12/06/2002	5.8	34	21	123	5	38	60	79	0	15	2	6	63	2	0.772	15.1	0
14/07/2002	6.31	88	29	142	6	54	104	98	0	22	3	19	32	9	0.61	12.7	0
31/07/2002	5.53	21	19	97	4	39	53	55	1	10	4	18	57	22	0.928		0
01/09/2002	6.17	67	29	153	9	62	103	121	0	21	0	2.5	40	3	0.673	16.7	0
29/09/2002	6.6	198	44	180	13	80	184	133	1	45	0	20	8	3	0.275	7	4
21/10/2002	6.24	60	32	155	17	64	95	163	1	31	3	25	12	6	0.376	9.1	0
08/12/2002	6.19	54	26	133	8	44	83	110	2	37	1	23	16	12	0.365	8.3	0
26/01/2003	5.25	-1	42	197	9	66	64	273	0	36	0	19	28	4	0.189	4.6	0
03/03/2003	5.84	15	30	155	9	43	55	161	2	45	0	5	38	5	0.27	6	2
28/04/2003	6.2	48	36	189	9	63	98	183	0	57	0	12	31	6	0.375		3
11/06/2003	5.75	32	23	120	3	43	66	89	0	14	3	14	47	15	0.831	15.9	0
24/07/2003	5.56	24	22	108	5	37	57	79	0	25	2	12	52	19	0.6	12.9	0
10/08/2003	6.33	129	37	169	10	69	166	120	1	59	1	9	39	76	0.473	15	0
08/09/2003	6.62	149	38	174	11	70	159	137	0	51	4	11	11	2	0.276	14.4	0
27/10/2003	6.35	125	35	170	11	88	187	160	0	38	0	8	7	2	0.178	22	0
16/12/2003	6	38	21	112	8	38	64	95	1	29	0		34	2	0.326		0

Appendix 6 Water chemistry for the Allt Riabhach na Bioraich (Upper site) June 1995 - December 2003

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
02/06/1995	6.17	38	23	139	7	39	60	105	0	20	0	2.5	49	2	0.457	9.4	0
15/07/1995	6.56	63	40	174	9	77	125	119	8	107	1	2.5	33	1	0.446	11	0
06/08/1995	6.59	84	30	186	10	53	108	137	6	43	1		53	1	0.488	9	0
04/09/1995	6.22	35	41	177	6	82	127	112	1	158	0	6	40	2	0.348	8.4	0
24/09/1995	5.56	9	28	146	5	62	86	105	1	94	0		60	8	0.488	11	0
11/11/1995	6.06	37	23	124	5	45	71	92	1	39	0	2.5	59	0	0.392	7.9	0
10/01/1996	5.42	3	20	106	5	39	49	83	2	60	3	4	44	5	0.301	6.7	4
27/02/1996	5.71	13	29	152	5	53	68	159	2	58			30	2	0.196		0
03/04/1996	6.02	23	31	145	8	58	88	127	7	82	0	2.5	27	4	0.193	4.3	0
02/05/1996	6.04	40	27	134	6	44	72	111	0	48	0	2.5	33	11	0.236	4.8	0
12/06/1996	5.55	16	22	112	2	36	52	89	0	23	3	4	59	8	0.546	11.1	0
04/07/1996	5.99	32	26	130	4	50	79	94	0	42	0	2.5	54	4	0.533	17.5	0
27/07/1996	6.3	67	27	134	6	56	103	100	0	30	1	2.5	39	7	0.528	11	0
18/08/1996	6.67	114	30	154	6	63	117	108	2	26	2	2.5	27	1	0.412	8.1	0
07/09/1996	6.48	88	29	148	10	60	110	113	1	24	0	2.5	32	6	0.487	10.1	0
28/09/1996	6.2	45	37	167	10	73	116	165	3	57	1	2.5	43	2	0.504	11.2	0
30/10/1996	5.62	14	20	97	6	36	53	80	1	21	1		70	4	0.514	10	0
03/12/1996	5.28	-1	43	218	7	69	75	290	2	40	1	2.5	36	6	0.16	4	2
28/01/1997	6.06	28	25	125	5	41	64	101	4	44	6	6	41	0	0.293	5.9	2
10/03/1997	5.63	7	36	182	8	53	66	218	2	39							0
30/04/1997	5.99	27	28	153	5	47	71	145	0	23	0	2.5	44	1	0.39	7.8	0
21/05/1997	6.2	37	25	137	3	43	70	115	0	20	1	2.5	51	13	0.48	10.1	0
05/07/1997	6.28	58	27	141	4	49	82	105	0	27	1	2.5	50	1	0.46	9.6	0
30/07/1997	6.19	49	29	137	5	55	97	101	0	19	1	2.5	67	6	0.83	16.9	0
19/08/1997	6.51	202	46	199	8	98	175	138	2	17	1	2.5	27	5	0.688	15	0
07/09/1997	5.76	21	25	125	4	46	68	104	0	18	1	2.5	90	28	0.714	14.1	0
05/10/1997	5.81	21	29	140	7	56	81	144	1	22	0	2.5	85	4	0.64	13	0
14/11/1997	6.06	36	24	134	9	47	72	110	2	27	1	2.5	64	8	0.561	12	1
05/01/1998	5.67	8	26	145	6	47	55	164	2	31	1	2.5	34	1	0.209	3.8	0
05/02/1998	5.75	14	21	103	5	33	48	93	2	27	1	2.5	47	0	0.333	7.6	0
21/03/1998	6.02	31	32	164	7	46	60	176	1	30	1	2.5	23	1	0.144	3.4	0
07/05/1998	5.76	19	24	127	4	39	55	108	0	16	1	2.5	43	8	0.501	10.1	0
20/06/1998	6.52	101	32	166	8	53	86	115	1	33	1	2.5	13	6	0.238	5.8	0
20/07/1998	6.08	43	23	125	4	47	71	78	0	15	1	2.5	67	3	0.709	14.1	0
09/08/1998	6.01	39	20	118	3	42	64	72	0	14	1	2.5	58	17	0.648	12.6	0
29/08/1998	6.46	83	25	137	5	38	514	90	0	21	1	2.5	12	27	0.38	7.1	0
27/09/1998	6.68	130	29	150	8	60	110	104	0	21	5	6	24	3	0.326	6.8	0
25/10/1998	5.69	15	20	100	6	36	51	89	0	19	3	6	52	6	0.473	10.5	0
25/11/1998	5.54	6	26	138	5	42	54	153	1	26	0	2.5	51	3	0.31	6.7	0
12/02/1999	5.67	6	45	248	7	71	82	315	2	38	0	2.5	18	2	0.099	3.1	0
25/03/1999	5.62	8	25	144	7	35	40	160	0	22	1	2.5	37	1	0.263	6	0
10/05/1999	5.84	24	28	149	8	45	64	136	0	25	3	10	51	0	0.566	12.5	0
17/06/1999	5.95	17	29	178	6	39	55	191	1	25	1	2.5	19	3	0.242	5.3	0
12/07/1999	6.24	63	26	157	5	51	84	119	0	15	0		64	13	0.729	14.6	0
03/08/1999	6.46	85	30	167	8	54	98	137	0	23	0	2.5	32	6	0.438	8.5	0
01/09/1999	5.8	28	27	135	4	55	85	108	0	39	4	6	75	2	0.665	14	0
26/09/1999	5.59	15	19	100	5	34	47	82	0	15	8	1	50	6	0.577	11.1	0
06/11/1999	5.22	-2	22	112	6	31	35	117	1	21	0	6	44	0	0.328	7.3	0
20/01/2000	5.93	19	25	138	4	38	53	145	2	27	1	2.5	28	1	0.19	4.3	0
05/03/2000	5.54	5	28	165	4	40	50	185	1	27	0	2.5	27	2	0.173	4	0
14/04/2000	6.34	54	29	159	6	49	87	158	0	23	0	6	21	3	0.207	4.7	0
31/05/2000	6.28	48	30	168	5	58	88	142	0	46	0	2.5	47	2	0.389	8.5	0

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
17/06/2000	6.45	44	31	179	4	54	82	171	1	28	0	2.5	36	0	0.276	6.1	0
12/07/2000	6.33	46	28	158	4	55	96	139	1	24	0	6	37	0	0.402	8.4	0
05/08/2000	6.38	60	31	173	6	55	89	145	1	37	1	6	33	6	0.44	11.9	2
04/09/2000	6.51	79	32	162	5	58	99	149	0	17	0	6	28	6	0.466	11	0
08/10/2000	5.57	15	27	139	6	46	62	144	0	18	1	2.5	67	2	0.626	10.4	0
21/11/2000	6.05	30	23	128	4	39	62	117	1	20	0	6	36	0	0.399	8.1	0
09/01/2001	5.97	23	18	100	4	30	51	75	1	22	0	6	49	2	0.371	8.6	0
08/03/2001	5.47	4	22	98	8	32	40	100	7	36	0	10	20	8	0.2	4.5	2
26/04/2001	5.99	30	25	133	6	43	98	116	2	33	0	2.5	25	20	0.447	9.5	0
06/06/2001	6.38	71	27	144	5	48	83	103	0	30	2	2.5	19	14	0.416	8.8	1
03/07/2001	6.07	45	22	121	3	42	73	76	0	19	32	35	96	5	0.852	14.8	0
23/07/2001	6.29	58	22	119	4	47	75	77	2	17	0	2.5	43	0	0.641	12.4	1
19/08/2001	6.1	44	20	102	3	40	66	63	1	14	2	6	40	22	0.686	13.6	0
07/10/2001	5.44	9	23	99	9	39	46	106	1	18	2	6	37	14	0.539	11	0
14/11/2001	6.31	39	20	106	7	36	63	86	2	20	5	6	38	0	0.374	8.7	0
10/12/2001	6.22	46	20	110	7	38	63	85	1	24	15	20	28	0	0.343	6.9	0
22/01/2002	5.32	0	17	98	7	24	31	103	0	16	0	6	26	4	0.259	5.9	0
04/04/2002	6.02	27	30	190	10	46	60	199	3	33	0	2.5	21	14	0.265	5.6	4
07/05/2002	6.36	59	30	179	8	44	71	155	0	23	0	6	11	3	0.233	5	0
12/06/2002	5.85	32	21	124	4	38	56	78	0	12	3	12	52	11	0.741	14.7	0
14/07/2002	6.33	70	26	141	5	49	82	100	0	13	3	14	26	13	0.618	13.7	0
31/07/2002	5.63	23	18	99	4	39	55	55	0	10	5	18	70	12	0.893		0
01/09/2002	6.23	59	25	142	6	59	94	115	0	15	0	6	43	2	0.664	15.7	0
29/09/2002	6.91	152	36	165	9	73	131	130	0	18	0	16	19	0	0.313	7.4	0
21/10/2002	6.35	54	32	154	20	63	91	169	0	27	2	28	16	2	0.316		0
08/12/2002	6.27	52	24	130	8	46	75	103	3	30	2	20	27	1	0.382	8.3	0
28/01/2003	5.23	-2	41	202	9	64	64	274	1	36	0	18	30	11	0.183	2.7	0
03/03/2003	5.82	13	29	153	9	42	51	158	2	43	0	6	17	18	0.265	6.6	2
28/04/2003	6.26	41	35	187	8	61	91	181	0	55	0	14	33	2	0.379		3
11/06/2003	5.81	31	22	119	2	43	64	89	0	14	2	25	57	5	0.813	15.6	0
21/07/2003	5.61	21	21	114	6	38	67	83	0	27	0	14	58	12	0.6	13.3	0
10/08/2003	6.3	83	28	156	8	58	96	114	0	19	1	12	50	1	0.582	14.3	0
08/09/2003	6.57	119	32	158	8	64	109	127	0	21	1	13	15	2	0.288	9.6	0
27/10/2003	6.45	99	31	164	11	85	146	156	1	22	0	8	8	2	0.187	24.4	0
16/12/2003	6.22	36	20	113	7	36	59	95	0	25	0		31	1	0.288		0

Appendix 7 Water chemistry for the Loch Laidon outflow September 1995 - December 2003

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
24/09/1995	6.15	24	24	150	4	39	69	136	2	43	1		20	0	0.225	7.1	0
11/11/1995	5.71	14	23	118	6	37	60	101	2	35	2	2.5	38	2	0.331	6.2	0
10/01/1996	5.57	7	18	102	5	32	49	86	3	38	0	2.5	35	0	0.303	6.4	2
27/02/1996	5.66	14	22	120	5	38	62	105	4	47			29	1	0.271		3
03/04/1996	6.08	35	32	148	8	61	99	129	6	91	0	2.5	31	3	0.209	4.7	1
02/05/1996	5.83	16	26	129	5	41	68	117	5	52	0	2.5	19	2		4.5	1
12/06/1996	5.75	16	27	132	5	41	68	117	3	47	3	4	32	3	0.271	6.1	2
27/07/1996	6.19	21	26	130	4	44	83	116	4	48	0	2.5	33	1	0.218	5	0
18/08/1996	6.27	27	25	130	5	44	87	115	4	47	0	2.5	14	0	0.214	5.2	3
07/09/1996	6.2	28	26	134	6	46	93	116	4	48	0	2.5	13	3	0.21	4.7	2
28/09/1996	6.25	26	27	137	5	44	76	121	4	50	0	2.5	20	1	0.231	5.2	0
30/10/1996	5.81	17	27	133	5	44	67	120	2	42	1		52	2	0.382	7.8	0
03/12/1996	5.52	6	28	145	7	44	53	160	2	34	1	6	30	7	0.269	5.9	0
28/01/1997	5.78	15	26	125	5	40	58	135	5	31	0	2.5	15	1	0.173	3.8	2
10/03/1997	5.51	2	32	171	5	45	55	196	2	34							0
30/04/1997	5.79	8	33	177	6	45	55	199	1	33	0	2.5	15	8	0.152	3.3	0
21/05/1997	5.54	3	30	167	6	42	51	188	2	31	1	2.5	22	0	0.174	4.2	5
05/07/1997	5.84	16	30	159	6	41	58	170	2	31	0		21	1	0.202	4.3	7
30/07/1997	6	15	29	159	6	41	61	162	2	32	9	10	16	5	0.197	4.8	0
19/08/1997	6.22	24	29	155	5	42	72	154	2	31	0	2.5	14	1	0.209	4.9	2
07/09/1997	6.08	20	29	155	5	42	69	153	2	31	1	2.5	27	1	0.263	5.9	0
05/10/1997	5.99	18	27	141	5	44	73	134	2	27	1	2.5	35	2	0.362	8.1	0
14/11/1997	6.31	26	25	137	7	39	63	128	3	28	1	2.5	22	3	0.323	7.2	2
05/01/1998	5.83	17	23	126	6	38	57	116	3	34	1	17	39	1	0.325	6	0
05/02/1998	5.75	13	23	119	5	34	50	116	2	28	1	2.5	43	1	0.249	5.7	0
21/03/1998	5.85	15	23	131	5	34	49	128	2	31	1	2.5	27	2	0.197	4.7	0
20/06/1998	5.9	15	27	156	9	41	56	161	2	29	1	2.5	18	3	0.168	4.1	0
20/07/1998	6.15	23	28	153	5	43	63	148	1	29	1	2.5	19	6	0.243	5.4	0
09/08/1998	6.06	26	26	142	4	41	62	126	3	28	0	2.5	29	2	0.293	7	0
29/08/1998	6.07	22	24	125	3	36	57	115	1	25	1	2.5	20	3	0.344	7	0
27/09/1998	6.08	28	22	122	4	38	69	105	2	24	1	2.5	26	1	0.373	7.7	0
25/10/1998	5.94	21	24	126	4	39	63	116	2	28	3	6	30	2	0.377	9.7	0
25/11/1998	5.63	10	28	147	5	43	60	165	1	29	1	2.5	34	5	0.285	6.6	0
12/02/1999	5.89	20	32	176	5	47	68	200	2	31	0	6	13	2	0.098	2.8	0
25/03/1999	5.48	2	36	203	5	45	47	243	1	31	1	6	28	1	0.149	3.9	0
10/05/1999	5.88	14	26	168	5	37	50	188	1	27	1	2.5	20	1	0.169	3.8	0
17/06/1999	5.81	23	24	142	3	42	58	130	0	12	2	6	49	12	0.579	11.7	0
12/07/1999	5.95	16	27	166	5	38	54	171	1	25	0		15	0	0.257	6.6	0
03/08/1999	6.09	19	26	153	4	38	59	156	1	24	0	2.5	18	0	0.255	5.8	0
01/09/1999	5.84	20	27	150	4	37	57	144	1	24	2	6	25	1	0.267	5.2	0
26/09/1999	5.99	23	25	133	4	37	64	132	3	27	2	2.5	23	0	0.34	7.2	0
06/11/1999	5.93	18	25	139	5	41	66	143	2	27	1	2.5	27	0	0.317	7	0
20/01/2000	5.65	8	27	155	3	40	56	174	2	30	2	6	17	2	0.127	3.3	0
05/03/2000	5.3	-1	39	225	5	55	55	272	1	34	1	2.5	23	5	0.102	2.9	0
14/04/2000	5.65	6	32	194	6	43	58	220	1	28	0	6	9	0	0.1	2.5	0
31/05/2000	5.88	10	30	179	5	48	66	206	1	28	0	2.5	22	4	0.114	2.6	0
17/06/2000	5.97	16	31	191	6	45	65	199	1	29	0	2.5	18	4	0.137	3.6	0
12/07/2000	5.97	15	30	178	4	43	57	186	1	29	0	6	9	5	0.357	4.2	0
05/08/2000	6.07	17	30	174	5	38	52	186	2	29	0	2.5	14	0	0.16	4.4	2
04/09/2000	6.11	22	31	168	4	38	60	186	1	30	0	2.5	7	0	0.17	4.4	0
08/10/2000	6.04	23	30	171	5	43	67	175	1	27	1	2.5	31	0	0.332	6.1	0

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
21/11/2000	5.93	22	25	135	5	36	61	134	2	22	0	17	27	0	0.312	6.3	0
09/01/2001	5.87	23	22	118	5	33	59	110	3	27	0	6	28	2	0.221	5.5	0
08/03/2001	5.67	10	20	100	5	26	41	99	8	26	0	11	13	2	0.23	4.6	3
26/04/2001	5.96	18	22	116	4	28	53	114	3	29	0	2.5	15	0	0.206	5	2
06/06/2001	5.97	19	23	126	5	29	51	115	3	31	2	6	15	2	0.207	5.2	4
03/07/2001	6.31	34	24	131	7	31	66	119	3	32	2	14	18	1	0.273	5.4	4
23/07/2001	6.27	32	24	143	15	32	60	129	5	31	0	2.5	12	0	0.277	7.1	7
19/08/2001	6	27	22	112	3	31	58	95	3	27	1	6	24	0	0.349	7.8	1
07/10/2001	6.05	27	24	115	5	34	57	107	4	28	3	10	26	3	0.379	8.7	0
14/11/2001	6.15	33	21	104	6	31	70	97	3	22	1	2.5	17	3	0.325	7.3	1
10/12/2001	5.96	28	20	107	8	32	59	101	2	23	3	6	22	2	0.3	6.5	0
22/01/2002	5.64	10	21	129	8	32	46	130	2	28	5	6	27	1	0.287	6.4	0
04/04/2002	5.78	11	39	233	7	55	64	284	1	37	0	2.5	5	6	0.095	2.8	0
07/05/2002	5.97	15	41	247	8	55	69	280	1	36	0	6	8	0	0.101	2.9	0
12/06/2002	5.87	15	34	202	6	48	60	209	0	29	1	11	17	4	0.251	6.7	0
14/07/2002	6.04	20	31	179	6	45	79	180	1	27	2	6	11	6	0.299	6.9	0
31/07/2002	5.92	20	28	172	5	40	56	164	1	25	1	11	15	9	0.318		0
01/09/2002	6.05	24	25	161	5	42	64	146	1	25	0	2.5	17	0	0.352	8.4	0
29/09/2002	6.03	29	26	157	6	43	74	145	2	25	0	6	9	9	0.365	8.3	0
21/10/2002	6.27	33	26	147	5	43	74	139	2	27	3	25	19	3	0.362	7.7	1
08/12/2002	5.98	23	25	138	6	39	62	132	3	30	1	20	21	6	0.356	8.7	4
26/01/2003	5.83	15	30	157	7	48	66	171	3	33	1	20	24	2	0.184	6.2	0
03/03/2003	5.83	12	30	154	6	42	51	177	3	31	1	8	17	1	0.217	5.4	3
28/04/2003	5.92	13	29	160	6	42	52	182	2	32	1	12	11	2	0.171		4
11/06/2003	5.96	19	27	151	7	38	53	153	1	30	1	12	16	0	0.288	6.2	3
21/07/2003	5.94	25	26	144	7	37	62	141	1	30	1	7	10	4	0.276	7.5	3
10/08/2003	6.15	21	24	139	5	38	60	135	2	29	0	6	24	6	0.27	10.8	1
08/09/2003	6.28	30	26	138	7	39	69	134	2	30	0	12	12	0	0.272	13.1	2
27/10/2003	6.13	36	25	137	7	52	101	135	2	29	0	9	12	1	0.279	24.5	0
16/12/2003	5.91	20	27	150	6	43	68	151	2	34	0		29	2	0.3		0

Appendix 8 Water chemistry for the recently planted forest site September 2000 - December 2003

Date	pH	Alk	Cond	Na	K	Mg	Ca	Cl	NO3	SO4	PO4-P	Total P	Al-NL	Al-L	Abs-250	TOC	NH4
04/09/2000	7.27	330	58	196	12	71	295	157	2	45	0	2.5	5	33	0.068	2.4	0
08/10/2000	5.89	22	28	160	5	46	56	173	0	14	0	2.5	39	8	0.227	6.3	0
21/11/2000	5.72	19	22	124	3	35	46	115	0	18	0	12	58	0	0.437	8.1	0
09/01/2001	5.73	16	16	87	3	24	38	60	1	19	0	17	51	3	0.374	7.9	0
08/03/2001	5.61	9	21	98	6	31	43	95	0	36	0	6	29	0	0.3	6.2	0
26/04/2001	5.79	19	25	143	5	40	57	127	0	32	0	2.5	59	2	0.385	8.8	4
06/06/2001	5.92	41	24	140	2	40	59	101	0	19	3	6	42	14	0.397	8.9	2
03/07/2001	5.74	37	20	113	1	39	63	64	0	12	2	6	108	0	0.752	15.2	0
23/07/2001	5.89	38	20	107	2	43	64	70	2	10	0	6	73	4	0.732	14.8	1
19/08/2001	5.77	47	20	106	3	48	73	69	1	10	14	16	42	34	0.771	17.9	0
07/10/2001	5.4	9	24	102	8	41	52	115	1	15	2	2.5	52	5	0.535	10.9	0
14/11/2001	5.91	30	19	96	6	35	60	80	1	17	2	2.5	31	6	0.408	9.4	0
10/12/2001	6	35	19	102	5	34	55	77	1	19	4	6	32	8	0.4	8.3	0
22/01/2002	5.52	5	17	101	5	27	36	106	0	16	0	2.5	22	1	0.263	6	0
04/04/2002	5.48	9	36	229	8	47	58	255	1	31	0	2.5	14	17	0.224	5.3	0
07/05/2002	5.76	39	33	210	10	43	58	189	0	16	2	6	26	10	0.316	7.3	0
12/06/2002	5.7	29	26	131	3	40	54	80	0	10	2	6	64	10	0.758		0
14/07/2002	5.93	71	27	145	4	54	80	99	0	10	4	16	36	19	0.646	14.8	0
31/07/2002	5.67	31	19	95	2	45	65	52	0	8	4	18	58	15	0.856		0
01/09/2002	6.06	75	25	139	3	65	97	118	0	12	0	2.5	41	7	0.619	14.1	0
29/09/2002	6	111	30	152	3	77	94	132	0	12	1	6	8	51	0.385	9.7	0
21/10/2002	6.1	27	30	146	10	57	81	163	0	26	2	26	27	15	0.283	7.9	2
08/12/2002	5.97	36	22	122	5	38	60	97	1	27	1	24	35	6	0.371	8.9	0
26/01/2003	5.42	4	41	206	6	66	77	272	0	35	0	17	22	5	0.18	4.6	0
03/03/2003	5.66	10	32	171	7	43	51	180	0	45	0	7	38	1	0.232	5.2	2
28/04/2003	5.74	19	33	184	4	50	65	189	0	44	0	13	27	5	0.257		4
11/06/2003	5.7	28	21	119	1	37	53	81	0	9	2	14	48	15	0.668	12.7	0
21/07/2003	5.68	29	18	97	2	37	57	64	0	16	5	10	30	16	0.511	11.8	1
10/08/2003	5.59	107	30	149	5	79	109	102	2	7	6	16	126	5	1.028	19.5	2
08/09/2003	5.65	126	32	142	3	73	109	123	0	12	0	15	23	8	0.304	11.5	0
27/10/2003	5.89	54	31	162	4	72	121	185	0	22	0	7	5	2	0.115	21.7	0
16/12/2003	6	32	18	108	4	32	58	85	0	24	0		36	3	0.318		0

Appendix 9 Macroinvertebrate taxon list and total abundances.

TAXON	CONTROL BURN										EXPERIMENTAL BURN										ALLT RIABHACH NA BIORAICH BURN							
	1993	1994	1996	1997	1998	1999	2000	2001	2002	.2003	1993	1994	1996	1997	1998	1999	2000	2001	2002	2003	1996	1997	1998	1999	2000	2001	2002	2003
NEMATODA			1								2		1	1							1							
Pisidium sp.												1																
OLIGOCHAETA	22	6	8	3	5	2	1	3	3	2	14	10	26		3			3	1		12		5	12	1	13	1	
NAIDIDAE																											1	
ENCHYTRAEIDAE																				4								2
LUMBRICULIDAE										1																	2	1
Stylodrilus heringianus																												2
LUMBRICIDAE										1																		1
HYDRACARINA						1		4	6						1			1	8							2	6	
COLLEMBOLA															1				1									1
SIPHLONURIDAE										1																		
Siphlonurus sp.																											1	
Siphlonurus lacustris								1	4	2			35				1		1		17					3		
Ameletus inopinatus	11	4			1	1	3																					
BAETIDAE									4	2																		
Baetis sp.				52								1																
Baetis rhodani	5		7		39	30	20	142	138	34				1	1	1			3				8	4		8	16	21
Baetis muticus	3	2	3				1	1			9		3															
HEPTAGENIIDAE					9					1																		
Heptagenia sp.									2																			
Heptagenia lateralis	3	18	11	9	2	3	13	10	16	4											2	1	2	1	2			
Ecdyonurus sp.					1																							
Ecdyonurus dispar				1																								
Leptophlebia sp.																			1									
Leptophlebia marginata			1			1					16	19	6			7	5	3		2								
Leptophlebia vespertina											20	61	9	9		7	15	42	5	2	5							
Brachyptera risi								1																1				
Protonemura praecox							1																					
Protonemura meyeri											1																	
Amphinemura sulcicollis	168	32	27	17	52	54	103	57	76	69	20	1	2	14	7	7	12	1	4	2	9	23	28	25	99	45	27	85
Nemurella picteti				1										1														
Nemoura sp.																	1					2						
Nemoura avicularis												2				1			1	1								
Nemoura cambrica											2		1			1		3						1				

TAXON	CONTROL BURN										EXPERIMENTAL BURN										ALLT RIABHACH NA BIORAICH BURN							
	1993	1994	1996	1997	1998	1999	2000	2001	2002	.2003	1993	1994	1996	1997	1998	1999	2000	2001	2002	2003	1996	1997	1998	1999	2000	2001	2002	2003
LEUCTRIDAE					1																							
Leuctra inermis	41	6	1	5	3	22	30	2	8	2	1											2	14	27	17	3	5	12
Leuctra hippopus		1													1		1	1										
Leuctra nigra											1																	
Perlodes microcephala	2					1																						
Isoperla grammatica	106	4	8	9	20	25	25	32	17	5	7				2	4	6	1	1		3	46	45	36	74	79	37	55
Siphonoperla torrentium	109	48	54	2	61	29	30	29	23	12	23	5		5	3	1	2				7	8	33	24	20	8	3	4
Chloroperla tripunctata				11																		5						
Pyrrhosoma nymphula											1	1				1												
Cordulegaster boltonii											1																	1
VELIIDAE																			3									
Dytiscidae undet. (larvae)												1		1							1							
Oreodytes rivalis	18	36	7	1																	1							
Oreodytes sanmarkii																								1		1		
Agabus guttatus											1																	
Platambus maculatus		1																										
HYDROPHILIDAE									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	54	56	2	5		17	1	1	1	2		2	3	7	9	18	22	20	19	18
Oulimnius sp.					3				83	11					9				27	20			1				79	25
Oulimnius tuberculatus	55	22	21	5		14	8	27			151	98	19	15		12	20	14			9	10		4	56	40		
Sialis fuliginosa																												1
Rhyacophila sp.								1		2																3		
Rhyacophila dorsalis	1		1	2		4	2	1																1		2	1	
POLYCENTROPODIDAE									4										5	1								
Plectrocnemia conspersa	6	1	5	3	2			4	8	1	13	9	9	15	1	2	5	35	9	5	11	1	1	1	2	3	4	4
Plectrocnemia geniculata		2										1																
Polycentropus sp.						2										2	6											
Polycentropus flavomaculatus		2	3		4			1	2	4	23	6	6		3	5		13	13	6	1			3			6	4
Hydropsyche siltalai	1				1					1																		
HYDROPTILIDAE										2	38				2				1	5								
Hydroptila sp.		2											1															
Oxyethira sp.		1										29				4		2										
LIMNEPHILIDAE undet.	10	7	6		3	3	4	1	3		66	2	7	4	17	41	47	5	6	15	6	3	6	5	8	6	4	8
Ecclisopteryx guttulata																							1					

TAXON	CONTROL BURN										EXPERIMENTAL BURN										ALLT RIABHACH NA BIORAICH BURN							
	1993	1994	1996	1997	1998	1999	2000	2001	2002	.2003	1993	1994	1996	1997	1998	1999	2000	2001	2002	2003	1996	1997	1998	1999	2000	2001	2002	2003
Potamophylax sp.										1																		
Potamophylax rotundipennis															1													
Halesus sp.								1									1											
Halesus radiatus													6					4										2
Halesus digitatus																		1								2		
DIPTERA					2				1	2					2				2	1			1	1				6
TIPULIDAE	2	1						2	1	3	1			1				1		1							1	3
Dicranota sp.	8	2	3	3	1	5	1	8	4	3	6	2	1	3	2	2	3	1			7		5	9		5	3	8
Psychodidae	1																											
CHIRONOMIDAE	26	17	28	13	6	11	4	40	12	15	56	86	104	15	24	36	22	89	33	33	14	7	10	18	6	186	8	18
SIMULIIDAE	23		1	23	3	11	1	5	3	2	2		1	1	5	6	11	3	8	14		12	1	76	1	2	7	1
Simulium latipes												3																
EMPIDIDAE						2		1							2	1												2
Clinocera sp.																	1											
Leuctra sp.									9	2									1							6	3	1
GERRIDAE																		1										
Hydropsyche sp.																		1										

Appendix 10 Control Burn macroinvertebrate summary statistics

Year	1993	1994	1996	1997	1998	1999	2000	2001	2002	2003
Total Count	768	231	256	178	307	257	314	409	428	241
Total no. of taxa	24	22	27	19	21	23	18	26	19	21
RICHNESS (rareftn 100)	17	17	18	15	12	17	13	15	14	17
HILL'S N1	11.5	11.9	12.8	10.6	8.01	11.8	7.8	8.9	8.7	9.0
HILL'S N2	8.4	9.0	9.0	7.5	5.9	9.3	5.6	5.8	6.2	6.0
EVENNESS (E5)	0.71	0.73	0.68	0.68	0.69	0.76	0.67	0.61	0.68	0.63
BMWP	110	99	125	88	88	118	93	108	88	104
ASPT	6.4	6.6	6.6	6.3	6.3	6.6	6.1	6.7	6.8	6.5

Appendix 11 Experimental Burn macroinvertebrate summary statistics

Year	1993	1994	1996	1997	1998	1999	2000	2001	2002	2003
Total Count	477	231	247	110	96	142	162	227	134	114
Total no. of taxa	25	20	20	18	20	22	19	22	18	14
RICHNESS (rareftn 100)	18	14	14	16	19	19	16	13	16	13
HILL'S N1	11.3	7.9	7.7	11.4	11.9	9.8	10.1	6.6	9.0	8.5
HILL'S N2	6.9	5.4	4.6	10.0	8.5	6.4	7.3	4.5	6.7	6.7
EVENNESS (E5)	0.57	0.64	0.54	0.87	0.69	0.61	0.69	0.67	0.71	0.76
BMWP	108	83	82	67	94	84	93	80	79	52
ASPT	6.4	5.5	5.9	6.1	6.3	6.5	7.0	5.7	6.6	5.2

Appendix 12 Allt Riabhach na Bioraich Burn macroinvertebrate summary statistics

Year	1996	1997	1998	1999	2000	2001	2002	2003
Total Count	109	128	171	268	315	437	234	286
Total no. of taxa	17	13	16	22	13	20	18	20
RICHNESS (rareftn 100)	17	12	13	16	10	13	15	16
HILL'S N1	12.6	7.6	8.8	10.3	6.6	6.7	9.1	9.9
HILL'S N2	11.9	5.5	6.8	7.5	5.1	4.2	6.0	6.7
EVENNESS (E5)	0.94	0.67	0.74	0.69	0.73	0.57	0.62	0.64
BMWP	89	78	83	105	75	95	80	85
ASPT	6.9	7.1	6.4	6.6	6.1	6.3	6.7	6.1

Appendix 13 Control Burn aquatic macrophyte percentage cover

	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2001**	**2002**	**2003**
Batrachospermum sp.	+	0.7	+		+				+	+	
Marsupella emarginata var *aquatica*	4.4	4.0	4.9	0.4	1.5	0.2	1.9	1.2	+	0.6	1.0
Scapania undulata	2.8	3.7	1.7	0.9	2.0	1.9	3.7	3.3	2.9	3.2	3.8
Racomitrium aciculare	0.3	+	2.1	0.4	+	+		0.7	0.1	0.6	1.1
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	4.4	5.9
Filamentous green algae	+	10.7	+	0.1	+	+	+	1.3	+	0.8	0.3

Sampling stretch 50m long.

Appendix 14 Experimental Burn aquatic macrophyte percentage 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. Sampling ceased in 1999.

Appendix 15 Allt Riabhach na Bioraich Burn aquatic macrophyte percentage cover

	1996	**1997**	**1998**	**1999**	**2001**	**2002**	**2003**
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	1.0	0.4
Racomitrium aciculare			0.2	0.2	0.2	0.2	0.2
TOTAL COVER (excluding filamentous green algae)	0.4	1.8	1.2	1.0	1.5	1.2	0.6
Filamentous green algae	0.4		+	+	+	0.2	3.9

Sampling stretch 50m long.

Appendix 16 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
Control Burn	2002	106	0.40	0.21
Control Burn	2003	104	0.15	0.13
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
Experimental Burn	2002	32	0.40	0.12
Experimental Burn	2003	38	0.03	0.24
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
ARnB Burn	2002	63	0.85	0.21
ARnB Burn	2003	65	0.19	0.08

Appendix 17 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		19 Aug	19 Aug
2000	20 Nov		4 Aug	4 Aug
2001	28 Sept	18 May	30 Jul	30 Jul
2002	24 Sept	15 May	28 Aug	28 Aug
2003	16 Sept	2 May	10 Aug	10 Aug

* Only control burn sampled in 1992

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