WM796

OPTIMIZATION OF BEST MANAGEMENT PRACTICES FOR BEEF CATTLE RANCHING IN THE LAKE OKEECHOBEE BASIN

Statistical Analysis

(Nutrient Concentrations)

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by

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Key words:
histograms, normal and lognormal distribution, Kolmogorov-Smirnov test, Chauvenet's criterion for outliers, 2-sample T-tests, Anova, General Linear Model tests, Tukey's w test

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I. Objectives

The MAERC Buck Island Ranch project seeks to evaluate the effects of cattle stocking rate on water quality. After gathering all the water quality result files, Laurence Amilhat performed the statistical analysis for the data of the years 1998/1999, that is to say the two first years of the project. However, the data did not yield clear conclusions. This paper reports the study and the conclusions that result from the 2001 data. This report can be also reach on the Internet at:

http://www.intellitemps.net/houssard/data_analysis/data_analysis.htm

II. Project design

The demonstration project seeks to evaluate four cattle stocking rates of cow-calf units on bahiagrass pastures sites. The infrastructure consists of multiple experimental pastures fenced and ditched separately from each other, and are instrumented, so that all surface water runoff can be captured and analyzed. The design is described in Table 1.

Table 1. Design of the stocking rate treatments demonstration project.

Block	Plot ID	Treatment		
		Description	Cow-Calf Units	Acres/Unit
Winter	W4 & W7	Control	0	N/A
	W1 & W6	Low	15	5.3
	W2 & W8	Medium	20	4
	W3 & W5	High	35	2.3
Summer	S1 & S8	Control	0	N/A
	S4 & S6	Low	15	5.3
	S2 & S7	Medium	20	4
	S3 & S5	High	35	2.3

These grazing blocks reflect the two principal pasturing regimes of a typical central Florida ranch. Each study animal was assigned to a stocking rate at the beginning of the study and remains at this same stocking rate for the life of the project. The winter sites are located on area containing a mixture of mature grasses, along with some bahiagrass. Winter pastures are for the grazing of cows immediately after calving and during breeding (dry season). The summer sites are improved pasture with bahiagrass and used for the grazing of cow-calf pairs. All the experimental pastures are similar in design and instrumentation. A data logger installed at each flume triggers the auto sampler based upon the flow volume and hydrograph geometry. The resulting water samples are shipped to the laboratory then analyzed for phosphorus, nitrate, ammonia and total nitrogen. Also, grab samples are taken manually and analyzed for soluble reactive phosphorus. The data logger records several different parameters including the water depth before (upstream) and after (downstream) the flume, the year, date, time, and sample number. The combination of these measurements and the laboratory results are saved in a database and then analyzed to assess the effectiveness of the stocking rate treatments.

III. Stages of the data analysis

a) Distribution of the data

First, it is important to have an idea of the data distribution. Indeed, each statistical test assumes that the data are normally distributed. This assessment was accomplished by producing frequency histograms.

The histograms reflect the kind of distribution, so it is important not to neglect this stage. Indeed, the choice of the width of intervals, called bin range, has an important influence on the shape of the distribution. If too many intervals are chosen then the number of values in each interval is small and the histogram appears flat and featureless. At the other extreme, if the histogram consists of only two or three intervals, then all the values will lie in those intervals and the shape of the histogram reveals little. There are no hard and fast rules about choosing the width of intervals but a useful rule of thumb is to choose about N = √n intervals, where n is the number of values. Once N has been rounded to a whole number, the interval width, w, can be calculating using:

w = range / N = (max value – min value) / N

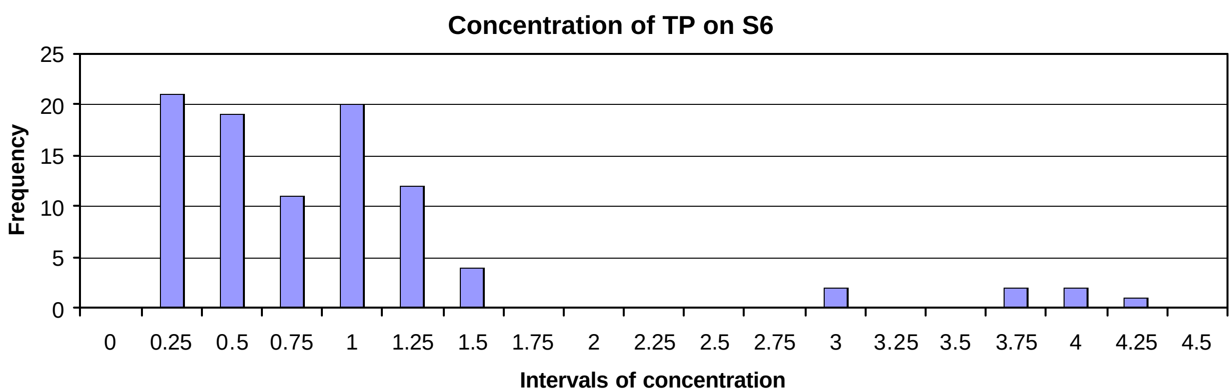

Figure 1. Example of a (non-normal) distribution.

The histogram shown in Figure 1 does not exhibit a normal distribution. Water quality data typically manifest a lognormal distribution. Therefore a log transformation is likely to yield a normal frequency distribution, as it can be seen on Figure 2.

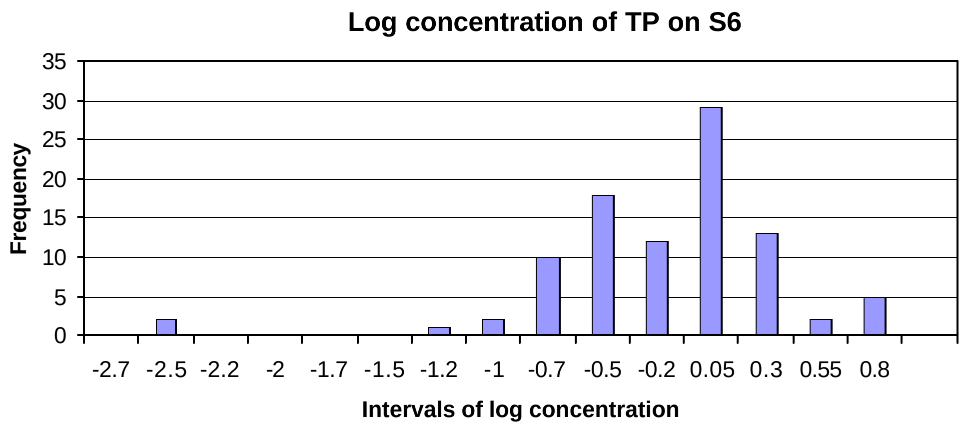

Figure 2. Example of a normal distribution.

It is possible to determine statistically if a distribution corresponds to a normal distribution or not. A relevant test is the Kolmogorov-Smirnov test, which compare an empiric distribution (Fn*(x)) to a theoretical continuous one (F(x)). We just compare the infinite norm of the 2 functions ($Dn = | F_n^* - F |_\infty$ = Sup {$|F_n^*(x)-F(x)|$, x € IR }) to a tabulate value dn. If $D_n < d_n$ (a), we can conclude that the distribution is a normal one (with a error of a %)

b) Outliers (Chauvenet's criterion)

Identification of outliers is important as they may indicate a novel effect such as the existence of incorrect recording of the measured value. Trying to identify the cause of an outlier is very important.

One approach to deciding whether an outlier should be removed from a group of values is to begin by asking the question: Given the scatter displayed by the data as a whole, what is the probability of obtaining a value at least as far from the mean as the outlier?

If this probability is very low then we have good statistical grounds for omitting the outlier from any further analysis. To carry out this study, we must assume that the scatter data is well described by the normal distribution. For each value x, we calculate

$$z = (x - \langle x \rangle) / s \qquad \text{[Eq.1]}$$

where <x> is the mean, s the standard deviation

Then, we find the probability that a value differs from the mean by at least z standard deviations (2*Norm(-8 < Z < -abs(z)) where Norm is the normal distribution (a statistic table or the direct Excel function *Normdist* can be used). Then, we multiply this probability by n, the number of values. It results the number of values N_v we expect to be at least as far from the mean as the outlier. If $N_v < 0.5$, we can reject this number of the study.

c) Means Test

By analyzing the treatment replicate results among themselves we seek to verify whether they are valid replicates (means not significantly different). One option in performing this verification is to run a paired test, but this test requires equal sample sizes and the assumption that our samples are dependent rather than independent measurements. Since neither of these assumptions holds true in our case, we instead choose to run a two-sample T-test. This allows us to assume independent samples and to test the difference between means calculated from unequal size samples.

d) ANOVA / GLM Tests

By performing an analysis of the variance (ANOVA), we seek to assess the significance of main effects on the nutrient concentrations and runoff loads. There are two effects in the MAERC pasture project, so the two-way variance analysis should be used. The two effects studied are the type of Block (winter or summer pasture) and the Treatment (cow-calf stocking rates). These test were previously carried out for the analysis of 1998/1999.

Unfortunately, ANOVA tests require equal subclass numbers, which is not verified for our current study. This difficulty was avoided for the 1998-1999 analyses by doing the test on the means only. But, taking into account the data variation would be more interesting. It is the reason why we chose to submit the data to general linear model (GLM) tests. To perform these tests, we had to use Minitab because MS Excel cannot do them.

It would be inappropriate to develop here the GLM [see http://www.statsoftinc.com/textbook/stglm.html as part of this report] but the presentation of the computerization may be relevant in this paper. To run the test, Minitab needs 3 columns of same length:

?? A column which specifies each value
?? A column which specifies the block corresponding to the data (summer/winter)
?? A column which specifies the treatment corresponding to the data (control/low/medium/high)

The results appear in a table (similar to a ANOVA table), gathering for each test (block/treatment/interaction block-treatment):

?? Df (degrees of freedom)
?? Seq SS (sum of squares)

?? Adj SS (adjusted sum of squares)
?? Adj MS (=Adj SS/Df)
?? F (F statistic)
?? P (probability of means being as different as observed if the null hypothesis is true)

The most important of these 6 numbers is the P-value. This value allows determination if the null hypothesis (stating that there is no main effect) must be rejected or not. If P < 0.05 (5%), we can conclude that there is a statistically significant effect.

IV. Data analysis

a) Distribution of data

i) NH3

The histogram shown in Figure 3 represents the distribution of NH3 for the summer plots. To make it clearer, the boxes have been replaced by points linked each together by lines. This avoids having to produce 16 different histograms figures or depicture 16 different bar sets in the same figure.

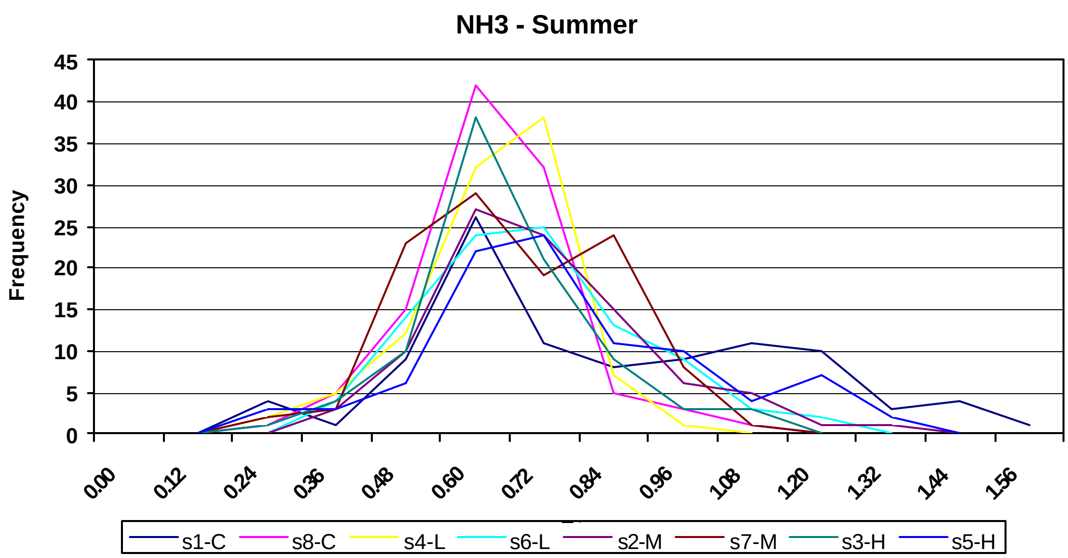

Figure 3. Histogram of NH3 concentration for the summer plots.

Table 2: Means and standard deviation for NH3

		Control		Low		Medium		High	
		1	2	1	2	1	2	1	2
Summer	Mean	0.65	0.29	0.30	0.41	0.41	0.34	0.33	0.49
	St Dev	0.56	0.14	0.30	0.26	0.28	0.20	0.20	0.37
Winter	Mean	0.40	0.21	0.23	0.23	0.58/0.40	0.20	0.20	0.25
	St Dev	0.67	0.11	0.12	0.10	1.71/0.32	0.16	0.29	0.24

(Without outliers)

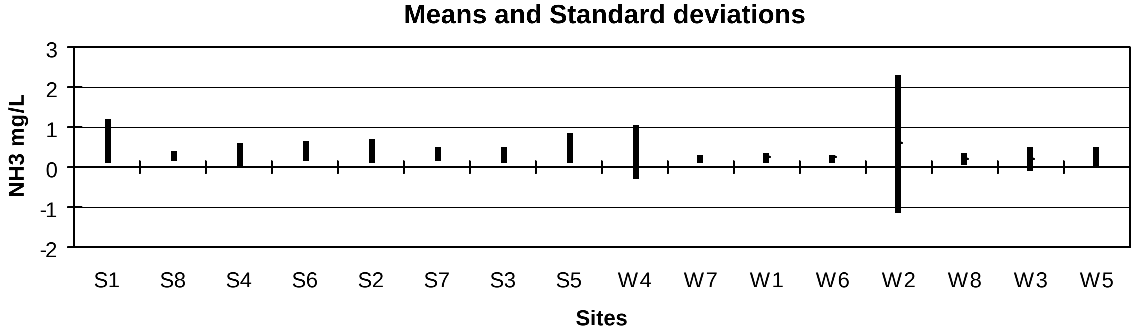

Figure 4. Graph showing the 68% confidence interval for NH3.

The abnormal standard deviation for w2 leads us to consider carefully the data for this site. Actually, we can see a value of 18 whereas all the other values are less than 4 (mean of 1.71 with this value 0.43 without). This value won't be considered in the tests since it can only be a mistake.

We can then check the shape of the distribution of the logarithm of the concentration since we will use these data for the following analysis.

Table 3: Frequency of log NH3 concentration

Bin	S1 C	S8 C	S4 L	S6 L	S2 M	S7 M	S3 H	S5 H	W4 C	W7 C	W1 L	W6 L	W2 M	W7 M	W3 H	W5 H
-2.00	1	1	0	0	0	2	0	2	2	0	0	0	0	0	2	2
-1.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-1.50	3	0	2	0	0	0	1	1	0	1	0	0	0	1	1	0
-1.25	1	1	3	0	2	1	1	2	1	2	2	2	0	2	5	3
-1.00	0	4	2	4	1	4	4	1	8	13	5	7	5	13	19	14
-0.75	4	11	8	13	8	18	8	5	22	28	28	24	22	28	19	22
-0.50	34	47	40	25	30	33	43	24	52	56	56	48	35	56	42	62
-0.25	14	35	40	31	35	36	23	29	21	14	17	20	30	14	2	15
0.00	22	4	2	19	12	14	7	19	4	0	5	0	11	0	0	4
0.25	14	0	0	2	3	0	2	8	5	0	0	0	10	0	0	1
0.50	5	0	0	0	1	0	0	1	2	0	0	0	0	0	1	1
0.75	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0
More	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

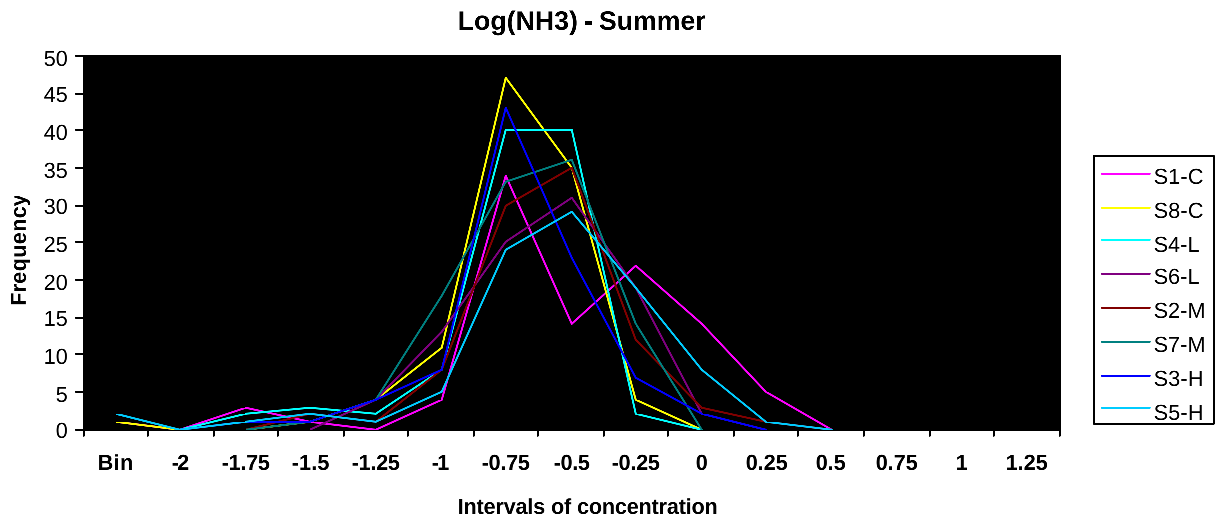

Figure 5. Histogram of log concentration NH3 for summer plots.

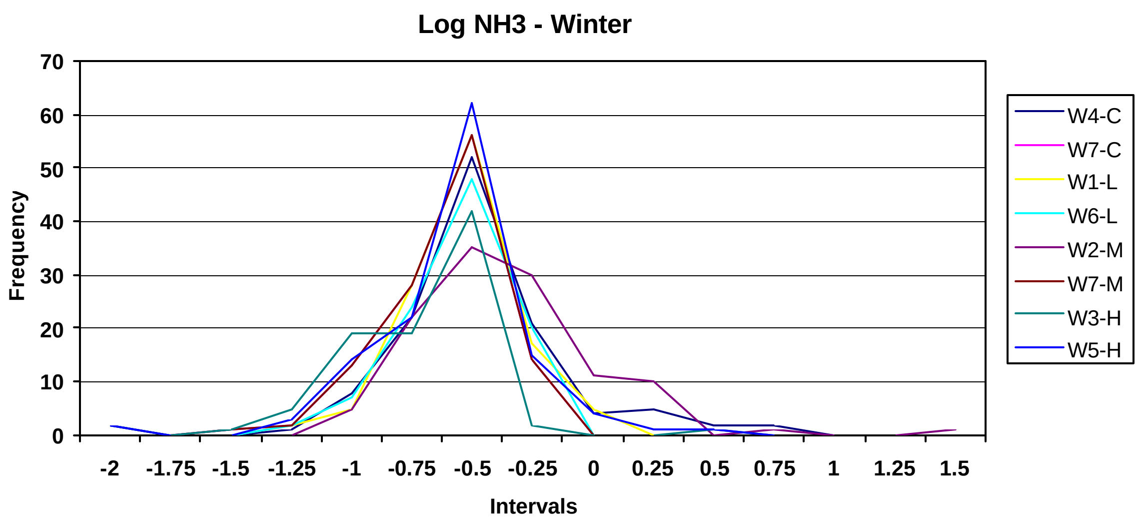

Figure 6: Histogram of log concentration NH3 for winter sites

ii) NOx

Table 4. Means and standard deviation for NOx.

		Control		Low		Medium		High	
		1	2	1	2	1	2	1	2
Summer	**Mean**	0.11/0.06	0.03	0.04	0.03	0.05	0.09	0.07	0.03
	St Dev	0.29/0.15	0.07	0.11	0.10	0.13	0.29	0.23	0.07
Winter	**Mean**	0.12	0.07	0.27/0.13	0.08	0.38/0.10	0.03	0.04	0.12
	St Dev	0.25	0.24	0.54/0.20	0.32	0.77/0.20	0.06	0.12	0.31

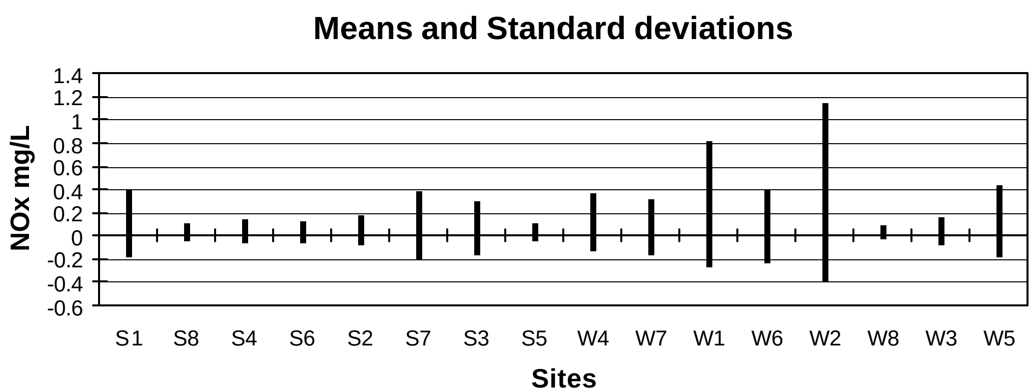

Figure 7. Graph showing the 68% confidence interval for NOx.

The same approach for NOx reveals abnormal values in the site w2, which will be removed from the tests. It is very difficult to interpret the results since each site presents a great range (max value/min value about 100), but most of the cases, it is not matter of isolated outliers, just the natural spread of the datapoints. Besides, it is not reasonable to apply the Chauvenet's criterion for outliers given the distribution, which is not Gaussian, unlike the other parameters (NH3, TP, TKN) are. Moreover, it would not be reasonable to get rid of 10% of the values.

Table 5. Frequency of log NOx concentration.

Bin	***S1-C***	***S8-C***	***S4-L***	***S6-L***	***S2-M***	***S7-M***	***S3-H***	***S5-H***	***W4-C***	***W7-C***	***W1-L***	***W6-L***	***W2-M***	***W7-M***	***W3-H***	***W5-H***
-2.00	62	72	74	60	61	69	63	72	42	56	44	50	42	58	50	51
-1.80	2	5	3	2	3	8	1	1	6	6	3	6	9	6	8	6
-1.60	9	8	5	15	10	10	11	5	16	18	7	17	8	18	17	8
-1.40	4	6	2	4	4	4	1	5	8	5	5	2	6	5	5	11
-1.20	4	5	5	4	4	3	5	2	10	11	6	10	5	11	3	13
-1.00	2	3	1	4	3	5	0	2	2	5	10	4	2	5	2	6
-0.80	3	0	2	2	1	1	1	0	11	4	2	4	7	4	2	4

-0.60	4	0	1	1	1	2	1	2	7	1	11	3	6	1	1	11
-0.40	1	3	0	1	1	1	0	3	4	2	5	2	6	2	1	6
-0.20	4	1	3	0	3	1	3	0	8	3	6	1	5	3	1	3
0.00	1	0	1	1	1	1	0	0	2	0	2	0	3	0	1	2
0.20	2	0	0	0	0	3	2	0	2	0	9	1	7	0	0	2
0.40	1	0	0	0	0	1	1	0	0	1	1	0	4	1	0	0
0.60	0	0	0	0	0	0	0	0	0	0	2	1	5	0	0	1

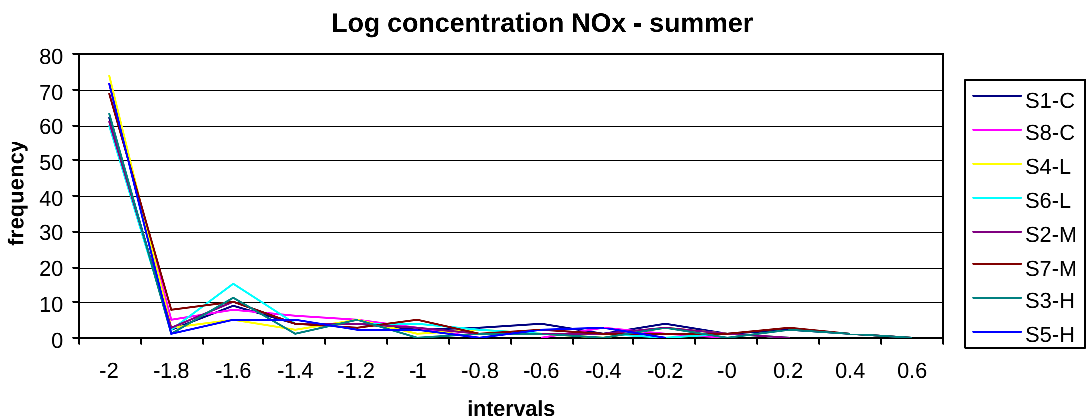

Figure 8. Histogram of log concentration NOx for summer sites.

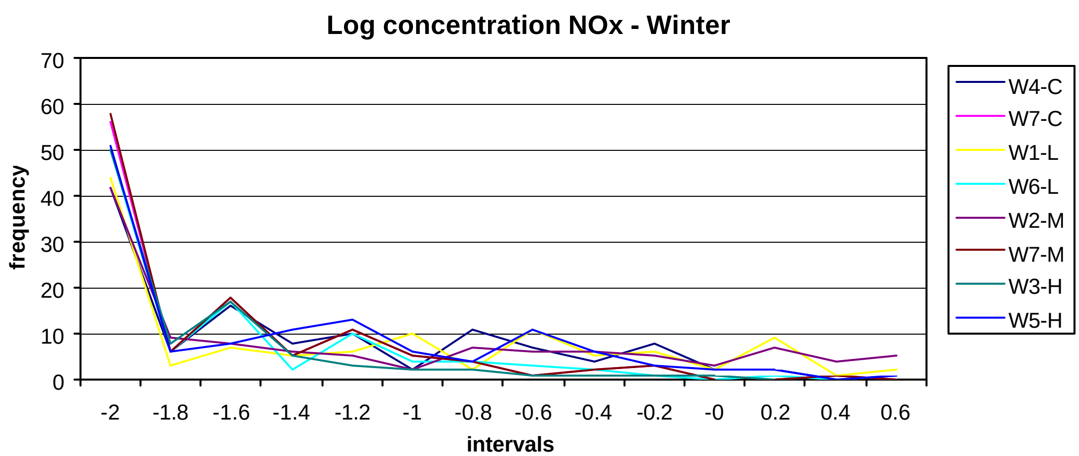

Figure 9. Histogram of log concentration NOx for winter sites.

Here, we must acknowledge that the concentration of NOx is not lognormally distributed. No need to say that Kolmogorov-Smirnov tests (which have been run for several sites) are unsuccessful. Indeed, the low values have really a great weight in the distribution. This means that the concentration is very often low, effectively zero. However, this property prevents us from being completely confident in the NOx GLM test, which requires a normal distribution.

iii) TKN

Table 6. Means and standard deviation for TKN.

		Control		Low		Medium		High	
		1	2	1	2	1	2	1	2
Summer	Mean	**4.14**	3.72	3.36	3.9	4.32	3.51	3.61	3.43
	St Dev	**1.95**	1.58	1.32	1.93	1.71	1.84	1.46	2.02
Winter	Mean	**3.07**	3.12	2.66	2.98	3.49/3.32	2.55/2.62	2.78	2.82
	St Dev	**1.43**	1.32	1.01	2.46	2.19/1.18	0.97/0.90	0.93	1.13

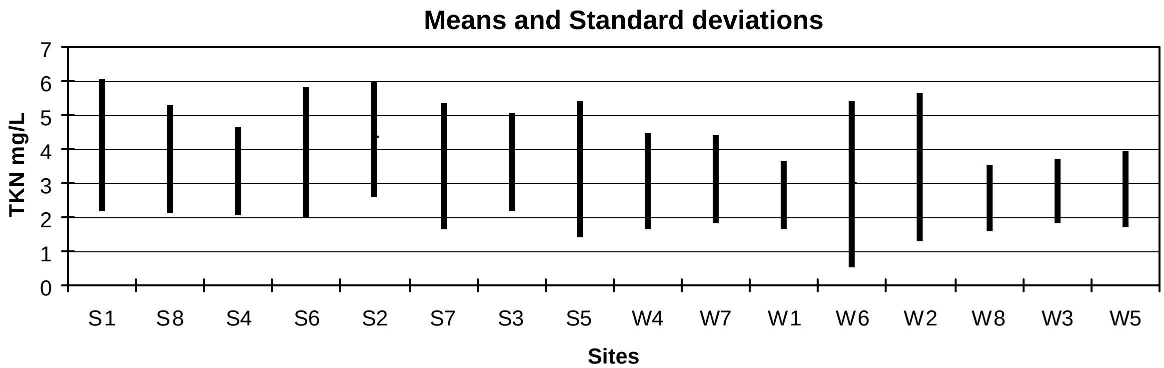

Figure 10. Graph showing the 68% confidence interval for TKN.

Table 7. Frequency of log TKN concentration.

Bin	S1-C	S8-C	S4-L	S6-L	S2-M	S7-M	S3-H	S5-H	W4-C	W7-C	W1-L	W6-L	W2-M	W7-M	W3-H	W5-H
-1.70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-1.50	0	4	0	2	0	0	0	2	0	0	1	0	0	0	0	0
-1.30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-1.10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
-0.90	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0
-0.70	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
-0.50	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0
-0.30	0	0	1	1	0	4	0	2	1	0	0	1	0	0	2	0
-0.10	0	1	2	2	0	1	0	3	1	4	0	2	0	4	0	1
0.10	8	0	5	4	3	2	6	2	9	8	15	13	9	8	3	9
0.30	7	10	12	12	4	23	5	16	21	14	19	16	8	14	7	24
0.50	12	11	13	8	13	18	21	15	34	28	31	19	34	28	52	38
0.70	38	57	54	43	41	36	38	33	46	51	47	43	56	51	26	49
0.90	28	18	9	22	29	23	18	18	6	9	0	6	8	9	1	3
1.10	4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

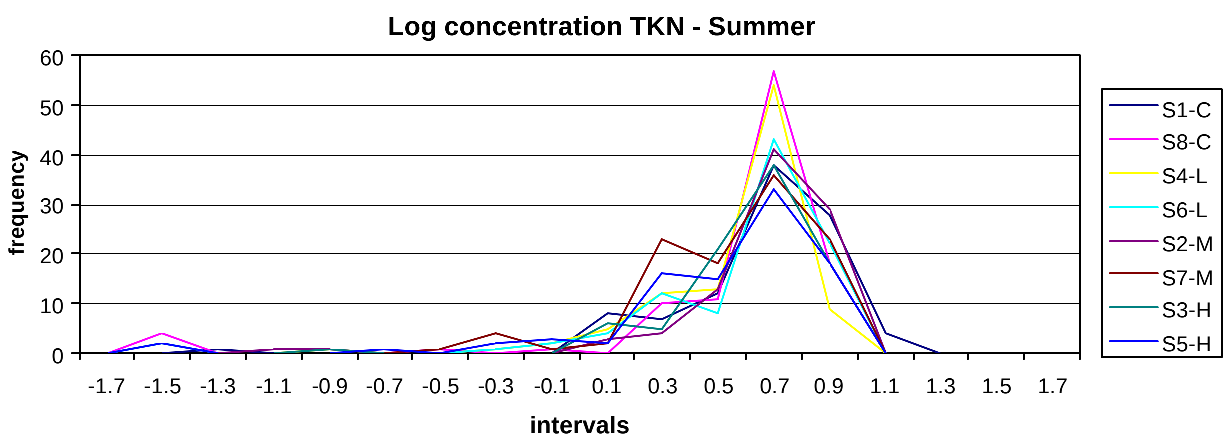

Figure 11. Histogram of log concentration TKN for summer sites

We can see that the log-concentration of TKN is skewed, not symmetric and has more values on the left tail.

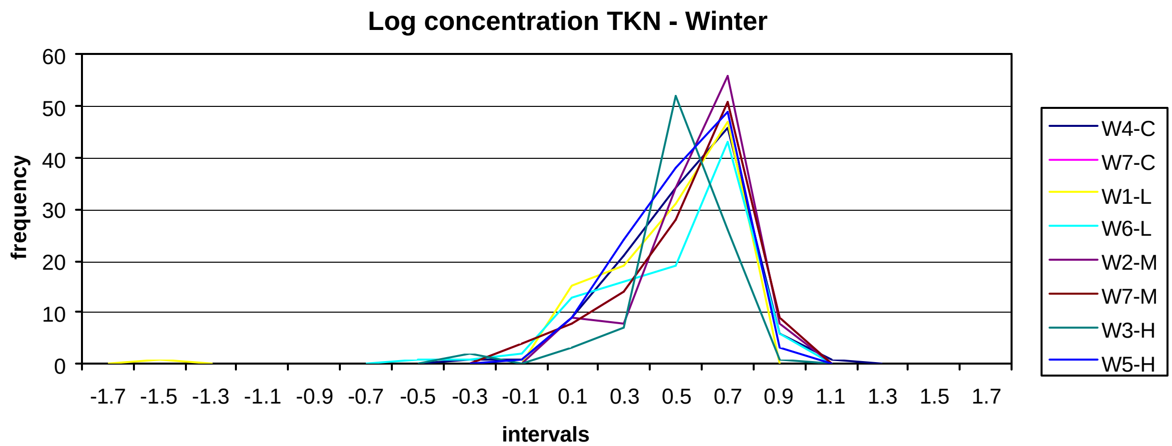

Figure 12. Histogram of log concentration TKN for winter sites.

iv) TP

Table 8. Means and standard deviation for TP

		Control		Low		Medium		High	
		1	2	1	2	1	2	1	2
Summer	Mean	1.07	0.82	1.11	0.85	0.88	0.7	0.79	0.8
	St Dev	0.87	0.57	0.98	0.88	0.5	0.76	0.5	0.98
Winter	Mean	0.11	0.15	0.12	0.18	0.14	0.08	0.24	0.16
	St Dev	0.13	0.16	0.09	0.17	0.20	0.10	0.27	0.25

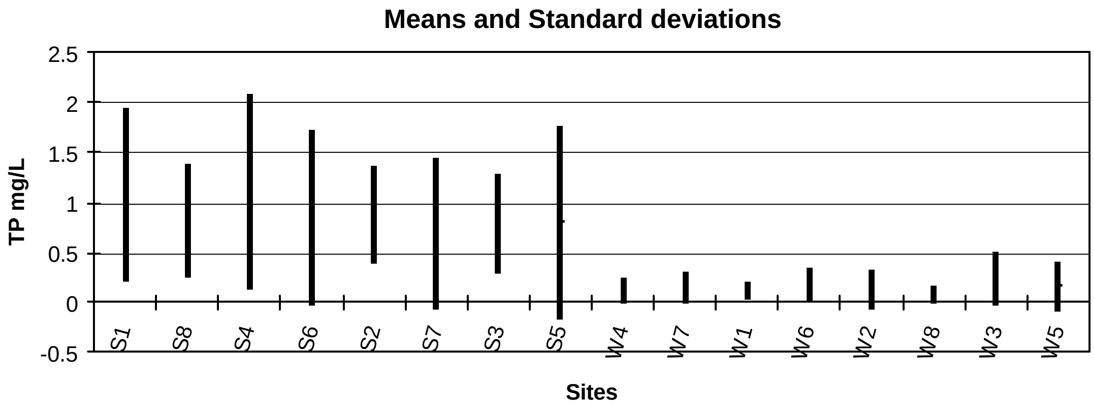

Figure 13. Graph showing the 68% confidence interval for TP.

It is obvious here that the summer pasture nutrient concentrations are higher than the winter pasture concentrations (factor of 5 or more).

Table 9. Frequency of log TP concentration.

	S1	S8	S4	S6	S2	S7	S3	S5	W4	W7	W1	W6	W2	W7	W3	W5
Bin	**C**	**C**	**L**	**L**	**M**	**M**	**H**	**H**	**C**	**C**	**L**	**L**	**M**	**M**	**H**	**H**
-2.70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-2.45	0	2	0	2	0	0	0	3	4	0	1	1	3	4	3	1
-2.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-1.95	0	2	1	0	1	2	0	0	2	1	8	1	0	2	2	0
-1.70	0	0	0	0	0	0	0	0	3	0	2	0	2	2	3	3
-1.45	1	2	0	0	0	2	1	1	13	6	5	1	5	18	3	3
-1.20	3	0	0	1	0	3	0	3	33	33	18	21	18	30	11	29
-0.95	8	1	1	2	3	6	9	3	30	25	29	25	45	35	10	31
-0.70	5	7	6	10	5	14	1	7	21	18	31	14	25	15	12	33
-0.45	18	10	18	18	12	18	13	24	4	26	17	27	11	4	30	14
-0.20	11	27	13	12	13	20	22	20	9	4	2	10	3	0	14	7
0.05	8	21	20	29	21	22	13	6	0	0	0	0	2	1	2	2
0.30	21	28	27	13	37	16	30	18	0	1	0	1	1	0	0	0
0.55	23	2	6	2	0	4	0	1	0	0	0	0	0	0	1	1
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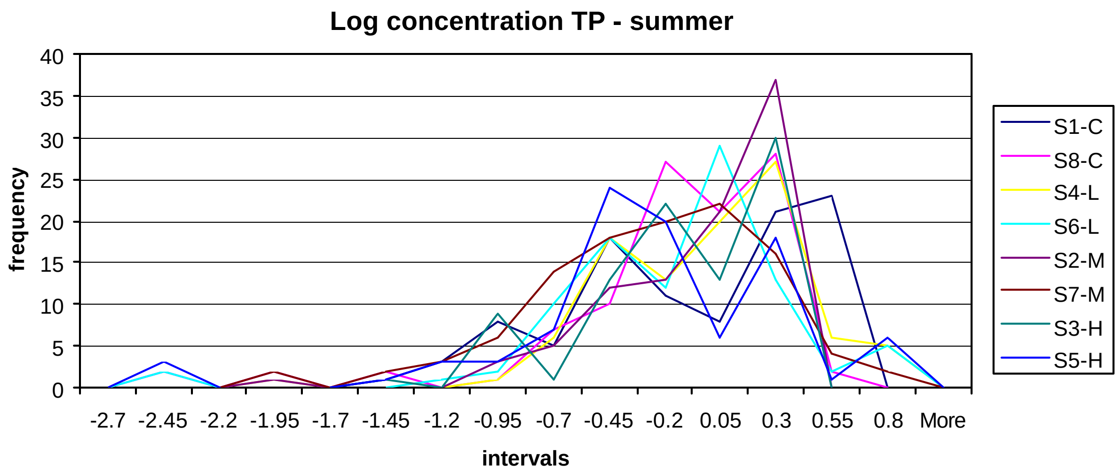


Figure 14. Histogram of log concentration TP for summer sites.

Like TKN, We can see that the log-concentration of TP is not symmetric and has more values on the left tail.

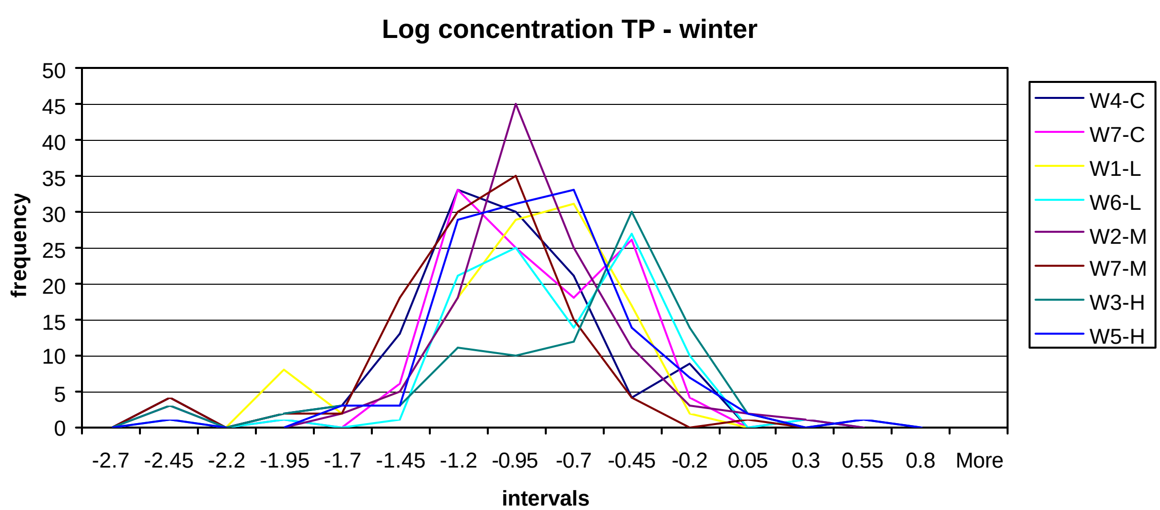


Figure 15. Histogram of log concentration TP for winter sites.

It is interesting to note that the log-concentration of TP for winter has a good bell shape (except for w3).

b) Duplicate tests

1. Year 2001

Here are the results of the tests to verify if the replicate means are similar. If the P-value is below 5%, it can be concluded that the 2 means cannot be considered as equal.

Table 10. P-value of the T-Tests for replicate sites (2001).

	Summer				Winter			
	Control	**Low**	**Medium**	**High**	**Control**	**Low**	**Medium**	**High**
NH3	**0.000**	**0.002**	**0.004**	**0.002**	**0.003**	0.429	**0.000**	0.161
NOx	**0.011**	0.710	0.219	0.081	0.066	**0.003**	**0.000**	**0.015**
TKN	0.082	**0.027**	**0.002**	0.564	0.767	0.076	0.245	0.845
TP	**0.016**	0.067	**0.053**	0.863	0.073	**0.000**	**0.004**	**0.032**

This shows that we must be very cautious drawing conclusions since for half of the sites (17 / 32), it is impossible to know what the real effect is. However, the ANOVA GLM procedure takes this into account.

2. Year 1999

Table 11. P-value of the T-Tests for replicate sites (1999).

	Summer				Winter			
	Control	**Low**	**Medium**	**High**	**Control**	**Low**	**Medium**	**High**
NH3	0.066	0.476	0.723	0.144	0.627	0.071	0.457	0.670
NOx	0.097	0.461	0.775	0.047	0.242	**0.016**	0.169	**0.000**
TKN	0.184	0.539	0.435	0.960	0.631	0.402	0.323	0.836
TP	0.067	0.477	0.723	0.144	0.627	0.071	0.458	0.670

The table 11 shows that the replicates for 1999 are correct and give the same means for a same treatment except in 2 cases.

3. Year 2000

Table 12. P-value of the T-Tests for replicate sites (2000).

	Summer				Winter			
	Control	**Low**	**Medium**	**High**	**Control**	**Low**	**Medium**	**High**
NH3	0.847	0.489	0.111	0.108	0.619	0.979	0.503	0.150
NOx	0.350	1.000	0.341	1.000	0.919	0.796	0.439	0.391
TKN	**0.001**	0.301	**0.012**	0.108	0219	0.327	0.822	0.138
TP	**0.000**	0.845	0.443	**0.037**	**0.008**	**0.019**	0.347	0.288

We can see on the table 12 that replicates for 2000 are quite good for NH3 and TKN. For TP and to a lesser extent for TKN, we can underline a difference between the means for several treatments.

c) GLM tests

i. Year 2001

Let's consider that we can run the tests. The following table shows the results for the four nutrients. (The Minitab window is shown in the Appendix)

Table 13. P-value of the GLM tests (2001).

	NH3	NO x	TKN	TP
Block	**0.000**	**0.000**	**0.000**	**0.000**
Treatment	0.056	0.313	**0.000**	**0.004**
B * T	**0.010**	0.138	**0.000**	**0.001**

Different conclusions can be drawn:

1. The block effect is always statistically significant. It means that summer and winter treatments have an influence on the nutrient concentrations.
2. For TKN and TP, the treatment effect is also significant. Concentrations differ with the treatment (control / low / medium / high).
3. For NOx, the very high P-value (31%) allows us to conclude that the concentration do not differ with the treatment
4. It is more difficult to conclude for NH3 since the value (5.6%) is closed to the threshold (5%). We can say that the treatment effect is not very significant but that the influence is yet more important than for NOx.

ii. Year 1999

The GLM method has not been applied for the data of the previous years. To complement the report, we can insert here the results for 1999.

Table 14. P-value of the GLM tests (1999).

	NH3	NO x	TKN	TP
Block	**0.000**	**0.001**	**0.000**	**0.000**
Treatment	**0.000**	**0.002**	0.970	0.883
B * T	0.117	**0.004**	0.027	0.638

Conclusions:

1. The block effect is always statistically significant. It means that summer and winter treatments have an influence on the nutrient concentrations.
2. For NH3 and NOx, the treatment effect is also significant. Concentrations differ with the treatment (control / low / medium / high).
3. For TKN and TP, the very high P-value (97% and 88%) allows us to conclude that the concentration do not differ with the treatment

iii. Year 2000

Table 15. P-value of the GLM tests (2000).

	NH3	NO x	TKN	TP
Block	0.000	0.000	0.000	0.864
Treatment	0.695	0.028	0.471	0.018
B * T	0.204	0.121	0.374	0.560

Conclusions:

1. The block effect is often statistically significant (for all the nutrients except TP). It means that summer and winter treatments have an influence on the nutrient concentrations.
2. There is no significant effect for any of the treatments

d) Concentration vs. Treatment

I. Year 2001

The previous test showed that in most of the cases, the treatments had an effect on the nutrient concentrations. In other cases the variability of the data could not allow drawing such a conclusion.

So, let's consider the TP concentration data, which satisfy the first assumption (lognormal distribution). We can report on a graph the concentration vs. the number of cow-calf by unit. Unfortunately, we do not obtain monotonous curves. Therefore, it is impossible to conclude on the nature of the effect although the apparent relationship is actually inverse. The study of the other nutrients leads to the same conclusions:

Figure 16. TP concentration vs. treatment.

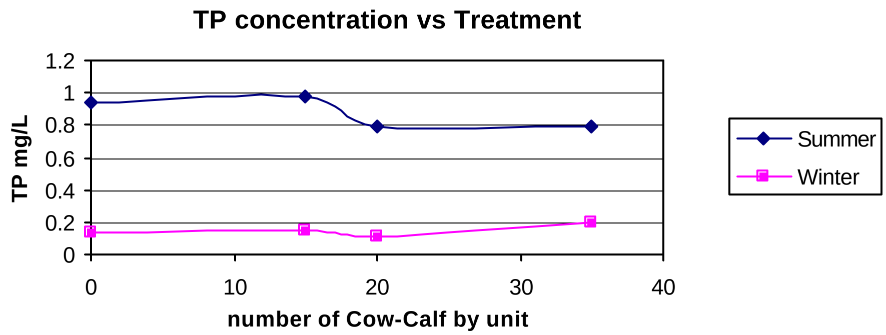


Figure 17. TKN concentration vs. treatment.

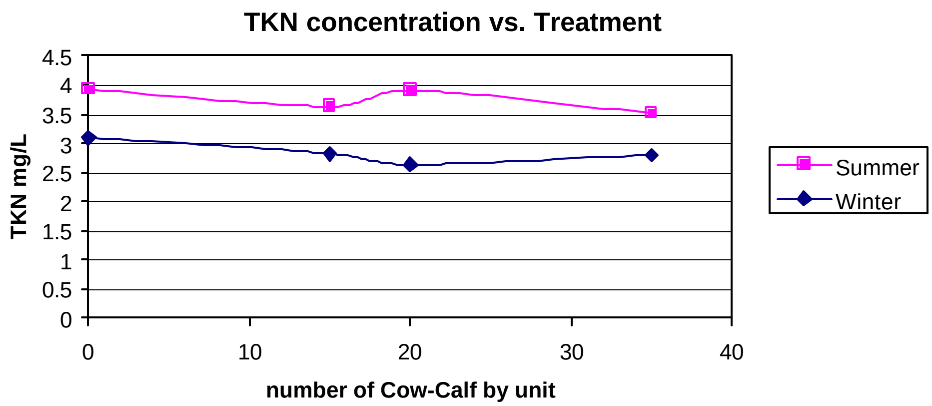


Figure 18. NOx concentration vs. treatment.

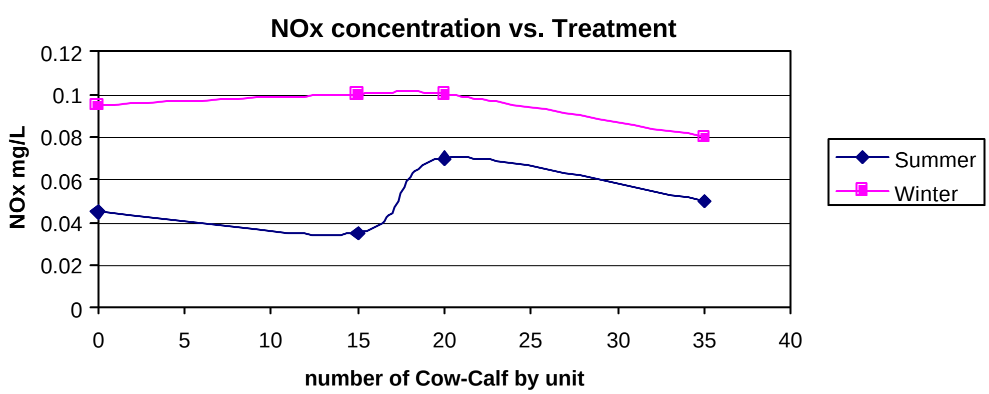
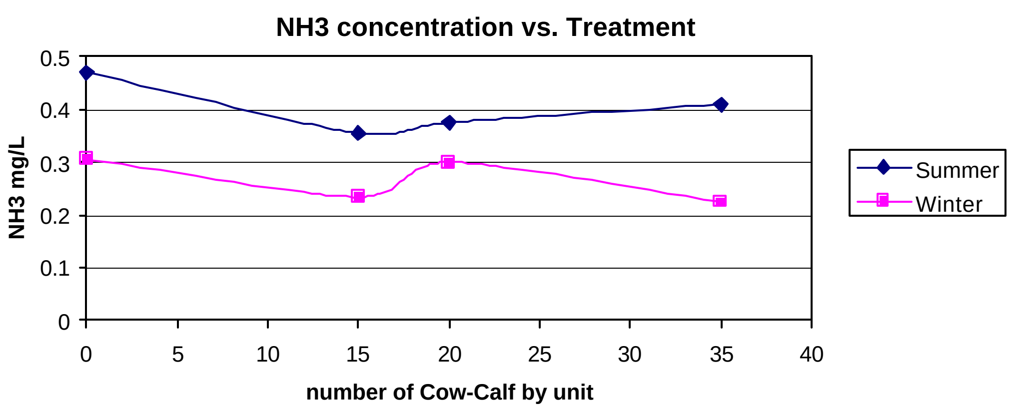


Figure 19. NH3 concentration vs. treatment.



II. Year 1999

Table 16. Means of concentration for each treatment.

		Control	Low	Medium	High
		0	**15**	**20**	**35**
NH3	Summer	0.305	0.365	0.500	0.425
	Winter	0.280	0.220	0.215	0.320
NOx	Summer	0.011	0.009	0.010	0.003
	Winter	0.017	0.025	0.018	0.028
TKN	Summer	4.310	6.500	8.670	5.590
	Winter	4.290	4.385	3.055	4.655
TP	Summer	0.656	0.765	1.130	0.795
	Winter	0.209	0.140	0.170	0.148

Figure 20. NH3 concentration vs. treatment.

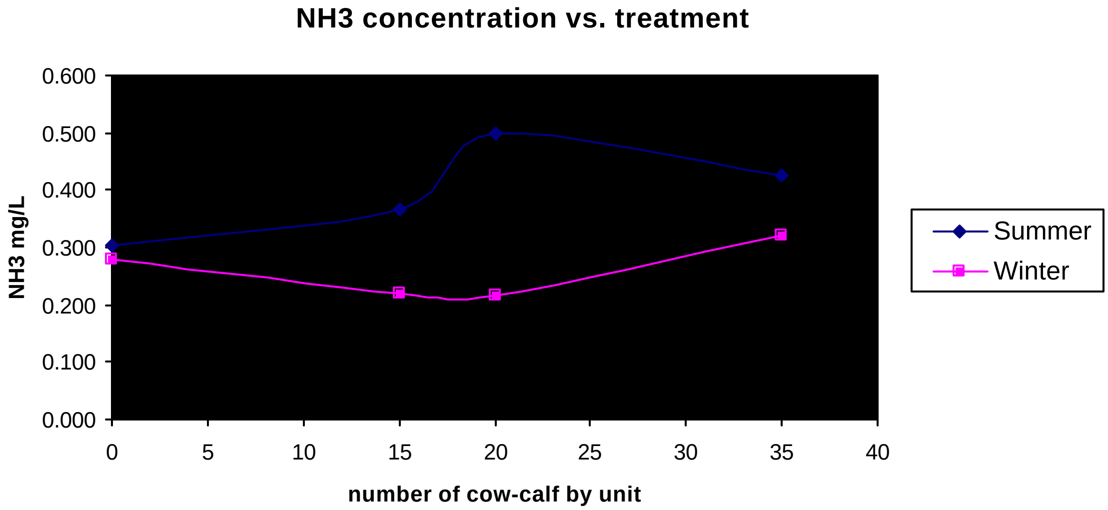


Figure 21. NOx concentration vs. treatment.

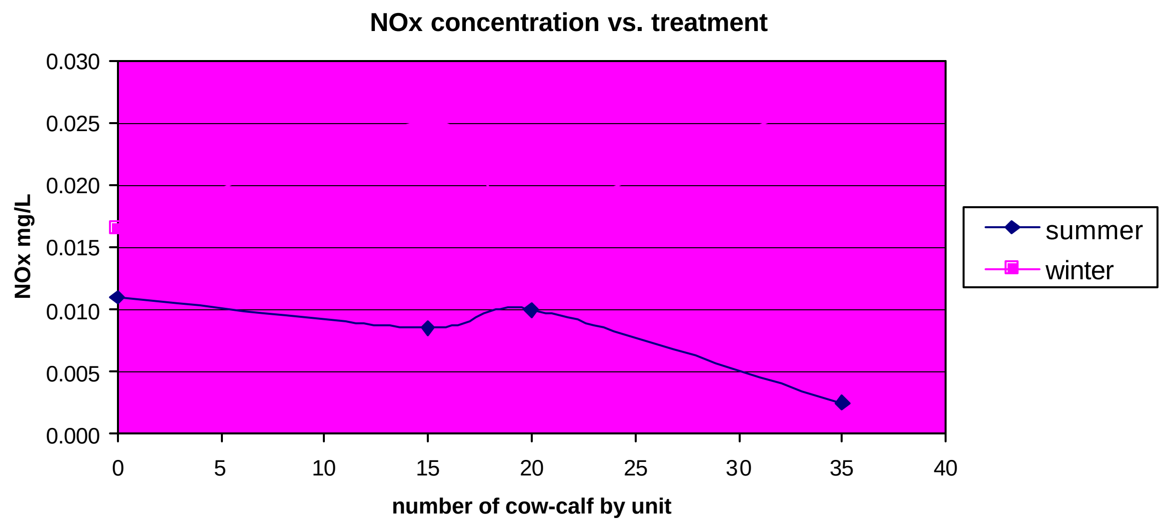


Figure 22. TKN concentration vs. treatment.

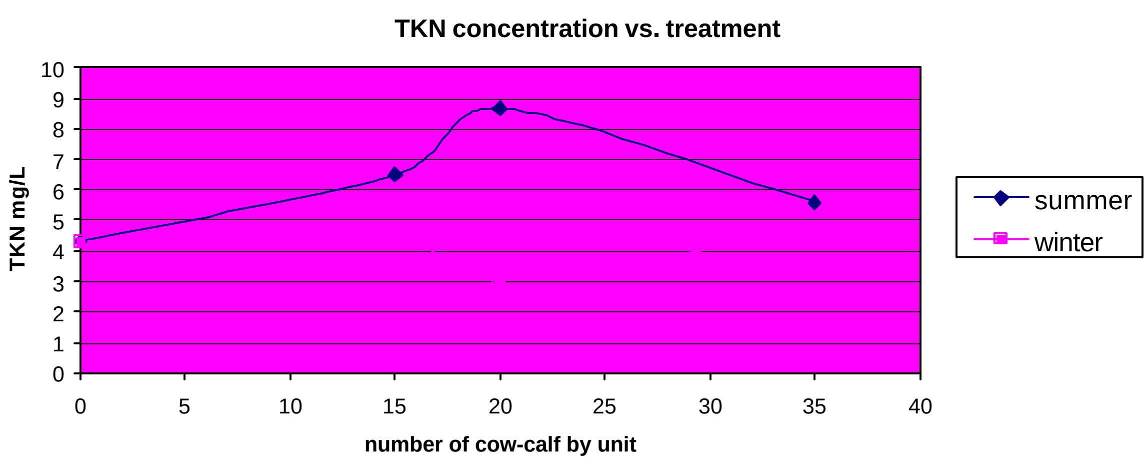
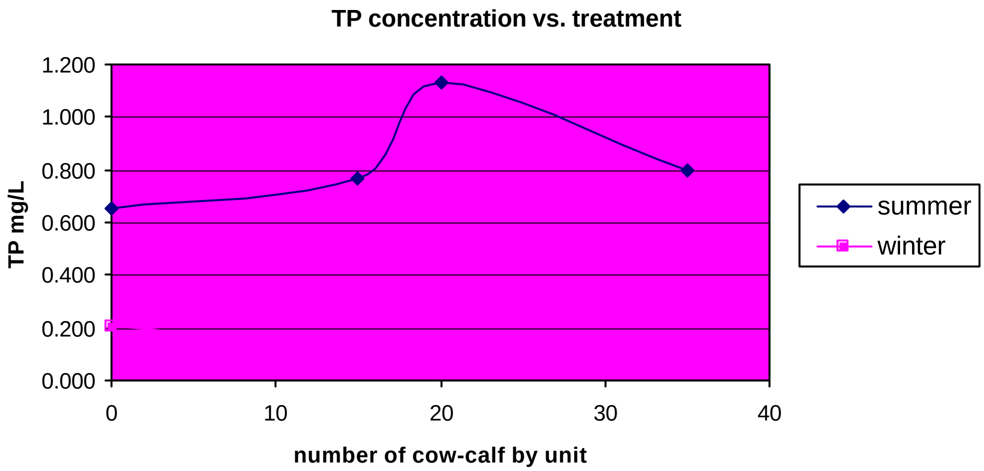


Figure 23. TP concentration vs. treatment.



III. Year 2000

Table 17. Means of concentration for each treatment.

		Control	Low	Medium	High
		0	**15**	**20**	**35**
NH3	Summer	0.275	0.128	0.099	0.112
	Winter	0.466	0.7373	0.7979	1.291
NOx	Summer	0.011	0.01	0.025	0.01
	Winter	0.1165	0.0257	0.095	0.075
TKN	Summer	2.65	2.71	2.058	2.272
	Winter	3.5235	4.6	4.2	5.1435
TP	Summer	0.402	0.277	0.184	0.212
	Winter	0.181	0.5262	0.118	0.393

Figure 24. NH3 concentration vs. treatment.

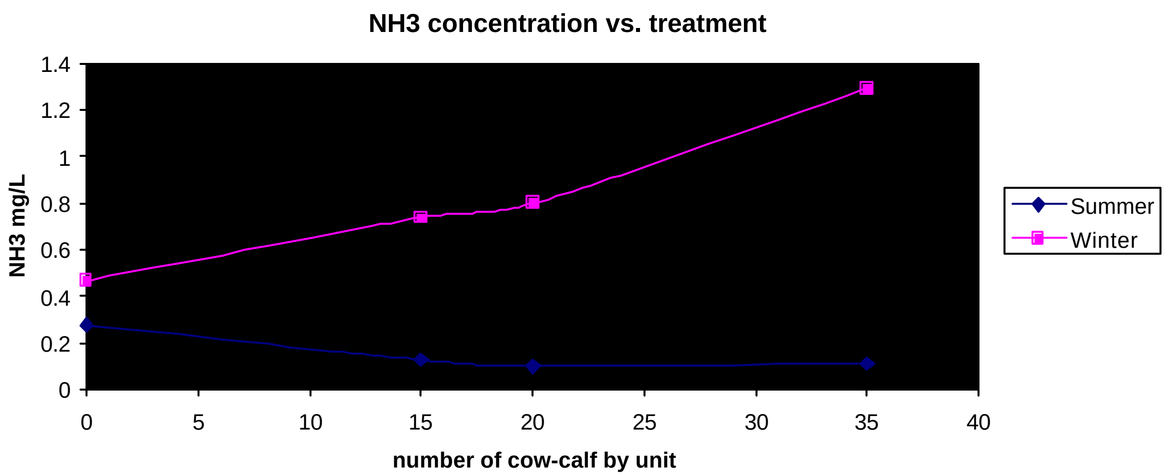


Figure 25. NOx concentration vs. treatment.

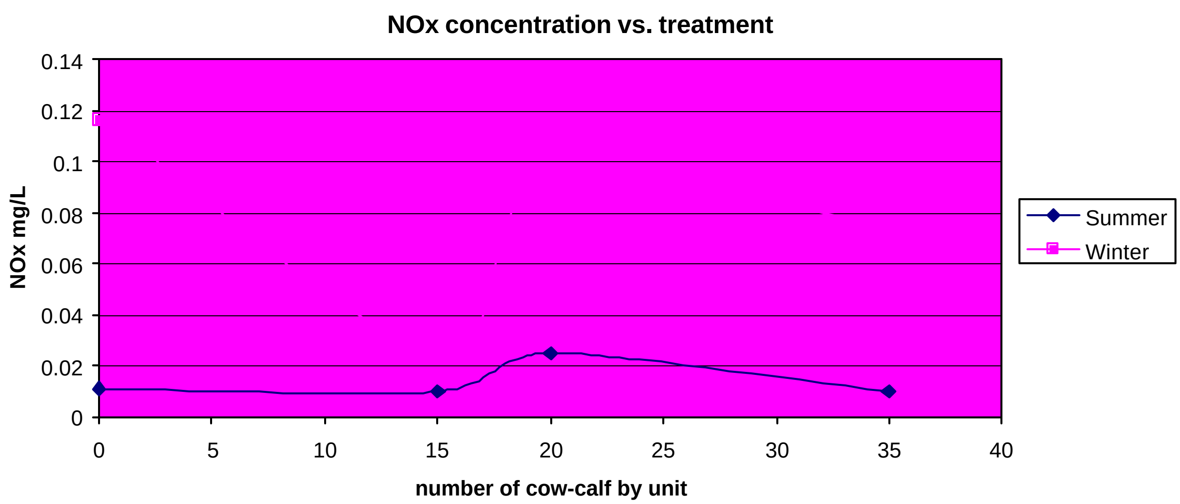


Figure 26. TKN concentration vs. treatment.

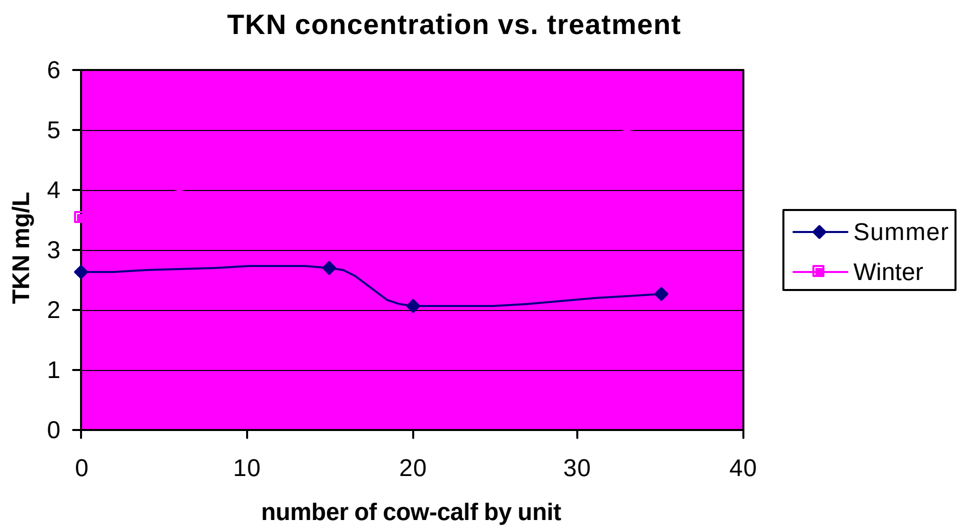
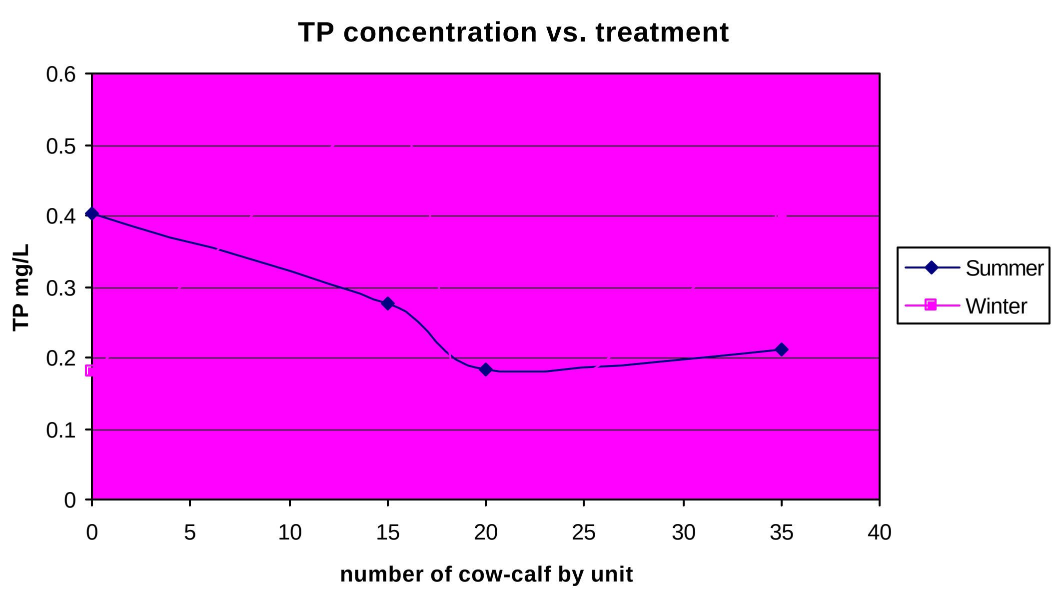


Figure 27. TP concentration vs. treatment.



V. Tukey's w test

1. Objective

So far, we carried out global tests in order to identify if a block or a treatment effect dould be found, analyzing, analyzing the whole data (16 sites). It is possible to process a more advanced study, analyzing all the treatments by pairs. Let's consider the Tukey's *w* procedure. It makes use of the Studentized range and is applicable to pairwise comparisons of means. It requires a single value for judging the significance of all differences and is thus quick and easy to use. However, this test can only consider one factor at a time (it is a one-way ANOVA test). It is the reason why we will apply it only for the sites within a block (summer/winter).

2. Tukey's *w* procedure on Minitab

MS Excel cannot carry out this kind of tests. Therefore, Minitab was used instead. Just as we did for the GLM test, we put all the data in a column with the treatment corresponding in another one. Obviously, the 2 columns must have the same length.

Then, we just select *Stat / ANOVA / One-way* and specify the option *Comparison / Tukey's* with a family error rate of 5%.

Therefore, we obtain in the Session window the results, which consist on:

?? A one-way analysis of variance for all the data
?? A table with the means, standard deviations and confidence interval
?? The Tukey's test

The first pair of number in the Tukey output table gives the confidence interval for the difference between the mean of *Column* and the mean of *Row* (for instance for the first test: mean of concentration of S1 – idem for S8). [See the first table]. If 0 is not included in this interval (when the 2 values have the same sign), it means that the means can be declared different (since the difference cannot be null).

If it is the case for 2 means in a same treatment, it means that 2 replications present different averages. Obviously, it is bad for our study since it shows we cannot trust the treatment effect. Other parameters we cannot identify have an effect on the concentrations. Don't forget that a negative result shows that 2 means are significantly different but a positive result do not show that the 2 means are equal!

Besides, the case when the values have the same sign is expected for sites of different treatments, otherwise, we can also say that the variability of the data avoids knowing which the higher value among the two of them is.

3. Tests

Here are presented the results of the Tukey's w procedure.

0	We cannot compare the 2 means
+	Mean of column > Mean of row
-	Mean of column < Mean of row

Therefore, an experiment for which the replicates gave the same means and for which it is possible to see a significant difference between the treatments have the following results (given that the more the treatment is important, the higher the concentration should be):

Table 18. Tukey's test - Example.

Tukey's procedure		Control		Low		Medium		High
Example		S1	S8	S4	S6	S2	S7	S3
Control	S8	0						
Low	S4	+	+					
	S6	+	+	0				
Medium	S2	+	+	+	+			
	S7	+	+	+	+	0		
High	S3	+	+	+	+	+	+	
	S5	+	+	+	+	+	+	0

a. Tukey's procedure – 1999

Table 19. Tukey's test - Summer pasture - NH3 – 1999.

Tukey's procedure		Control		Low		Medium		High
NH3 - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	0						
Low	S4	0	0					
	S6	+	0	0				
Medium	S2	0	-	0	-			
	S7	0	0	0	0	0		
High	S3	0	0	0	-	0	0	
	S5	0	0	0	0	+	0	0

Table 20. Tukey's test - Winter pasture – NH3 – 1999.

Tukey's procedure		Control		Low		Medium		High
NH3 - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	0						
Low	W1	+	0					
	W6	0	0	0				
Medium	W2	0	0	0	0			
	W8	0	0	-	0	0		
High	W3	0	0	0	0	0	0	
	W5	0	0	-	0	-	0	0

Table 21. Tukey's test - Summer pasture - NOx – 1999.

Tukey's procedure		Control		Low		Medium		High
NOx - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	0						
Low	S4	0	0					
	S6	0	0	0				
Medium	S2	0	0	0	0			
	S7	0	0	0	0	0		
High	S3	0	0	0	0	+	+	
	S5	0	0	0	0	+	+	0

Table 22. Tukey's test - Winter pasture - NOx – 1999.

Tukey's procedure		Control		Low		Medium		High
NOx - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	0						
Low	W1	-	-					
	W6	0	0	+				
Medium	W2	0	0	0	0			
	W8	0	0	0	0	0		
High	W3	0	0	+	0	0	0	
	W5	0	0	0	0	0	0	-

Table 23. Tukey's test - Summer pasture - TKN – 1999.

Tukey's procedure		Control		Low		Medium		High
TKN - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	0						
Low	S4	0	0					
	S6	0	0	0				
Medium	S2	0	0	0	0			
	S7	0	0	0	0	0		
High	S3	0	0	0	0	0	0	
	S5	0	0	0	0	0	0	0

Table 24. Tukey's test - Winter pasture - TKN – 1999.

Tukey's procedure		Control		Low		Medium		High
TKN - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	0						
Low	W1	0	0					
	W6	0	0	0				
Medium	W2	0	0	0	0			
	W8	0	0	0	0	0		
High	W3	0	0	0	0	0	0	
	W5	0	0	0	0	0	0	0

Table 25. Tukey's test - Summer pasture - TP – 1999.

Tukey's procedure		Control		Low		Medium		High
TP - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	0						
Low	S4	0	0					
	S6	0	0	0				
Medium	S2	0	0	0	0			
	S7	0	0	0	0	0		
High	S3	0	0	0	0	0	0	
	S5	0	0	0	0	0	0	0

Table 26. Tukey's test - Winter pasture - TP – 1999.

Tukey's procedure		Control		Low		Medium		High
TP - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	0						
Low	W1	0	0					
	W6	0	0	0				
Medium	W2	0	0	0	0			
	W8	0	0	0	0	0		
High	W3	0	0	0	0	0	0	
	W5	0	0	0	0	0	0	0

b. Tukey's procedure – 2000

Table 27. Tukey's test - Summer pasture - NH3 – 2000.

Tukey's procedure		Control		Low		Medium		High
NH3 - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	0						
Low	S4	0	0					
	S6	0	0	0				
Medium	S2	0	0	0	0			
	S7	0	0	0	0	0		
High	S3	0	0	0	0	0	0	
	S5	0	0	0	0	0	0	0

Table 28. Tukey's test - Winter pasture - NH3 – 2000.

Tukey's procedure		Control		Low		Medium		High
NH3 - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	0						
Low	W1	0	0					
	W6	0	0	0				
Medium	W2	0	0	0	0			
	W8	0	0	0	0	0		
High	W3	0	0	0	0	0	0	
	W5	0	0	0	0	0	0	0

Table 29. Tukey's test - Sumer pasture - NOx – 2000.

Tukey's procedure		Control		Low		Medium		High
NOx - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	0						
Low	S4	0	0					
	S6	0	0	0				
Medium	S2	0	0	0	0			
	S7	0	0	0	0	0		
High	S3	0	0	0	0	0	0	
	S5	0	0	0	0	0	0	0

Table 30. Tukey's test - Winter pasture - NOx – 2000.

Tukey's procedure		Control		Low		Medium		High
NOx - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	0						
Low	W1	0	0					
	W6	0	0	0				
Medium	W2	0	0	0	0			
	W8	0	0	0	0	0		
High	W3	0	0	0	0	0	0	
	W5	0	0	0	0	0	0	0

Table 31. Tukey's test - Summer pasture - TKN – 2000.

Tukey's procedure		Control		Low		Medium		High
TKN - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	-						
Low	S4	0	0					
	S6	-	0	0				
Medium	S2	0	0	0	0			
	S7	0	0	0	0	0		
High	S3	0	0	0	0	0	0	
	S5	-	0	0	0	0	0	0

Table 32. Tukey's test - Winter pasture - TKN – 2000.

Tukey's procedure		Control		Low		Medium		High
TKN - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	0						
Low	W1	0	0					
	W6	0	0	0				
Medium	W2	0	0	0	0			
	W8	0	0	0	0	0		
High	W3	0	0	0	0	0	0	
	W5	0	0	0	0	0	0	?? 0

Table 33. Tukey's test - Summer pasture - TP – 2000.

Tukey's procedure		Control		Low		Medium		High
TP - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	-						
Low	S4	-	0					
	S6	-	0	0				
Medium	S2	0	0	0	0			
	S7	0	0	0	0	0		
High	S3	0	0	0	0	0	0	
	S5	-	0	0	0	0	0	0

Table 34. Tukey's test - Winter pasture - TP – 2000.

Tukey's procedure		Control		Low		Medium		High
TP - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	0						
Low	W1	0	0					
	W6	-	0	-				
Medium	W2	0	0	0	+			
	W8	0	0	0	+	0		
High	W3	0	0	0	0	0	-	O
	W5	0	0	0	+	0	0	0

c. Tukey's procedure – 2001

Table 35. Tukey's test - Summer pasture - NH3 – 2001.

Tukey's procedure		Control		Low		Medium		High
NH3 - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	+	0					
Low	S4	+	0					
	S6	0	0	0				
Medium	S2	0	0	0	0			
	S7	+	0	0	0	0		
High	S3	+	0	0	0	0	0	
	S5	0	+	0	0	0	0	0

Table 36. Tukey's test - Winter pasture - NH3 – 2001.

Tukey's procedure		Control		Low		Medium		High
NH3 - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	+						
Low	W1	0	0					
	W6	0	0	0				
Medium	W2	0	+	0	+			
	W8	+	0	0	0	+		
High	W3	-	0	+	-	+	0	
	W5	0	0	0	0	+	0	0

Table 37. Tukey's test - Summer pasture - NOx – 2001.

Tukey's procedure		Control		Low		Medium		High
NOx - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	0						
Low	S4	0	0					
	S6	0	0	0				
Medium	S2	0	0	0	0			
	S7	0	0	0	0	0		
High	S3	0	0	0	0	0	0	
	S5	0	0	0	0	0	0	0

Table 38. Tukey's test - Winter pasture - NOx – 2001.

Tukey's procedure		Control		Low		Medium		High
NOx - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	+						
Low	W1	0	+					
	W6	0	0	+				
Medium	W2	0	+	0	+			
	W8	+	0	+	0	+		
High	W3	0	0	+	0	+	0	
	W5	0	0	0	0	0	+	-

Table 39. Tukey's test - Summer pasture - TKN – 2001.

Tukey's procedure		Control		Low		Medium		High
TKN - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	0						
Low	S4	0	0					
	S6	0	0	0				
Medium	S2	0	0	0	0			
	S7	0	0	0	0	0		
High	S3	0	0	0	-	0	0	
	S5	0	0	0	0	+	0	0

Table 40. Tukey's test - Winter pasture - TKN – 2001.

Tukey's procedure		Control		Low		Medium		High
TKN - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	0						
Low	W1	0	0					
	W6	0	0	0				
Medium	W2	0	0	-	0			
	W8	0	+	0	0	+		
High	W3	0	0	0	0	0	0	
	W5	0	0	0	0	0	0	0

Table 41. Tukey's test - Summer pasture - TP – 2001.

Tukey's procedure		Control		Low		Medium		High
TP - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	0						
Low	S4	0	0					
	S6	0	0	0				
Medium	S2	0	0	0	0			
	S7	0	0	+	0	0		
High	S3	0	0	0	0	0	0	
	S5	0	0	+	0	0	0	0

Table 42. Tukey's test - Winter pasture - TP – 2001.

Tukey's procedure		Control		Low		Medium		High
TP - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	-						
Low	W1	0	0					
	W6	-	0	0				
Medium	W2	0	0	0	0			
	W8	0	+	+	+	+		
High	W3	+	0	-	0	0	+	
	W5	-	0	0	0	0	+	0

4. Conclusion

I considered as useless the fact of drawing a conclusion for each test. Indeed, all the results go along the same lines:

?? The majority of the cells are null, what it means that the distributions do not allow comparing two means each other.

?? There is not a majority of positive results compared to negative ones. It states that a more important treatment increase a nutrient concentration sometimes, decrease it other times.

Therefore, all the different conclusions agree to say that the data of 1999/2000/2001 are incapable to bring to the fore a difference between the 4 different treatments: control, low, medium, high. Consequently:

?? Either it does exist an influence but the experiment has not managed to unveil it, because of experiment errors or simply because the signal is lost in a noise of high amplitude.

?? Either it must be admitted that the density of cow/calf by unit has no effect on the concentration of the 4 nutrients concerned.

Conclusion

This paper brings to the fore the difficulty of drawing conclusions for the Buck Island Project. First of all, we have seen that the data contained several anomalies, which revealed experimental errors (measuring the parameter) or computer errors (reporting the value in the database) mistakes. Nevertheless, after eliminating the outliers the statistical tests were performed. Then, the different conclusions must be drawn very cautiously because all the distributions used did not respect the normal distribution. Afterwards, we realized that means, which were supposed to be equal, are not, nearly for half of them, so that it is difficult to figure out what really happens (Sometimes, we have a ratio of 10 between two means representing the same treatment!). Lastly, even if the GLM tests state that an effect for a nutrient can be identified, it is less obvious to find the nature of this effect given that the curves of the concentration vs. the treatments are not monotonous (increasing curves were expected).

Appendix 1: GLM tests with Minitab (1999)

Factor	Type	Levels	Values			
Block	fixed	2	summer	winter		
Treatment	fixed	4	control	high	low	medium

Analysis of Variance for NH3, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	5.57339	4.90896	4.90896	122.67	0.000
Treatment	3	0.88935	0.82794	0.27598	6.90	0.000
Block*Treatment	3	0.23691	0.23691	0.07897	1.97	0.117
Error	729	29.17291	29.17291	0.04002		

Analysis of Variance for NOx, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	0.63091	0.91773	0.91773	11.09	0.001
Treatment	3	1.42231	1.19704	0.39901	4.82	0.002
Block*Treatment	3	1.13306	1.13306	0.37769	4.56	0.004
Error	731	60.49710	60.49710	0.08276		
Total	738	63.68338				

Analysis of Variance for TKN, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	2.59755	2.55429	2.55429	34.07	0.000
Treatment	3	0.05938	0.01850	0.00617	0.08	0.970
Block*Treatment	3	0.69137	0.69137	0.23046	3.07	0.027
Error	728	54.58008	54.58008	0.07497		
Total	735	57.92837				

Analysis of Variance for TP, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	119.906	114.569	114.569	810.40	0.000
Treatment	3	0.071	0.093	0.031	0.22	0.883
Block*Treatment	3	0.240	0.240	0.080	0.57	0.638
Error	729	103.060	103.060	0.141		
Total	736	223.277				

Appendix 2: GLM tests with Minitab (2000)

Factor	Type	Levels	Values			
Block	fixed	2	summer	winter		
Treatment	fixed	4	control	high	low	medium

Analysis of Variance for NH3, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	11.5341	11.5655	11.5655	48.36	0.000
Treatment	3	0.3635	0.3468	0.1156	0.48	0.695
Block*Treatment	3	1.1206	1.1206	0.3735	1.56	0.204
Error	87	20.8044	20.8044	0.2391		
Total	94	33.8226				

Analysis of Variance for NOx, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	4.1344	4.0470	4.0470	21.31	0.000
Treatment	3	1.2505	1.8139	0.6046	3.18	0.028
Block*Treatment	3	1.1362	1.1362	0.3787	1.99	0.121
Error	87	16.5216	16.5216	0.1899		
Total	94	23.0426				

Analysis of Variance for TKN, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	1.05733	0.93519	0.93519	13.22	0.000
Treatment	3	0.14164	0.18021	0.06007	0.85	0.471
Block*Treatment	3	0.22337	0.22337	0.07446	1.05	0.374
Error	87	6.15329	6.15329	0.07073		
Total	94	7.57563				

Analysis of Variance for TP, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	0.0068	0.0058	0.0058	0.03	0.864
Treatment	3	1.8215	2.0574	0.6858	3.52	0.018
Block*Treatment	3	0.4041	0.4041	0.1347	0.69	0.560
Error	87	16.9694	16.9694	0.1951		
Total	94	19.2017				

Appendix 3: GLM Test with Minitab (2001)

Factor	Type	Levels	Values
Block	fixed	2	summer winter
Treatment	fixed	4	control high low medium

Analysis of Variance for NH3_log, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	12.4749	12.5995	12.5995	119.27	0.000
Treatment	3	0.9325	0.7995	0.2665	2.52	0.056
Block*Treatment	3	1.2111	1.2111	0.4037	3.82	0.010
Error	1653	174.6262	174.6262	0.1056		
Total	1660	189.2447				

Analysis of Variance for NOx_log, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	24.3559	24.6486	24.6486	77.02	0.000
Treatment	3	1.2503	1.1405	0.3802	1.19	0.313
Block*Treatment	3	1.7684	1.7684	0.5895	1.84	0.138
Error	1653	528.9825	528.9825	0.3200		
Total	1660	556.3571				

Analysis of Variance for TKN_log, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	48.321	46.815	46.815	169.17	0.000
Treatment	3	93.519	81.524	27.175	98.20	0.000
Block*Treatment	3	93.588	93.588	31.196	112.73	0.000
Error	1652	457.173	457.173	0.277		
Total	1659	692.601				

Analysis of Variance for TP_log, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	247.353	245.141	245.141	1085.14	0.000
Treatment	3	3.332	3.032	1.011	4.47	0.004
Block*Treatment	3	3.611	3.611	1.204	5.33	0.001
Error	1653	373.425	373.425	0.226		
Total	1660	627.721				

Appendix 4

Tukey's test – NH3 – Summer - 1999

Source	DF	SS	MS	F	P
S	7	1.1349	0.1621	5.36	0.000
Error	381	11.5143	0.0302		
Total	388	12.6491			

```
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level       N      Mean     StDev   -------+---------+---------+---------
1          50   -0.5175    0.1721                   (-----*-----)
2          45   -0.4797    0.1400                        (-----*-----)
3          29   -0.5221    0.2896                 (-------*-------)
4          44   -0.5632    0.1838             (------*-----)
5          45   -0.6170    0.1841       (-----*-----)
6          57   -0.6493    0.1560   (-----*----)
              0.2078      0.2484       0.2204      0.1656-)
8          52   -0.6139    0.1543       (-----*-----)
                                    -------+---------+---------+---------
Pooled StDev =   0.1738                 -0.640    -0.560    -0.480
```

Tukey's pairwise comparisons

Family error rate = 0.0500
Individual error rate = 0.00258

Critical value = 4.29

Intervals for (column level mean) - (row level mean)

	1	2	3	4	5	6	7
2	-0.1461						
	0.0706						
3	-0.1185	-0.0832					
	0.1277	0.1680					
4	-0.0633	-0.0283	-0.0851				
	0.1547	0.1953	0.1672				
5	-0.0089	0.0261	-0.0307	-0.0580			
	0.2078	0.2484	0.2204	0.1656			
6	0.0296	0.0644	0.0069	-0.0197	-0.0729		
	0.2340	0.2747	0.2474	0.1919	0.1375		
7	-0.0538	-0.0191	-0.0771	-0.1033	-0.1564	-0.1820	
	0.1433	0.1842	0.1574	0.1014	0.0469	0.0080	-0.0458
8	-0.0080	0.0268	-0.0304	-0.0573	-0.1104	-0.1365	-0.0458
	0.2009	0.2415	0.2140	0.1587	0.1043	0.0658	0.1491

Tukey's test – NOx – Summer - 1999

Source	DF	SS	MS	F	P
S	7	1.5997	0.2285	4.53	0.000
Error	383	19.3157	0.0504		
Total	390	20.9154			

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev  --------+---------+---------+--------
1          50   -1.8242    0.2117                     (------*-----)
2          45   -1.7801    0.2707                         (------*------)
3          29   -1.9896    0.0559   (-------*-------)
8          53   -1.8969    0.2291             (-----*-----)
5          45   -1.9444    0.1324        (------*-----)
6          57   -1.8751    0.2367                (----*-----)
7          67   -1.7955    0.2906                        (----*-----)
8          53   -1.8969    0.2291             (-----*-----)
                                   --------+---------+---------+--------
Pooled StDev =   0.2246                 -2.00     -1.90     -1.80
```

Tukey's pairwise comparisons

Family error rate = 0.0500
Individual error rate = 0.00258

Critical value = 4.29

Intervals for (column level mean) - (row level mean)

	1	2	3	4	5	6	7
2	-0.1840						
	0.0959						
3	0.0064	0.0473					
	0.3244	0.3717					
4	-0.0578	-0.0174	-0.2455				
	0.2221	0.2698	0.0789				
5	-0.0198	0.0207	-0.2074	-0.1055			
	0.2602	0.3079	0.1170	0.1817			
6	-0.0811	-0.0409	-0.2699	-0.1671	-0.2052		
	0.1829	0.2308	0.0408	0.1046	0.0665		
7	-0.1560	-0.1159	-0.3455	-0.2421	-0.2802	-0.2023	
	0.0986	0.1467	-0.0427	0.0205	-0.0176	0.0432	
8	-0.0617	-0.0214	-0.2501	-0.1476	-0.1857	-0.1082	-0.0239
	0.2070	0.2548	0.0646	0.1286	0.0905	0.1518	0.2265

Tukey’s test – TKN – Summer - 1999

Source	DF	SS	MS	F	P
S	7	0.6218	0.0888	1.29	0.252
Error	380	26.0863	0.0686		
Total	387	26.7081			

```
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level      N      Mean     StDev    ----------+---------+---------+------
1         50    0.6403    0.1472               (--------*--------)
2         45    0.6839    0.0993                    (--------*---------)
3         28    0.5964    0.2703      (------------*-----------)
4         45    0.5641    0.2798     (---------*--------)
5         44    0.5999    0.3105         (---------*---------)
7         66    0.6598    0.2194                   (------*-------)
8         53    0.5721    0.3379       (--------*-------)
                                    ----------+---------+---------+------
Pooled StDev =    0.2620                    0.560     0.640     0.720
```

Tukey's pairwise comparisons

Family error rate = 0.0500
Individual error rate = 0.00258

Critical value = 4.29

Intervals for (column level mean) - (row level mean)

	1	2	3	4	5	6	7
2	-0.2069						
	0.1197						
3	-0.1437	-0.1038					
	0.2315	0.2788					
4	-0.0871	-0.0477	-0.1590				
	0.2396	0.2874	0.2236				
5	-0.1239	-0.0845	-0.1957	-0.2044			
	0.2047	0.2525	0.1886	0.1327			
6	-0.1147	-0.0756	-0.1881	-0.1955	-0.1606		
	0.1933	0.2414	0.1788	0.1215	0.1584		
7	-0.1685	-0.1295	-0.2426	-0.2494	-0.2145	-0.2024	
	0.1296	0.1778	0.1159	0.0579	0.0948	0.0850	
8	-0.0885	-0.0493	-0.1614	-0.1691	-0.1343	-0.1227	-0.0589
	0.2249	0.2730	0.2100	0.1531	0.1899	0.1806	0.2343

Tukey's test – TP – Summer - 1999

```
Source     DF       SS        MS        F        P
S           7    0.945     0.135     0.82    0.575
Error     381   63.117     0.166
Total     388   64.063
                                   Individual 95% CIs For Mean
3          28  -0.4637    0.5062  (---------*---------)
Level       N     Mean     StDev  -+---------+---------+---------+-----
1          49  -0.3688    0.3963          (------*-------)
2          45  -0.3312    0.3362            (-------*-------)
3          28  -0.4637    0.5062  (---------*---------)
4          45  -0.3865    0.4409        (-------*-------)
5          45  -0.3259    0.4862            (-------*-------)
6          57  -0.3308    0.3167             (------*------)
7          67  -0.3581    0.4637            (-----*------)
8          53  -0.2583    0.3077                 (-------*------)
                                  -+---------+---------+---------+-----
Pooled StDev =   0.4070         -0.60     -0.45     -0.30     -0.15

Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.00258

Critical value = 4.29

Intervals for (column level mean) - (row level mean)

        1           2           3           4           5           6       7
2  -0.2925
    0.2174
3  -0.1976     -0.1647
    0.3874      0.4296
4  -0.2371     -0.2050     -0.3743
    0.2727      0.3156      0.2201
5  -0.2978     -0.2656     -0.4350     -0.3210
    0.2120      0.2550      0.1594      0.1996
6  -0.2785     -0.2466     -0.4178     -0.3020     -0.2413
    0.2025      0.2458      0.1521      0.1904      0.2511
7  -0.2428     -0.2111     -0.3834     -0.2665     -0.2058     -0.1952
    0.2214      0.2648      0.1722      0.2095      0.2701      0.2498
8  -0.3551     -0.3232     -0.4938     -0.3785     -0.3178     -0.3080  -0.3267
    0.1342      0.1774      0.0831      0.1221      0.1827      0.1632   0.1272
```

Tukey's test – TP – Winter - 1999

Source	DF	SS	MS	F	P
W	7	0.561	0.080	0.70	0.670
Error	340	38.748	0.114		
Total	347	39.308			

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
1          50   -1.0910    0.3116                 (--------*--------)
2          38   -1.2183    0.4920  (----------*----------)
3          31   -1.1500    0.2242        (-----------*-----------)
4          74   -1.1744    0.2284          (-------*------)
5          44   -1.1224    0.3340             (---------*---------)
6          52   -1.1958    0.2663    (--------*---------)
7          37   -1.1285    0.5474         (----------*----------)
8          22   -1.1278    0.1573        (-------------*-------------)
                                   ---+---------+---------+---------+---
Pooled StDev =   0.3376            -1.30     -1.20     -1.10     -1.00
```

Tukey's pairwise comparisons

Family error rate = 0.0500
Individual error rate = 0.00260

Critical value = 4.29

Intervals for (column level mean) - (row level mean)

	1	2	3	4	5	6	7
2	-0.0931						
	0.3477						
3	-0.1751	-0.3162					
	0.2931	0.1795					
4	-0.1040	-0.2482	-0.1946				
	0.2709	0.1605	0.2436				
5	-0.1802	-0.3226	-0.2677	-0.2470			
	0.2431	0.1309	0.2126	0.1429			
6	-0.0980	-0.2411	-0.1866	-0.1640	-0.1364		
	0.3076	0.1960	0.2782	0.2067	0.2831		
7	-0.1846	-0.3263	-0.2708	-0.2521	-0.2224	-0.2875	
	0.2596	0.1467	0.2279	0.1602	0.2345	0.1530	
8	-0.2252	-0.3649	-0.3077	-0.2953	-0.2620	-0.3285	-0.2764
	0.2988	0.1838	0.2633	0.2020	0.2728	0.1925	0.2750

Tukey’s test – TKN – Winter - 1999

Source	DF	SS	MS	F	P
W	7	0.4373	0.0625	0.75	0.627
Error	340	28.1854	0.0829		
Total	347	28.6227			

```
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level       N      Mean     StDev     --------+---------+---------+--------
1          50    0.4951    0.1350               (-------*-------)
2          38    0.4140    0.3825     (--------*---------)
3          31    0.5332    0.2055                (---------*---------)
4          74    0.5106    0.2907                 (------*------)
5          44    0.5228    0.2246                 (-------*--------)
6          52    0.5303    0.2671                  (-------*-------)
7          37    0.4691    0.4813           (--------*--------)
8          22    0.4809    0.1190         (-----------*----------)
                                      --------+---------+---------+--------
Pooled StDev =   0.2879                     0.40      0.50      0.60
```

Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.00260

Critical value = 4.29

Intervals for (column level mean) - (row level mean)

	1	2	3	4	5	6	7
2	-0.1068						
	0.2691						
3	-0.2377	-0.3306					
	0.1616	0.0922					
4	-0.1753	-0.2709	-0.1643				
	0.1444	0.0777	0.2095				
5	-0.2082	-0.3022	-0.1944	-0.1785			
	0.1529	0.0846	0.2152	0.1541			
6	-0.2081	-0.3027	-0.1953	-0.1777	-0.1864		
	0.1379	0.0701	0.2011	0.1384	0.1714		
7	-0.1633	-0.2568	-0.1485	-0.1343	-0.1411	-0.1267	
	0.2155	0.1467	0.2768	0.2174	0.2485	0.2490	
8	-0.2092	-0.3009	-0.1912	-0.1824	-0.1861	-0.1728	-0.2470
	0.2377	0.1671	0.2958	0.2418	0.2700	0.2715	0.2233

Tukey’s test – NOx – Winter - 1999

Source	DF	SS	MS	F	P
W	7	4.001	0.572	5.10	0.000
Error	340	38.136	0.112		
Total	347	42.137			

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev  ---------+---------+---------+-------
1           50   -1.6297    0.6012                          (-----*------)
2           38   -1.8272    0.2905            (------*------)
3           31   -1.9612    0.1287  (-------*-------)
4           74   -1.8702    0.2650           (----*----)
5           44   -1.7024    0.3174                     (------*-----)
6           52   -1.8538    0.2289           (-----*------)
7           37   -1.9170    0.1534      (------*------)
8           22   -1.6828    0.4269                   (---------*--------)
                                    ---------+---------+---------+-------
Pooled StDev =   0.3349                  -1.95     -1.80     -1.65
```

Tukey's pairwise comparisons

Family error rate = 0.0500
Individual error rate = 0.00260

Critical value = 4.29

Intervals for (column level mean) - (row level mean)

	1	2	3	4	5	6	7
2	-0.0211						
	0.4162						
3	0.0992	-0.1119					
	0.5637	0.3798					
4	0.0545	-0.1598	-0.3083				
	0.4265	0.2457	0.1264				
5	-0.1373	-0.3498	-0.4970	-0.3612			
	0.2827	0.1002	-0.0205	0.0256			
6	0.0229	-0.1902	-0.3379	-0.2002	-0.0567		
	0.4253	0.2434	0.1232	0.1675	0.3595		
7	0.0670	-0.1449	-0.2916	-0.1578	-0.0120	-0.1553	
	0.5076	0.3244	0.2032	0.2513	0.4412	0.2817	
8	-0.2068	-0.4165	-0.5615	-0.4341	-0.2848	-0.4294	-0.5077
	0.3131	0.1278	0.0049	0.0593	0.2457	0.0874	0.0394

Tukey’s test – NH3 – Winter – 1999

```
Source     DF        SS        MS        F        P
W           7    1.6877    0.2411     5.14    0.000
Error     340   15.9624    0.0469
Total     347   17.6501

                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --------+---------+---------+--------
1          50   -0.8703    0.3043  (----*-----)
2          38   -0.7827    0.2125         (-----*-----)
3          31   -0.7563    0.2536           (-----*-----)
4          74   -0.7273    0.2175               (---*----)
5          44   -0.6336    0.1340                      (----*-----)
6          52   -0.7538    0.1874            (----*----)
2          38   -0.7827    0.2125         (-----*-----) r M
8          22   -0.6339    0.1394                    (------*-------)
                                   --------+---------+---------+--------
Pooled StDev =   0.2167                 -0.84     -0.72     -0.60


Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.00260

Critical value = 4.29

Intervals for (column level mean) - (row level mean)

       1           2           3           4           5           6         7
2  -0.2290
    0.0539
3  -0.2642     -0.1855
    0.0363      0.1326
4  -0.2633     -0.1866     -0.1696
   -0.0226      0.0758      0.1116
5  -0.3725     -0.2947     -0.2768     -0.2189
   -0.1008     -0.0036      0.0314      0.0314
6  -0.2466     -0.1691     -0.1516     -0.0924     -0.0144
    0.0138      0.1114      0.1467      0.1455      0.2549
7  -0.2707     -0.1924     -0.1742     -0.1175     -0.0381     -0.1531
    0.0144      0.1112      0.1459      0.1471      0.2551      0.1296
8  -0.4045     -0.3249     -0.3056     -0.2530     -0.1713     -0.2871  -0.2852
   -0.0682      0.0273      0.0608      0.0662      0.1719      0.0472   0.0687
```

Tukey's test – NH3 – Summer – 2000

Source	DF	SS	MS	F	P
S	7	1.818	0.260	1.14	0.350
Error	52	11.797	0.227		
Total	59	13.616			

```
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level       N      Mean     StDev   -+---------+---------+---------+-----
1           8   -0.8803    0.5185                  (---------*---------)
2           7   -1.3169    0.3951      (---------*----------)
3           5   -1.3442    0.4011   (------------*-----------)
4           8   -1.0078    0.5259                (--------*---------)
5           8   -0.9350    0.4057                  (--------*---------)
6           5   -1.1830    0.3564        (-----------*-----------)
7          11   -0.9720    0.4543                  (-------*-------)
8           8   -0.8242    0.6182                     (--------*---------)
                                    -+---------+---------+---------+-----
Pooled StDev =   0.4763          -1.75     -1.40     -1.05     -0.70
```

Tukey's pairwise comparisons

Family error rate = 0.0500
Individual error rate = 0.00262

Critical value = 4.47

Intervals for (column level mean) - (row level mean)

	1	2	3	4	5	6	7
2	-0.3425						
	1.2158						
3	-0.3943	-0.8542					
	1.3222	0.9089					
4	-0.6253	-1.0883	-1.1948				
	0.8802	0.4700	0.5218				
5	-0.6980	-1.1611	-1.2675	-0.8255			
	0.8075	0.3973	0.4490	0.6800			
6	-0.5555	-1.0154	-1.1134	-0.6830	-0.6103		
	1.1610	0.7476	0.7909	1.0335	1.1063		
7	-0.6078	-1.0728	-1.1842	-0.7353	-0.6625	-1.0230	
	0.7913	0.3830	0.4398	0.6638	0.7366	0.6010	
8	-0.8089	-1.2719	-1.3784	-0.9364	-0.8636	-1.2171	-0.8474
	0.6966	0.2864	0.3382	0.5691	0.6419	0.4994	0.5517

Tukey's test – NOx – Summer – 2000

Source	DF	SS	MS	F	P
S	7	0.1797	0.0257	0.56	0.788
Error	52	2.4011	0.0462		
Total	59	2.5808			

```
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level        N      Mean     StDev     -------+---------+---------+---------
1            8   -2.0000    0.0000         (---------*---------)
2            7   -2.0000    0.0000        (----------*----------)
3            5   -2.0000    0.0000      (------------*------------)
4            8   -2.0000    0.0000         (---------*---------)
5            8   -2.0000    0.0000         (---------*---------)
6            5   -2.0000    0.0000      (------------*------------)
7           11   -1.8585    0.4692                   (--------*--------)
8            8   -1.9404    0.1687            (----------*---------)
                                       -------+---------+---------+---------
Pooled StDev =   0.2149                    -2.10     -1.95     -1.80
```

Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.00262

Critical value = 4.47

Intervals for (column level mean) - (row level mean)

	1	2	3	4	5	6	7
2	-0.3515						
	0.3515						
3	-0.3872	-0.3977					
	0.3872	0.3977					
4	-0.3396	-0.3515	-0.3872				
	0.3396	0.3515	0.3872				
5	-0.3396	-0.3515	-0.3872	-0.3396			
	0.3396	0.3515	0.3872	0.3396			
6	-0.3872	-0.3977	-0.4296	-0.3872	-0.3872		
	0.3872	0.3977	0.4296	0.3872	0.3872		
7	-0.4571	-0.4699	-0.5078	-0.4571	-0.4571	-0.5078	
	0.1741	0.1869	0.2248	0.1741	0.1741	0.2248	
8	-0.3992	-0.4112	-0.4468	-0.3992	-0.3992	-0.4468	-0.2338
	0.2800	0.2919	0.3276	0.2800	0.2800	0.3276	0.3974

Tukey's test – TKN – Summer – 2000

Source	DF	SS	MS	F	P
S	7	1.2179	0.1740	4.29	0.001
Error	52	2.1081	0.0405		
Total	59	3.3260			

Level	N	Mean	StDev
1	8	0.0536	0.2229
2	7	0.2340	0.1247
3	5	0.2723	0.1101
4	8	0.3252	0.0988
5	8	0.3975	0.1449
6	5	0.4623	0.2539
7	11	0.2992	0.2561
8	8	0.5525	0.2645

```
Individual 95% CIs For Mean
Based on Pooled StDev
----+---------+---------+---------+--
(-----*-----)
       (-----*-----)
        (------*------)
           (-----*-----)
              (-----*-----)
               (------*-------)
           (----*----)
                    (-----*-----)
----+---------+---------+---------+--
  0.00      0.25      0.50      0.75
```

Pooled StDev = 0.2013

Tukey's pairwise comparisons

Family error rate = 0.0500
Individual error rate = 0.00262

Critical value = 4.47

Intervals for (column level mean) - (row level mean)

	1	2	3	4	5	6	7
2	-0.5098						
	0.1489						
3	-0.5815	-0.4109					
	0.1441	0.3344					
4	-0.5899	-0.4206	-0.4158				
	0.0465	0.2382	0.3099				
5	-0.6622	-0.4929	-0.4881	-0.3905			
	-0.0258	0.1659	0.2375	0.2459			
6	-0.7716	-0.6009	-0.5925	-0.4999	-0.4276		
	-0.0459	0.1444	0.2125	0.2257	0.2980		
7	-0.5414	-0.3729	-0.3702	-0.2697	-0.1974	-0.1802	
	0.0501	0.2425	0.3163	0.3217	0.3941	0.5064	
8	-0.8172	-0.6479	-0.6430	-0.5455	-0.4732	-0.4530	-0.5490
	-0.1807	0.0109	0.0826	0.0909	0.1632	0.2726	0.0424

Tukey’s test – TP – Summer – 2000

Source	DF	SS	MS	F	P
S	7	5.456	0.779	4.94	0.000
Error	52	8.205	0.158		
Total	59	13.661			

```
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level         N      Mean     StDev    ---+---------+---------+---------+---
1             8   -1.3358    0.3469     (----*-----)
2             7   -0.9032    0.3575            (-----*-----)
3             5   -0.9738    0.3646         (-------*------)
4             8   -0.5956    0.4026                  (-----*-----)
5             8   -0.4842    0.3093                     (----*-----)
6             5   -0.5459    0.4502                  (------*------)
7            11   -0.7598    0.4032                (----*----)
8             8   -0.3409    0.5103                        (----*-----)
                                       ---+---------+---------+---------+---
Pooled StDev =    0.3972               -1.50     -1.00     -0.50      0.00
```

Tukey's pairwise comparisons

Family error rate = 0.0500
Individual error rate = 0.00262

Critical value = 4.47

Intervals for (column level mean) - (row level mean)

	1	2	3	4	5	6	7
2	-1.0824						
	0.2172						
3	-1.0778	-0.6646					
	0.3538	0.8057					
4	-1.3679	-0.9574	-1.0940				
	-0.1124	0.3422	0.3376				
5	-1.4794	-1.0688	-1.2054	-0.7392			
	-0.2238	0.2308	0.2262	0.5164			
6	-1.5057	-1.0925	-1.2220	-0.7655	-0.6541		
	-0.0741	0.3778	0.3662	0.6660	0.7775		
7	-1.1594	-0.7505	-0.8912	-0.4192	-0.3078	-0.4633	
	0.0074	0.4636	0.4632	0.7476	0.8590	0.8911	
8	-1.6226	-1.2121	-1.3486	-0.8824	-0.7710	-0.9207	-1.0022
	-0.3671	0.0875	0.0829	0.3731	0.4845	0.5108	0.1646

Tukey's test – TP– Winter – 2000

Source	DF	SS	MS	F	P
W	7	3.2243	0.4606	5.39	0.001
Error	27	2.3093	0.0855		
Total	34	5.5335			

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev  ---------+---------+---------+-------
1            5   -0.8834    0.4354        (----*-----)
2            6   -0.8977    0.1735        (----*----)
3            4   -0.3650    0.2809                  (-----*-----)
4            5   -0.9268    0.1465       (----*-----)
5            4   -0.5900    0.2645             (-----*-----)
6            4   -0.1343    0.3047                      (-----*-----)
7            3   -0.6259    0.0709            (-----*------)
8            4   -1.1435    0.4395  (-----*-----)
                                   ---------+---------+---------+-------
Pooled StDev =   0.2925                  -1.00     -0.50      0.00
```

Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.00285

Critical value = 4.64

Intervals for (column level mean) - (row level mean)

	1	2	3	4	5	6	7
2	-0.5668 0.5953						
3	-1.1620 0.1253	-1.1520 0.0868					
4	-0.5635 0.6503	-0.5519 0.6102	-0.0819 1.2054				
5	-0.9371 0.3503	-0.9270 0.3117	-0.4535 0.9035	-0.9805 0.3069			
6	-1.3928 -0.1054	-1.3827 -0.1440	-0.9092 0.4478	-1.4362 -0.1488	-1.1342 0.2228		
7	-0.9582 0.4433	-0.9502 0.4068	-0.4720 0.9937	-1.0016 0.3999	-0.6969 0.7688	-0.2412 1.2245	
8	-0.3836 0.9037	-0.3736 0.8652	0.0999 1.4569	-0.4270 0.8603	-0.1250 1.2320	0.3307 1.6876	-0.2153 1.2504

Tukey's test – TKN– Winter – 2000

Source	DF	SS	MS	F	P
W	7	1.0621	0.1517	1.92	0.105
Error	27	2.1302	0.0789		
Total	34	3.1923			

```
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level        N      Mean     StDev   ------+---------+---------+---------+
1            5    0.5648    0.1685                 (------*-------)
2            6    0.6067    0.2391                   (-----*------)
3            4    0.6971    0.5596                    (-------*-------)
4            5    0.4773    0.1679              (-------*------)
5            4    0.0914    0.4327   (--------*-------)
6            4    0.6940    0.1897                    (-------*-------)
7            3    0.5872    0.0129               (---------*--------)
8            4    0.5829    0.0532                (--------*-------)
                                     ------+---------+---------+---------+
Pooled StDev =    0.2809                 0.00      0.35      0.70      1.05
```

Tukey's pairwise comparisons

Family error rate = 0.0500
Individual error rate = 0.00285

Critical value = 4.64

Intervals for (column level mean) - (row level mean)

	1	2	3	4	5	6	7
2	-0.6000						
	0.5161						
3	-0.7505	-0.6852					
	0.4859	0.5045					
4	-0.4954	-0.4286	-0.3984				
	0.6703	0.6875	0.8380				
5	-0.1448	-0.0795	-0.0460	-0.2323			
	1.0916	1.1102	1.2573	1.0041			
6	-0.7475	-0.6822	-0.6486	-0.8350	-1.2543		
	0.4889	0.5076	0.6547	0.4015	0.0490		
7	-0.6955	-0.6321	-0.5940	-0.7829	-1.1997	-0.5970	
	0.6506	0.6712	0.8137	0.5631	0.2080	0.8107	
8	-0.6364	-0.5710	-0.5375	-0.7238	-1.1432	-0.5405	-0.6996
	0.6001	0.6187	0.7658	0.5126	0.1601	0.7628	0.7082

Tukey's test – NOx– Winter – 2000

```
Source      DF        SS        MS        F        P
W            7     3.258     0.465     0.96    0.478
Error       27    13.070     0.484
Total       34    16.327

                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev  ---------+---------+---------+-------
1            5   -1.7772    0.4982      (---------*--------)
2            6   -1.0943    1.0354             (-------*--------)
3            4   -2.0000    0.0000  (---------*----------)
4            5   -1.2660    0.7238            (--------*--------)
5            4   -1.5689    0.8621        (----------*---------)
6            4   -1.8495    0.3010    (----------*---------)
7            3   -1.3010    0.0000           (----------*-----------)
8            4   -1.5797    0.8406        (---------*----------)
                                    ---------+---------+---------+-------
Pooled StDev =   0.6957                    -2.10     -1.40     -0.70


Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.00285

Critical value = 4.64

Intervals for (column level mean) - (row level mean)

          1          2          3          4          5          6        7
2   -2.0652
     0.6994
3   -1.3085    -0.5678
     1.7541     2.3792
4   -1.9550    -1.2106    -2.2653
     0.9325     1.5539     0.7972
5   -1.7396    -0.9989    -2.0452    -1.2283
     1.3230     1.9481     1.1831     1.8343
6   -1.4590    -0.7183    -1.7646    -0.9478    -1.3336
     1.6036     2.2287     1.4636     2.1148     1.8947
7   -2.1432    -1.4074    -2.4424    -1.6320    -2.0114    -2.2919
     1.1909     1.8208     1.0445     1.7021     1.4756     1.1950
8   -1.7288    -0.9881    -2.0344    -1.2176    -1.6034    -1.8839  -1.4648
     1.3338     1.9589     1.1938     1.8450     1.6249     1.3443   2.0221
```

Tukey's test – NH3– Winter – 2000

Source	DF	SS	MS	F	P
W	7	1.693	0.242	0.94	0.496
Error	27	6.980	0.259		
Total	34	8.673			

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
1           5   -0.4120    0.7171    (---------*--------)
2           6   -0.2207    0.5776         (--------*-------)
3           4   -0.3637    0.6385    (----------*---------)
4           5   -0.4960    0.4846   (--------*--------)
5           4    0.2615    0.1215                 (---------*----------)
6           4   -0.4230    0.5200   (----------*---------)
7           3   -0.3732    0.1434  (------------*-----------)
8           4   -0.4099    0.2554   (----------*---------)
                                   ----------+---------+---------+------
Pooled StDev =   0.5084                   -0.50      0.00      0.50
```

Tukey's pairwise comparisons

Family error rate = 0.0500
Individual error rate = 0.00285

Critical value = 4.64

Intervals for (column level mean) - (row level mean)

	1	2	3	4	5	6	7
2	-1.2013						
	0.8189						
3	-1.1673	-0.9338					
	1.0708	1.2198					
4	-0.9710	-0.7349	-0.9868				
	1.1391	1.2854	1.2513				
5	-1.7925	-1.5590	-1.8047	-1.8765			
	0.4456	0.5946	0.5544	0.3616			
6	-1.1080	-0.8745	-1.1203	-1.1920	-0.4951		
	1.1301	1.2791	1.2389	1.0461	1.8640		
7	-1.2571	-1.0272	-1.2646	-1.3411	-0.6395	-1.3239	
	1.1795	1.3320	1.2835	1.0954	1.9087	1.2242	
8	-1.1211	-0.8876	-1.1334	-1.2051	-0.5082	-1.1927	-1.2373
	1.1170	1.2660	1.2258	1.0330	1.8510	1.1665	1.3109

Tukey's test – NH3– Summer – 2001

```
Source      DF        SS        MS        F        P
NH3          7     4.263     0.609     5.63    0.000
Error      765    82.682     0.108
Total      772    86.945
```

```
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level       N      Mean     StDev   -------+---------+---------+---------
S1_NH4_l   98   -0.3757    0.4604                           (-----*------)
S8_NH4_l  103   -0.6002    0.2597    (-----*-----)
S4_NH4_l   97   -0.5882    0.2650     (-----*------)
S6_NH4_l   94   -0.4794    0.2835             (------*------)
S2_NH4_l   92   -0.4689    0.2820              (------*------)
S7_NH4_l  108   -0.5650    0.3331       (-----*------)
S3_NH4_l   89   -0.5526    0.2570        (------*------)
S5_NH4_l   92   -0.4498    0.4207                  (------*------)

                                    -------+---------+---------+---------
Pooled StDev =   0.3288                 -0.60     -0.50     -0.40
```

Tukey's procedure		Control		Low		Medium		High
NH3 - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	0.0838 0.3652						
Low	S4	*0.0697* *0.3554*	-0.1292 0.153					
	S6	-0.0403 0.2477	-0.0215 0.263	-0.2532 0.0355				
Medium	S2	-0.0515 0.238	-0.0118 0.2743	-0.0258 0.2644	-0.1358 0.1567			
	S7	*0.0502* *0.3285*	-0.1022 0.1725	-0.1627 0.1163	-0.055 0.2263	-0.0454 0.2376		
High	S3	*0.0309* *0.3229*	-0.0968 0.1919	-0.1108 0.182	-0.2207 0.0743	-0.0646 0.2319	-0.1303 0.1552	
	S5	-0.0707 0.2188	*0.0073* *0.2935*	-0.2836 0.0067	-0.1166 0.1759	-0.1662 0.1279	-0.0262 0.2568	-0.2511 0.0454

Conclusion: it is impossible to distinguish each other most of the means. The positive results we obtain for the Control treatment seems only reflect an abnormal mean for S1.

Tukey’s test – NH3– Winter – 2001

```
Source     DF        SS        MS        F        P
NH3         7    9.0144    1.2878    14.02    0.000
Error     880   80.8104    0.0918
Total     887   89.8248
```

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
W4        119   -0.6029    0.3834                   (---*--)
W7        114   -0.7375    0.2438           (---*---)
W1        113   -0.6730    0.2141               (---*---)
W6        101   -0.6944    0.2241              (---*---)
W2        115   -0.4835    0.3594                           (---*--)
W8        111   -0.7877    0.2930        (--*---)
W3         91   -0.8319    0.3338   (----*---)
W5        124   -0.7088    0.3175             (---*--)

                                   ----------+---------+---------+------
Pooled StDev =    0.3030                 -0.75     -0.60     -0.45
```

Tukey's Procedure		Control		Low		Medium		High
NH3 - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	0.0141 0.255						
Low	W1	-0.1908 0.0507	-0.0575 0.1865					
	W6	-0.0329 0.2159	-0.0823 0.1687	-0.1044 0.1473				
Medium	W2	-0.0008 0.2396	*0.1325* *0.3755*	-0.3112 -0.0677	*0.0856* *0.3363*			
	W8	*0.0635* *0.3061*	-0.0724 0.1728	-0.0081 0.2376	-0.0331 0.2197	0.1819 0.4265		
High	W3	*-0.357* *-0.101*	-0.2236 0.0348	*0.0294* *0.2884*	*-0.2703* *-0.0046*	*0.2194* *0.4774*	-0.1742 0.0858	
	W5	-0.0121 0.2239	-0.0906 0.1479	-0.0837 0.1554	-0.1376 0.1088	*0.1063* *0.3443*	-0.0412 0.199	-0.25 0.0038

Conclusion: it is again very difficult to see a difference between the means. We cannot trust the few positive results we find because of the negative results for the replicates plots.

Tukey's test – NOx– Summer – 2001

```
Source      DF        SS        MS        F        P
NO x         7     2.639     0.377     1.74    0.098
Error      766   166.406     0.217
Total      773   169.045



                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level        N      Mean     StDev    --+---------+---------+---------+----
S1          98   -1.6502    0.6042                     (------*-------)
S8         103   -1.8271    0.3611      (-------*------)
S4          97   -1.8201    0.4212       (------*-------)
S6          94   -1.7890    0.3820         (-------*-------)
S2          92   -1.7663    0.4568           (-------*-------)
S7         109   -1.7302    0.5402               (------*------)
S3          89   -1.7633    0.5185           (-------*-------)
S5          92   -1.8397    0.3769     (-------*-------)

                                      --+---------+---------+---------+----
Pooled StDev =   0.4661              -1.92     -1.80     -1.68     -1.56
```

Tukey's procedure		Control		Low		Medium		High
NOx -Summer		**S1**	**S8**	**S4**	**S6**	**S2**	**S7**	**S3**
Control	**S8**	-0.0226 0.3764						
Low	**S4**	-0.0327 0.3723	-0.193 0.2071					
	S6	-0.0653 0.3429	-0.1636 0.2398	-0.2357 0.1736				
Medium	**S2**	-0.891 0.3214	-0.142 0.2636	-0.152 0.2595	-0.1847 0.23			
	S7	-0.1168 0.2768	-0.0974 0.2912	-0.2872 0.1075	-0.2578 0.1402	-0.2363 0.1641		
High	**S3**	-0.0939 0.3201	-0.1408 0.2684	-0.1508 0.2643	-0.1834 0.2348	-0.2131 0.2072	-0.2351 0.1689	
	S5	-0.157 0.3948	-0.2154 0.1902	-0.1861 0.2254	-0.2581 0.1566	-0.1351 0.2819	-0.3097 0.0907	-0.1338 0.2866

Conclusion: all the data are here confined in the same range. No conclusion is allowed.

Tukey's test – NOx– Winter – 2001

```
Source     DF        SS        MS        F        P
NO x        7    37.358     5.337    14.41    0.000
Error     879   325.598     0.370
Total     886   362.956

                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --------+---------+---------+--------
W4        118   -1.4341    0.6279                  (----*---)
W7        114   -1.6772    0.4799        (----*---)
W1        113   -1.2644    0.7829                         (---*----)
W6        101   -1.6547    0.5167         (----*----)
W2        115   -1.2443    0.8519                          (---*----)
W8        111   -1.8156    0.3471   (---*----)
W3         91   -1.7687    0.4015    (----*----)
W5        124   -1.4587    0.6222                 (----*---)

                                   --------+---------+---------+--------
Pooled StDev =    0.6086                -1.75     -1.50     -1.25
```

Tukey's Procedure		Control		Low		Medium		High
NOx - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	**0.0006** **0.4856**						
Low	W1	-0.0732 0.4128	*0.1678* *0.658*					
	W6	-0.0297 0.4708	-0.2297 0.2748	**0.1375** **0.6431**				
Medium	W2	-0.0521 0.4318	*0.1889* *0.6769*	-0.2646 0.2245	*0.1586* *0.6622*			
	W8	*0.1374* *0.6256*	-0.1078 0.3846	*0.3046* *0.798*	-0.0929 0.4148	**0.3257** **0.817**		
High	W3	-0.5921 -0.077	-0.351 0.1681	*0.2443* *0.7644*	-0.3809 0.1528	*0.2654* *0.7834*	-0.2142 0.308	
	W5	-0.2128 0.262	-0.0211 0.4581	-0.0457 0.4345	-0.0515 0.4434	-0.0246 0.4535	*0.1156* *0.5981*	**-0.5648** **-0.0551**

Conclusion: the bad values for the replicate tests avoid drawing any conclusion.

Tukey’s test – TKN– Summer – 2001

```
Source      DF        SS        MS        F        P
TKN          7     1.757     0.251     1.92    0.063
Error      764    99.836     0.131
Total      771   101.593

                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level        N      Mean     StDev  -------+---------+---------+---------
S1          98    0.5428    0.3127                (------*------)
S8         102    0.4571    0.4865        (------*------)
S4          97    0.4670    0.2666        (-------*------)
S6          94    0.4826    0.4201          (------*-------)
S2          92    0.5708    0.3137                   (------*------)
S7         108    0.4642    0.2996         (-----*------)
S3          89    0.5002    0.2636           (-------*-------)
S5          92    0.4060    0.4515  (-------*------)
                                    -------+---------+---------+---------
Pooled StDev =    0.3615                 0.40      0.50      0.60
```

Tukey's Procedure TKN - Summer		Control		Low		Medium		High
		S1	S8	S4	S6	S2	S7	S3
Control	S8	-0.0694 0.2408						
Low	S4	-0.0812 0.2329	-0.1456 0.1654					
	S6	-0.0982 0.2185	-0.1312 0.1824	-0.1744 0.1431				
Medium	S2	-0.1872 0.1312	-0.0439 0.2714	-0.0558 0.2634	-0.0726 0.249			
	S7	-0.0744 0.2315	-0.1442 0.1586	-0.1506 0.1561	-0.1361 0.1731	-0.049 0.2622		
High	S3	-0.1179 0.2032	-0.116 0.2022	-0.1278 0.1941	*-0.1447* *-0.1797*	-0.0924 0.2337	-0.1211 0.1929	
	S5	-0.0224 0.296	-0.2088 0.1066	-0.0986 0.2206	-0.2375 0.0842	*0.0031* *0.3265*	-0.2138 0.0973	-0.0688 0.2572

Conclusion: most of the data are confined in the same range. The 2 positive results are not enough to draw viable conclusions.

Tukey's test – TKN– Winter – 2001

```
Source       DF        SS        MS        F        P
TKN           7    1.6613    0.2373     3.97    0.000
Error       880   52.6131    0.0598
Total       887   54.2744

                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level         N      Mean     StDev  ---------+---------+---------+-------
W4          119    0.4304    0.2334                (-----*------)
W7          114    0.4412    0.2312                  (-----*-----)
W1          113    0.3749    0.2718        (------*-----)
W6          101    0.4000    0.2840           (------*------)
W2          115    0.4938    0.2014                         (------*-----)
W8          111    0.3395    0.3184   (-----*------)
W3           91    0.4121    0.1894             (------*------)
W5          124    0.4079    0.1974             (-----*-----)
                                     ---------+---------+---------+-------
Pooled StDev =     0.2445                     0.350     0.420     0.490
```

Tukey's Procedure		Control		Low		Medium		High
TKN - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	-0.108 0.0864						
Low	W1	-0.1529 0.0419	-0.1648 0.0322					
	W6	-0.07 0.1307	-0.1425 0.0602	-0.1267 0.0764				
Medium	W2	-0.0336 0.1604	-0.0454 0.1506	*-0.2171* *-0.0206*	-0.0074 0.1949			
	W8	-0.007 0.1888	*0.0028* *0.2006*	-0.0637 0.1345	-0.0415 0.1625	**0.0556** **0.253**		
High	W3	-0.1216 0.085	-0.1334 0.0752	-0.1417 0.0673	-0.0951 0.1193	-0.0224 0.1858	-0.0323 0.1775	
	W5	-0.0728 0.1176	-0.1295 0.063	-0.1295 0.0634	-0.0915 0.1074	-0.0102 0.1818	-0.0284 0.1654	-0.0983 0.1065

Conclusion: no constructive conclusion can be drawn from this test.

Tukey's test – TP– Summer – 2001

```
Source      DF        SS        MS        F        P
TP           7     6.225     0.889     3.47    0.001
Error      765   196.065     0.256
Total      772   202.290
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level        N      Mean     StDev   ----+---------+---------+---------+--
S1          98   -0.2036    0.5240                 (-----*------)
S8         102   -0.2828    0.5681            (-----*------)
S4          97   -0.1382    0.4392                     (------*------)
S6          94   -0.2915    0.5335           (------*-----)
S2          92   -0.1763    0.3936                  (------*------)
S7         109   -0.3933    0.5052    (------*-----)
S3          89   -0.2458    0.4046              (------*------)
S5          92   -0.3991    0.6270   (------*------)
                                     ----+---------+---------+---------+--
Pooled StDev =    0.5063              -0.45     -0.30     -0.15      0.00
```

Tukey's Procedure		Control		Low		Medium		High
TP - Summer		S1	S8	S4	S6	S2	S7	S3
Control	S8	-0.138 0.2965						
Low	S4	-0.2853 0.1546	-0.0732 0.3624					
	S6	-0.1338 0.3096	-0.2282 0.2109	-0.069 0.3756				
Medium	S2	-0.2503 0.1956	-0.1142 0.3274	-0.2615 0.1855	-0.11 0.3405			
	S7	-0.0241 0.4035	-0.322 0.1011	*0.0407* *0.4694*	-0.1144 0.3179	-0.0004 0.4345		
High	S3	-0.1826 0.2671	-0.1858 0.2598	-0.333 0.1178	-0.1815 0.2728	-0.1587 0.2979	-0.0719 0.3669	
	S5	-0.0274 0.4184	-0.3371 0.1045	*0.0374* *0.4844*	-0.3328 0.1176	-0.0036 0.4493	-0.2232 0.2116	-0.075 0.3816

Conclusion: The distributions are too superposed to be capable providing a conclusion.

Tukey's test – TP – Summer – 2001

```
Source      DF        SS        MS        F        P
TP           7    12.803     1.829     9.74    0.000
Error      880   165.275     0.188
Total      887   178.078
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev  ----+---------+---------+---------+--
W4         119   -1.1719    0.4767        (----*----)
W7         114   -0.9879    0.3619                   (----*----)
W1         113   -1.0774    0.4195              (----*----)
W6         101   -0.9046    0.4028                        (----*-----)
W2         115   -1.0334    0.4218                (----*----)
W8         111   -1.2588    0.4194  (----*----)
W3          91   -0.8655    0.5602                          (-----*----)
W5         124   -0.9890    0.4018                   (----*----)
                                    ----+---------+---------+---------+--
Pooled StDev =   0.4334              -1.28     -1.12     -0.96     -0.80
```

Tukey's Procedure		Control		Low		Medium		High
TP - Winter		W4	W7	W1	W6	W2	W8	W3
Control	W7	**-0.3563** **-0.0118**						
Low	W1	-0.0782 0.2672	-0.2641 0.085					
	W6	*-0.4452* *-0.0895*	-0.0963 0.263	-0.3529 0.0071				
Medium	W2	-0.0334 0.3104	-0.2193 0.1282	-0.2182 0.1301	-0.3081 0.0505			
	W8	-0.0865 0.2604	*0.0957* *0.4463*	*0.0057* *0.3571*	*0.1735* *0.5351*	**0.0505** **0.4004**		
High	W3	*0.1233* *0.4895*	-0.0624 0.3072	*-0.3971* *-0.0267*	-0.151 0.2291	-0.3523 0.0166	*0.2074* *0.5792*	
	W5	*-0.3516* *-0.0142*	-0.1717 0.1695	-0.2594 0.0825	-0.2606 0.0918	-0.2146 0.1258	*0.0981* *0.4417*	-0.058 0.3049

Conclusion: we have here more positive results but it is difficult to trust them because of the replicate tests. Anyway, we cannot identify a general law to identify the different means.