5 Habitat restoration

Much of the former Marsh Fritillary habitat in de Avalon Marshes has suffered severely from drainage caused by neighbouring peat excavations. The desiccation of the habitat has resulted in Purple Moor-grass and scrub encroachment and the abundance of the host plant Devil's-bit Scabious has declined considerably while it has completely disappeared in some areas. The vegetation in the Lows south, the study site, is now in "unfavourable condition". To restore the vegetation to "favourable condition", it is necessary to significantly reduce the cover of Purple Moor-grass and scrub species. To allow re-establishment of the Marsh Fritillary butterfly, re-establishment and increase in cover of the host plant is necessary.

This chapter discusses the experiment that explores under which conditions a rapid increase in host plant cover will be possible (section 5.4) and what management regimes result in a decrease in cover of Purple Moor-grass and scrub species (section 5.5). First however, the overall set-up of the experiment, the baseline study conducted at the start of the experiment and the soil characterization are discussed in section 5.1, 5.2 and 5.3 respectively.

5.1 Set-up of the experiment

In March 2004, four experimental blocks were established in the area known as the Lows south on Shapwick Heath NNR. Each block comprises 12 plots of 5 by 5 metres present inside a fenced area, and two plots of 5 by 5 metres outside the fenced area (see the next page for the experimental design). The treatments rotovation, rotovation + 1 hay cut, rotovation + 2 hay cuts, 1 hay cut, two hay cuts, grazing and a control were randomly assigned to the fourteen plots in a block, with each treatment assigned twice. The two grazed treatments were necessarily assigned to two plots outside the exclosure. The distance between the plots was set to 1 metre. Each plot was marked by a permanent post in the south-west corner. The disturbance treatment was applied in March by means of a rotovator to a depth of 25 centimetres. In each block, seeds of Devil's-bit Scabious were sown in one of the two plots receiving a particular treatment (see section 5.4). The hay cuts were applied with a brush cutter, the timing was July in the case of one hay cut and July and October in the treatments consisting of two hay cuts.

5.2 Baseline study

This part of the study aims to investigate whether there are any differences between the plots at the beginning of the experiment. If there were, any measured difference would have to be weighed when analysing the results of the experiment. For further data see Borsje (2004b).

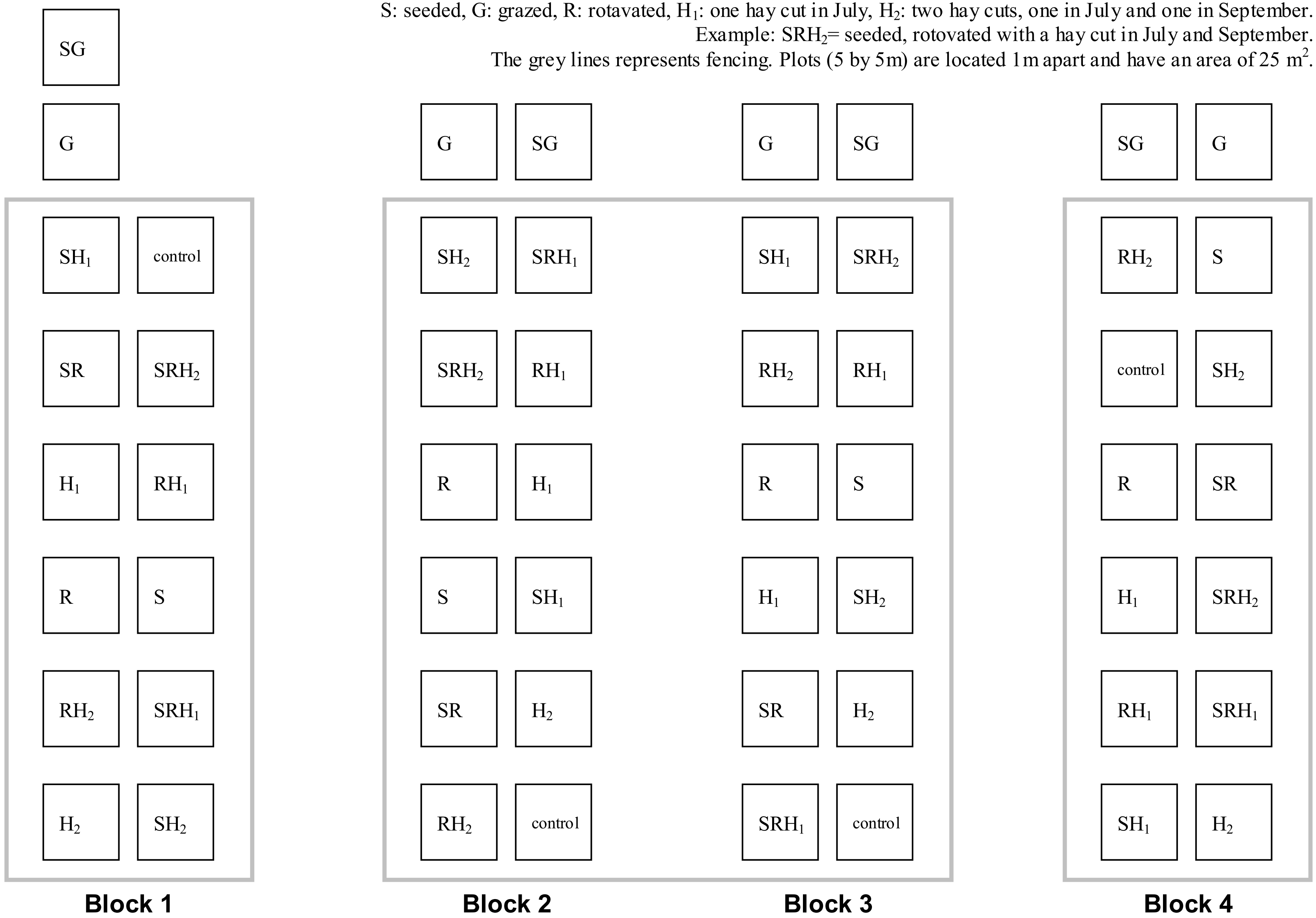
Main question
Do any differences occur between blocks or within blocks, that need to be taken into account when analysing and interpreting the results of this study?

5.2.1 Methods

In June, in all non-rotovated plots, the species present and their percentage cover were recorded in 8 randomly assigned 1 square metre quadrats. Vegetation cover was assessed by estimating the percentage cover of Purple Moor-grass, fine grasses (including sedges), rushes, Devil's-bit Scabious, other forbs, scrub, bare ground and litter. In May, vegetation height was recorded in each plot with help of a graduated pole and a drop disc (wood, diameter 30 centimetres, weight 175 grammes, fifteen measurements per plot) (Stewart and others 2001). For each non-rotovated plot, a mean Ellenberg

Experimental design

S: seeded, G: grazed, R: rotavated, H_1: one hay cut in July, H_2: two hay cuts, one in July and one in September.
Example: SRH_2= seeded, rotovated with a hay cut in July and September.
The grey lines represents fencing. Plots (5 by 5m) are located 1m apart and have an area of 25 m^2.



score for fertility, pH and moisture was calculated for the 8 quadrats with help of the software program Mavis (Mavis plot analyser Version 1.00). This program uses recalculated Ellenberg values applicable to the British situation (Hill and others 1999). Each score was cover-weighted using the formula Score= Sum (E * c)/ Sum c, in which E= Ellenberg score for each species and c = cover value for each species. A mean percentage competitor, stress tolerator and ruderal based upon the proportion of each species attributable to different parts of the C-S-R triangle (Grime and others 1988) was calculated in Mavis. With help of the software program Canoco for windows version 4.5, patterns of variation in floristic composition between the blocks and their relationship with the estimated environmental variables were studied. Linear ordination methods (Principal Component Analysis and Redundancy analysis) were used as the beta diversity in community composition was not high (length longest gradient < 3) (Lepš & Šmilauer, 2003). For analysis in Canoco, species percentage scores were log-transformed (log (score+1)). Further analysis in SPSS was carried out to detect any significant differences. Variables were tested for normality (Shapiro-Wilk) and homogeneity of variance (Levene). For analysis in SPSS 12.0.1 cover data was arc sine and log (value+1) transformed.

5.2.2 Results

In the Redundancy Analysis of plant species composition and environmental variables of the 4 blocks, two axes were found to be significant with eigenvalues of 0.18 and 0.15 respectively. Of all environmental variables entered in the analysis, percentage ruderals (r=0.88), percentage competitors (r=-0.81) and number of species (r=0.72) were most strongly correlated with the first axis, while percentage scrub (r=0.77), Ellenberg fertility (r=0.53) and Ellenberg pH (r=0.49) were most strongly correlated with the second axis.

The distance biplot of samples and environmental variables (fig 5.1) suggests that the number of species, % stress tolerators, % ruderals, and fertility and pH values are higher for block 1 and 4 than for blocks 2 and 3, while block 2 and 3 seem to be associated with high moisture values, a high % competitors and a higher vegetation height.
The correlation biplot of samples and species (fig 5.2) indicates that the abundance of forb species and fine grasses is higher in block 1 and 4, compared to block 2 and 3. Block 1 and 2 seem to have higher abundances of coarse grass (Purple Moor-grass), while block 4 has a high abundance of Devil's-bit Scabious compared to the other blocks. The spread of the samples of block 1 and 4 in the ordination space suggests that considerable variation in species composition exists within a block.

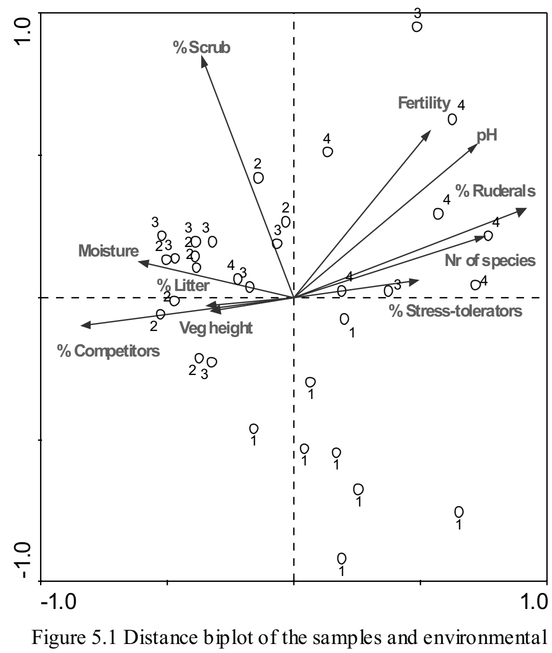


Figure 5.1 Distance biplot of the samples and environmental variables . Samples are labelled with block numbers.

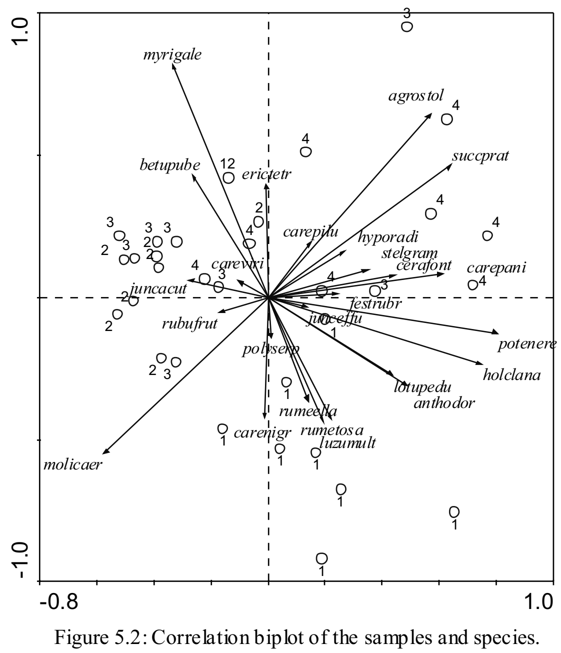


Figure 5.2: Correlation biplot of the samples and species. Samples are labelled with block numbers. Plant species are assigned by the first four letters of the latin genus and species names, except for *Rumex acetosa* and *Rumex acetosella*. These species are assigned by rumetosa and rumeella respectively.

F-tests showed that significant differences exist between blocks. Tukey's Honestly Significant Difference tests have been used to compare the four blocks. See figures 5.3 until 5.10 for the results. The percentage coarse grasses declines from about 70% in block 1 to about 60% in block 4 (F=6.18, df=3, p<0.001). Percentage scrub is lower in block 1 than in all the other three blocks with only 6 percent cover as opposed to values around 15 percent in the other blocks (F=53.87, df=3, p<0.001). The percentage fine grasses is higher (F=13.24, df=3, p<0.001) and the percentage litter is significantly lower (F=11.95, df=3, p<0.001) in block 4 than in the other 3 blocks, while the number of species is also significantly higher in block 4 (F=16.49, df=3, p<0.001). See appendix III for a species list per block with information about the number of quadrats per block containing the species. Forbs have a higher part in the species composition in block 1 and 4 with mean values of 16 and 15 percent , while forbs in block 2 and 3 only have an abundance of 5-6 percent (F=28.86, df=3, p<0.001). Devil's-bit Scabious is absent from block 1, and is most abundant in block 3 and 4, although the mean percentage per block does not exceed 1.06 percent. No significant differences in terms of mean vegetation height could be detected in May.

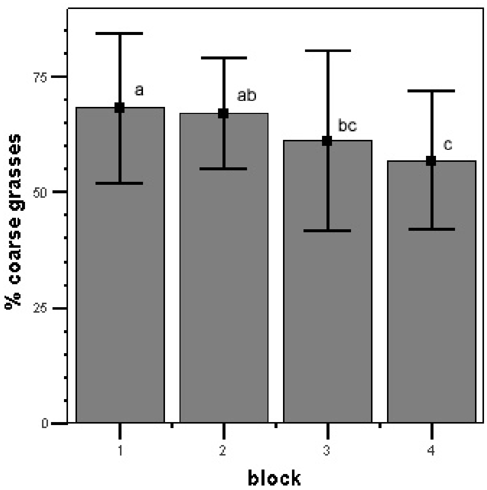


Fig 5.3: Bars represent mean % coarse grasses per block. Bars with different letters differ significantly. Error bars show mean +/- 1.0 SD.
n=64 for each block.

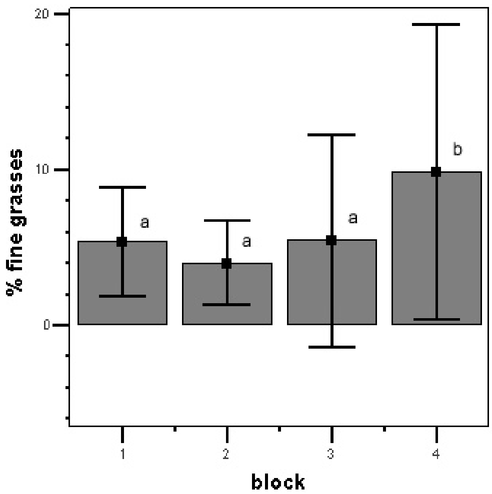


Fig 5.4: Bars represent mean % fine grasses per block. Bars with different letters differ significantly. Error bars show mean +/- 1.0 SD.
n=64 for each block.

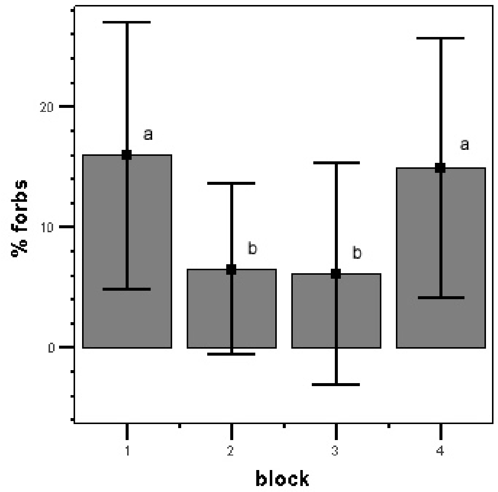


Fig 5.5: Bars represent mean % forbs per block. Bars with different letters differ significantly. Error bars show mean +/- 1.0 SD.
n=64 for each block.

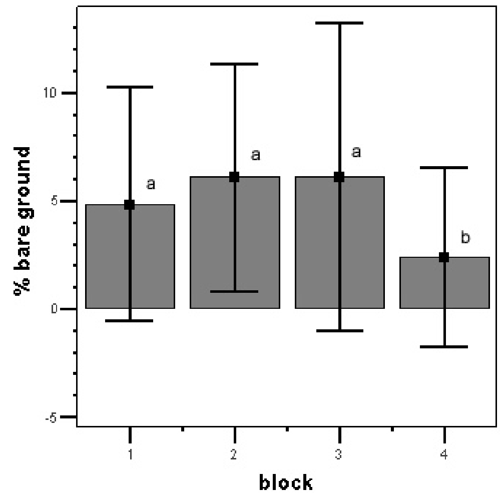


Fig 5.6: Bars represent mean % bare ground per block. Bars with different letters differ significantly. Error bars show mean +/- 1.0 SD.
n=64 for each block.

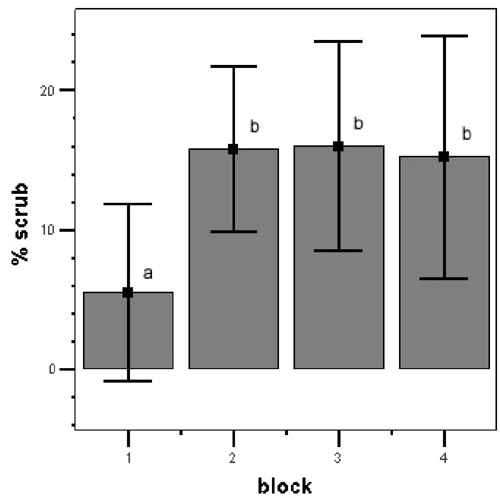


Fig 5.7: Bars represent mean % scrub per block. Bars with different letters differ significantly. Error bars show mean +/- 1.0 SD.
n=64 for each block.

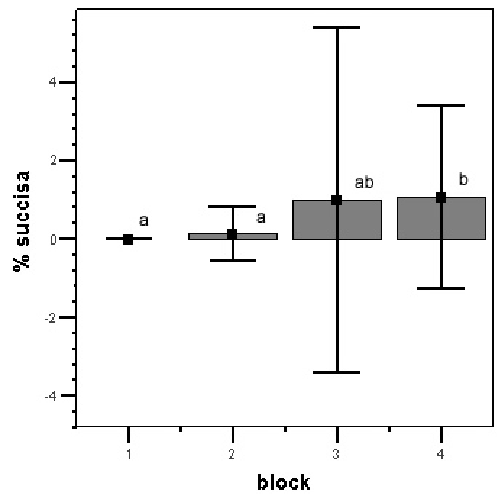


Fig 5.8: Bars represent mean % Devil's-bit Scabious (*Succisa*) per block. Bars with different letters differ significantly. Error bars show mean +/- 1.0 SD.
n=64 for each block.

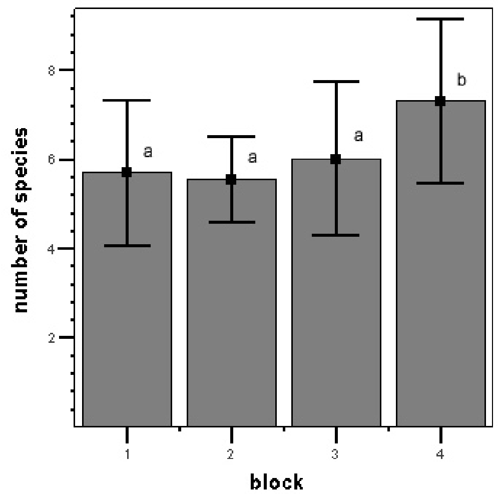


Fig 5.9: Bars represent mean number of species per block. Bars with different letters differ significantly. Error bars show mean +/- 1.0 SD.
n=64 for each block.

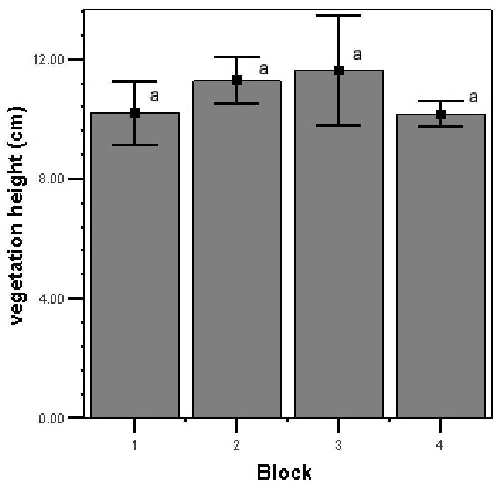


Fig 5.10: Bars represent mean vegetation height (cm) per block. Bars with different letters differ significantly. Error bars show mean +/- 1.0 SD.
n=120 for each block.

5.2.3 Discussion & Conclusion

The baseline data suggests that significant differences exist between the four blocks and variation in species composition exists within blocks. Chapter 7 of this report shows that high percentages of fine grasses and forbs are associated with presence of Devil's-bit Scabious, Therefore, block 4 seems to have more favourable circumstances for the species and indeed the cover of the host plant is now already highest in this block, although the mean abundance over the block is low. Furthermore, blocks differ in their abundances of scrub and coarse grasses. As one of the aims of this study is to investigate suitable management regimes that reduce the cover of Purple Moor-grass and scrub species, it is important to take the initial differences in cover in account. When block is found to be a significant factor during analysis of the data for the first year of the experiment (see section 5.5), it is recommended that the cover percentages for the variables coarse grasses, fine grasses, forbs, scrub, litter and Devil's-bit Scabious are used as covariables.

5.3 Soil characterization

The study site is located in the remnant raised bog in the Avalon Marshes in the Somerset Levels on a soil designated as Turbary Moor Complex. Soil analysis has been carried out to characterize the soil conditions in terms of pH, P, K, Mg, total N and organic matter content.

5.3.1 Methods

In August 2004, 5 soil samples (0-15 cm depth) were randomly collected in each block from rotovated and undisturbed (further referred to as control) soil by means of a soil corer. These 5 samples were thoroughly mixed to form one soil sample from undisturbed soil per block and one soil sample of rotovated soil per block. The 8 samples have been analyzed for pH, P, K, Mg, total N and organic matter following methods described in 'The analysis of Agricultural materials" (HMSO, 1986). The results have been compared with values found by Critchley and others (2002).

5.3.2 Results

The results for pH, P, K, Mg, total N and organic mattter for the rotovated and control soil samples in the four blocks are presented in table 5.1. Figure 5.11 until 5.15 represent the results for the four control samples graphically. No consistent pattern in terms of higher or lower nutrient levels for certain blocks can be detected in the data. It is assumed that the differences in terms of soil nutrients are negligible and caused by natural heterogeneity in the soil. No significant differences could be detected between the control and rotovated soil samples (t-test, $n_{control}$=4, $n_{rotovated}$=4, α=0.05). Blackstock and others (1998) have published analytical soil data from a M25b mire community in Wales in mmole/kg units. Because the soil density of the Shapwick samples was known, it was possible to re-calculate the mg/l units to mg/kg and the Blackstock mmole/kg units to mg/kg. However, the recalculated values differed strongly and comparison was not useful. Comparison with published data for a M24 mire community which was presented in the same units as the Shapwick data (Critchley and others 2002) indicates that the data for the Shapwick samples is correct, as the differences between values for the M24 community and those found on Shapwick are relatively small (see figure 5.16 and table 5.2), and similar to the differences between the data for M24 and M25b communities as presented in Blackstock and others (1998) with the values for M25b communities being higher than those for M24 communities.

5.3.3 Discussion & Conclusion

No major differences are assumed to exist in terms of soils conditions in the four experimental blocks, and the rotovation treatment has had no significant effect on the soil conditions in the concerning plots.

Table 5.1 Values measured for P, K, Mg, total N and % Organic Matter in the four experimental blocks B1, B2, B3 and B4 for control and rotovated ('R') samples.

Block	P mg/l	K mg/l	Mg mg/l	total N g/kg	% OM
B1	24	134	284	21	90.4
B1R	22.0	122.0	243.0	18.2	88.3
B2	16	127	240	22.4	94.3
B2R	22.0	136.0	198.0	19.6	91.3
B3	16	127	224	25.2	87.3
B3R	15.0	138.0	192.0	21.0	92.2
B4	29	114	267	22.4	89.4
B4R	17.0	167.0	234.0	23.8	94.5

Table 5.2 Values from Critchley and others (2002) and the values measured on Shapwick (means 4 blocks).

Variable	Shapwick	Critchley et al.
pH	4.18	4.65
P mg/l	20.13	17
K mg/l	133.13	76
Mg mg/l	235.25	207
total N %	2.17	1.93
OM %	90.96	36.6

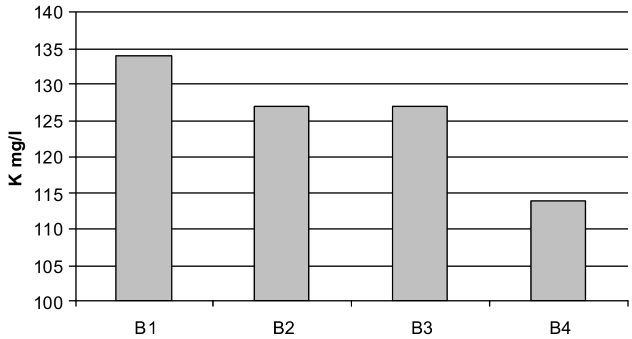


Figure 5.11 Values measured for K (mg/l) in the four experimental blocks.

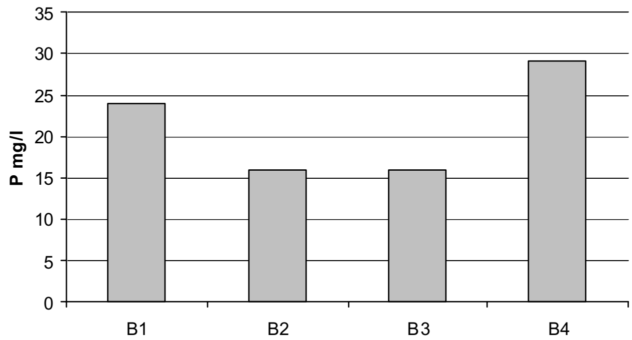


Figure 5.12 Values measured for P (mg/l) in the four experimental blocks.

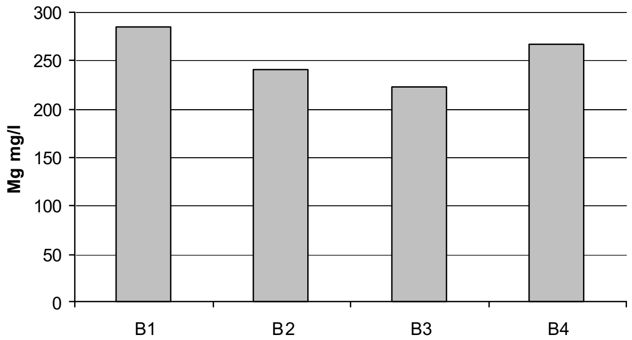


Figure 5.13 Values measured for Mg (mg/l) in the four experimental blocks.

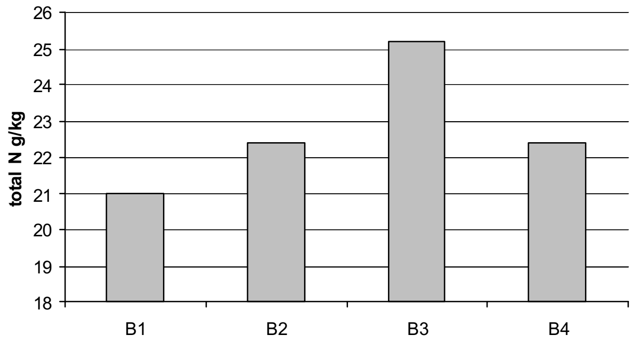


Figure 5.14 Values measured for total N (g/kg) in the four experimental blocks.

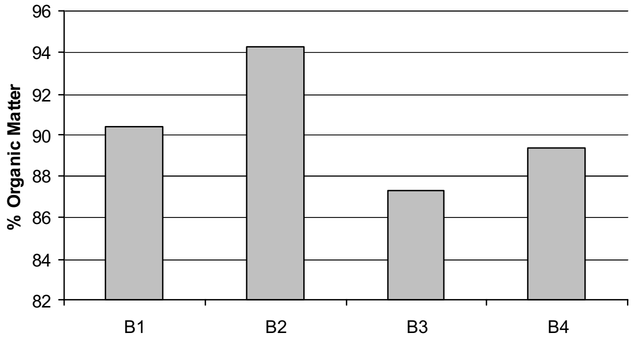


Figure 5.15 Values measured for % organic matter in the four experimental blocks.

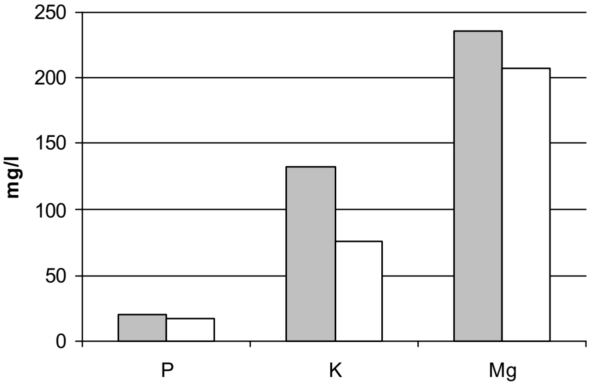


Figure 5.16 Values from Critchley and others (2002) (white bars) and the values measured on Shapwick (means 4 blocks, grey bars) for P, K and Mg (mg/l).

5.4 Re-establishment & increase in cover of Devil's-bit Scabious

This section describes the experiment that studies possibilities to realize re-establishment and increase in cover of Devil's-bit Scabious.

Main question
Is it possible to realize favourable conditions for germination and/or establishment of Devil's-bit Scabious by means of different management regimes and the resulting differences in habitat characteristics at micro-scale?

Research questions
1. What is the effect of the applied treatments on the vegetation characteristics, such as vegetation height, percentage of bare ground and vegetation structure height?
2. What is the percentage germination of Devil's-bit Scabious achieved in the sown plots compared to natural seed dispersal plots?
3. What is the percentage establishment of Devil's-bit Scabious achieved in the sown plots compared to plots with natural seed establishment?
4. What is the effect of the treatments on the mortality, development, vitality and establishment of the seeded Devil's-bit Scabious plants and does competition among the seedlings have any influence?
5. Do disturbance and differences in management regime, resulting in differences in habitat characteristics at micro-scale influence the germination, establishment and development of Devil's-bit Scabious?

Hypotheses
It is assumed that:
1. In the disturbed treatments, germination and establishment will be higher than in any of the other treatments as a result of the increased amount of bare ground available and the strongly reduced competition of existing vegetation.
2. Germination, establishment and development of Devil's-bit Scabious will be higher in treatments that receive one or two hay cuts than in treatments that receive no hay cut, as a result of the removal of competing vegetation. It is assumed that the seedlings will not be affected by the cut, as they are rosettes and located close to the ground.
3. Germination, establishment and development will be higher in the treatments that receive a hay cut than in the grazed areas, because although competing vegetation is also removed by grazing, this often only occurs locally and the subsequent trampling of the seedlings will result in higher mortality rates.
4. The survival of Devil's-bit Scabious seedlings will be negatively influenced by a higher density of seedlings (competitors) in the direct neighbourhood of the Devil's-bit Scabious seedlings.

5.4.1 Methods

Devil's-bit Scabious seeds were gathered in hay meadows present on Shapwick Heath NNR. The seeds were dried and stored in a cool and dark place (about 15ºC) for a few months. In January, the seeds were moved to a shed for six weeks. In this shed, temperatures fluctuated between –4ºC and +6ºC with outside temperatures. This had the effect of a frost treatment and simulated temperature fluctuations as they would occur in the field, which was thought to be sufficient for breaking dormancy of the seeds. In March 2004, the Devil's-bit Scabious seeds were sown soon after the rotovation treatment was applied in the concerning plots. Seeds were sown in a density of 1kg per hectare (2.14 grammes per plot, about 1400 seeds assuming a seed weight of 0.00154 grammes).

5.4.2 Results

No Devil's-bit Scabious seedlings were recorded during monitoring in May, while in September, only two seedlings were found in a treatment that had received one hay cut. No further measurements have been carried out on these two seedlings. The failure of germination and establishment of Devil's-bit Scabious makes answering of the research questions not possible. The effects of the treatments on the vegetation height, the percentage bare ground and the vegetation structure height are discussed in section 5.5.

5.4.3 Discussion & Conclusion

A crude conclusion of this study could be that the applied treatments did not create suitable conditions for germination and subsequent establishment of Devil's-bit Scabious.
However, very low germination percentages seem to be a common problem encountered during studies concerning sowing of Devil's-bit Scabious (Warren and others 2002; Hooftman and others 2003; Bulman 2001). Seed germination has been found to be very low (Hooftman & Diemer 2002) and germination percentages vary considerably between years (pers. comm. P. Vergeer).

Furthermore, appropriate conditions for storing seeds and breaking dormancy seem to be unclear. Kotorová & Lepš (1999) found that chilling at -14ºC and +4ºC negatively influenced germinability of Devil's-bit Scabious seeds. Soons & Heil (2002) stored Devil's-bit Scabious seeds at 18ºC for four months and subsequently found reasonably high numbers of viable seeds per seed head. Vergeer and others (2004) stored seeds at 4ºC for 6 weeks to break dormancy and found germination percentages of about 6-15 %. Isselstein and others (2002) stored them at 5ºC and the seeds were sown in March. They found high germination percentages of about 50%. In a study by Bulman (2001) seeds were dried and kept in a cool, dry and dark place. These seeds were only stored for a short period of time as they were sown coinciding with the natural seed fall in autumn (pers. comm. C. Bulman), but germination percentages were low with a maximum mean of 4%.

The treatment of the seeds sown during this project resulted in almost no germination. Also during germination tests, none of the seeds germinated, and the seeds became mouldy very quickly. In general, Devil's-bit Scabious seeds seem to be very susceptible to fungal infection (Vergeer and others 2003; pers. comm. J. Tallowin). Tetrazolium tests did not detect any living tissue, although the embryo seemed to be well developed in most seeds. Also seeds soaked in gibberellic acid, a plant hormone that is thought to break dormancy and promote growth, did not germinate.

Since germination percentages are thought to vary considerably between years, and 2003 was a relatively dry, hot year, this might have affected seed set and seed development of Devil's-bit Scabious. Maybe the percentage germination found during the abovementioned studies has not been affected by the methods of storing, but by the conditions during seed development on the parent plant. Unfortunately, these studies give no information about the seed set conditions, so it is not possible to speculate further on the causes for low or high germination percentages. It is clear that further research into factors that affect viability and germinability of Devil's-bit Scabious is desirable. Only when the viability and germinability of the seeds can be well predicted and is thus a constant factor, conclusions can be drawn about the successfulness of treatments investigating suitable re-establishment conditions.

It is recommended that half of each plot that received seeds in March 2004 is reseeded with the natural seed fall in the autumn of 2004, this time in a higher density of 5kg seeds per hectare. This enables further monitoring of the seeding carried out in March 2004, while the second, higher density seeding will hopefully result in reasonable germination percentages, which makes evaluation of the effect of the applied treatments on the establishment of Devil's-bit Scabious possible.

5.5 Decrease in cover of Purple Moor-grass & scrub

The Lows south and Ashcott plot are currently in "unfavourable condition" (English Nature 2003). In order to achieve favourable condition by 2010, the cover of coarse grasses and scrub needs to be reduced significantly in favour of fine grasses and forbs. During this experiment, the effects of different management regimes on the cover of Purple Moor-grass, scrub, fine grasses, Devil's-bit Scabious and other forbs are studied. The overall set up of the experiment is described in section 5.1. The baseline study that was carried out prior to analysis of this experiment is discussed in section 5.2.

Main question
Is it possible to significantly reduce the cover of Purple Moor-grass and scrub species in favour of forbs and fine grasses by means of different management regimes?

Hypotheses

- By means of cutting and grazing, the dominance of Purple Moor-grass will be reduced and this will favour establishment and increase in cover of fine grasses and forbs.
- For cutting, this effect will be stronger as the cutting regime is more intensive.
- Rotovation will result in a total setback of the dominance of Purple Moor-grass and scrub species, however, when it is not followed up by vegetation management the former standing vegetation will reappear quickly. Rotovation and subsequent vegetation management in the form of hay cutting will strongly reduced the dominance of Purple Moor-grass in favour of fine grasses and forbs.

Research questions

1. What is the effect of the applied treatments on the vegetation height, the percentage bare ground and vegetation structure height?
2. Which species establish under the different treatments?
3. How does the cover of Purple Moor-grass, scrub species, fine grasses, Devil's-bit Scabious and other forbs change as a result of the applied treatments?

5.5.1 Methods

Treatments comprise rotovation, rotovation + 1 hay cut, rotovation + 2 hay cuts, 1 hay cut, two hay cuts, grazing and a control (see experimental design on page 40). The grazing treatment consisted of grazing with Red Devon cattle (1.7 LU per hectare, June until September, assuming for cattle 1 animal = 0.5 LU). The disturbance treatment was applied in March by means of a rotovator to a depth of 25 centimetres. The hay cuts were applied with a brush cutter, the timing was July in the case of one hay cut and July and October in the treatment consisting of two hay cuts. The hay cuts in the rotovated plots were not applied during this first year of the experiment, as there was too much bare crumbly soil present, which makes raking off without causing major disturbance not possible.

In June, the percentage cover of all present species and the percentage cover of coarse grasses, fine grasses (including sedges), rushes, Devil's-bit Scabious, other forbs, scrub, bare ground and litter was estimated in eight 1 square metre quadrats in each rotovated plot. In September, in eight 1 square metre quadrats in each plot, vegetation cover was again assessed by estimating the percentage cover of Purple Moor-grass, fine grasses (including sedges), rushes, Devil's-bit Scabious, other forbs, scrub, bare ground and litter. Furthermore, in June and September, vegetation structure height was assessed by carrying out 15 random measurements with a sward stick in each quadrat (Stewart and others 2001). The vegetation height was monitored in every plot monthly from May onwards until September. Vegetation height was recorded with help of a graduated pole and a drop disc (wood, diameter 30 centimetres, weight 175 grammes, fifteen measurements per plot) (Stewart and others 2001). In September, germination and establishment was assessed in 5 square metre quadrats in all treatments in a block.

Shapiro-Wilk tests were used to test the data for normality and Levene's test was used to investigate whether the variances were homogeneous. For most variables, the data was not normally distributed and the variances were significantly not homogeneous. Arc sine followed by log (value +1)-transformation did result in normal distributed residuals for some variables, however, not for all. As no non-parametric version of a General Linear Model (GLM) is available in SPSS at the moment (these models are being developed), GLM in the software package SPSS 12.0.1 was used to analyse the data. However, it is recommended that, once a non-parametric form of GLM is available, the data is analysed using the non-parametric form. In the GLM analysis, "treatment" was used as fixed factor and "block" as random factor. For each of the variables coarse grasses, fine grasses, forbs, Devil's-bit Scabious scrub and bare ground, cover data recorded in September was used as dependant variable and cover data recorded in June was used as covariate.

The process of vegetation community restoration is often slow and therefore this experiment is necessarily a long-term experiment, and any conclusion drawn after only one growing season would be premature. The results as found after this growing season in comparison to the baseline study consist of short-term effects of the treatments, while the focus of this study is on the long-term effects on the species composition. Furthermore, the baseline study was carried out in June, while monitoring after the treatments were applied took place in September. True changes in vegetation cover can only be detected when comparing the baseline cover data (recorded in June), with cover data recorded in the same month in the coming years. Therefore, except during regression analysis, no statistical tests have been carried out and data is presented graphically only in order to identify any possible trends. In part of the graphs, cover data as recorded during the baseline study is included to make visual comparison with the starting point possible.

5.5.2 Results

Effects of the treatments on the vegetation height and structure

Fig 5.17 until 5.20 show the vegetation height as it was recorded in the treatments in the 4 blocks. As can be seen in fig 5.20, there was only very little re-growth of the vegetation after the hay cut in July, so that the second hay cut, which was planned for September, was delayed until October. Monitoring took place in September. Therefore, all non-rotovated treatments per block that involved hay cutting have been merged to a treatment "hay cut". Furthermore, as no hay cuts have been carried out in any of the rotovated plots, all rotovated treatments in a block were merged to form the treatment "rotovated". The average for vegetation structure height was higher in control plots than in the other treatments (fig 5.21), and the same accounts for the standard deviation of vegetation structure height.

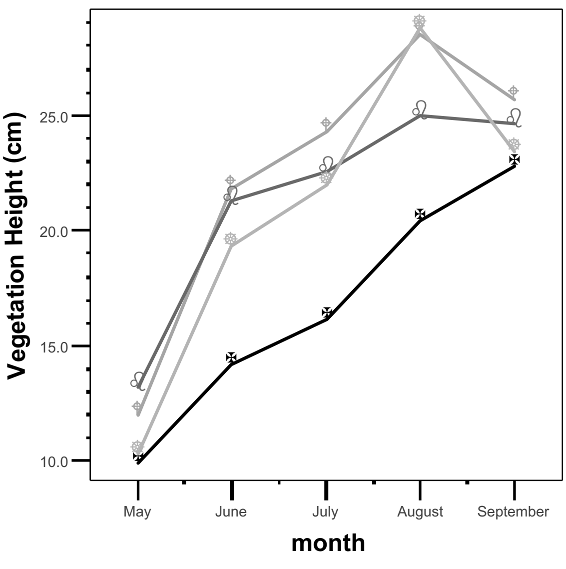


Figure 5.17 Vegetation height (cm) in the treatment control. ▲= block 1, ● = block 2, X = block 3 and ■ = block 4. Dot/lines show means. $N_{control}$=30, n_{grazed}=30, n_{haycut}=60, $n_{rotovated}$=90 for each block.

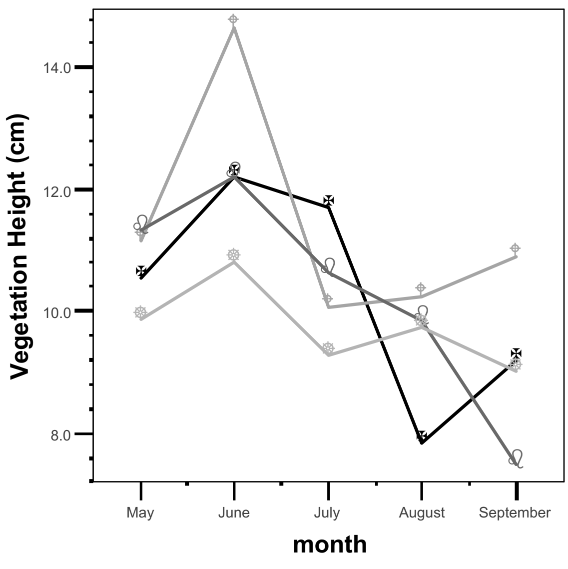


Figure 5.20 Vegetation height (cm) in the treatment grazing. ▲= block 1, ● = block 2, X = block 3 and ■ = block 4. Dot/lines show means. $N_{control}$=30, n_{grazed}=30, n_{haycut}=60, $n_{rotovated}$=90 for each block.

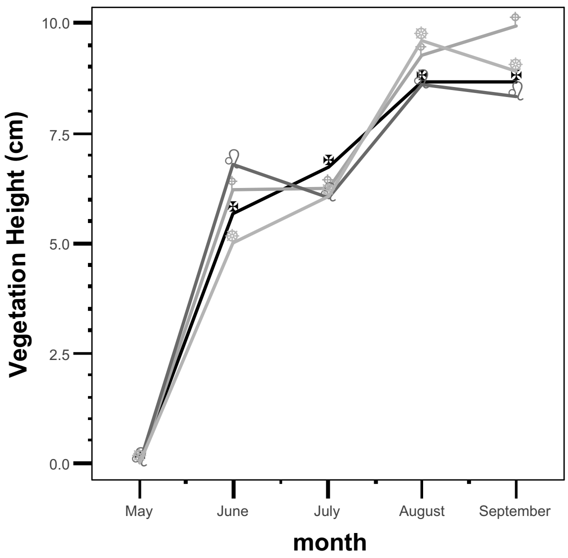


Figure 5.19 Vegetation height (cm) in the treatment rotovation. ▲= block 1, ● = block 2, X = block 3 and ■ = block 4. Dot/lines show means. $N_{control}$=30, n_{grazed}=30, n_{haycut}=60, $n_{rotovated}$=90 for each block.

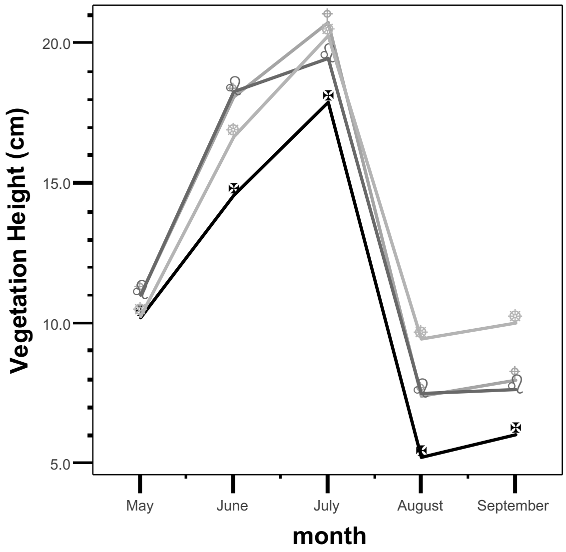


Figure 5.20 Vegetation height (cm) in treatment hay cut. ▲= block 1, ● = block 2, X = block 3 and ■ = block 4. Dot/lines show means. $N_{control}$=30, n_{grazed}=30, n_{haycut}=60, $n_{rotovated}$=90 for each block.

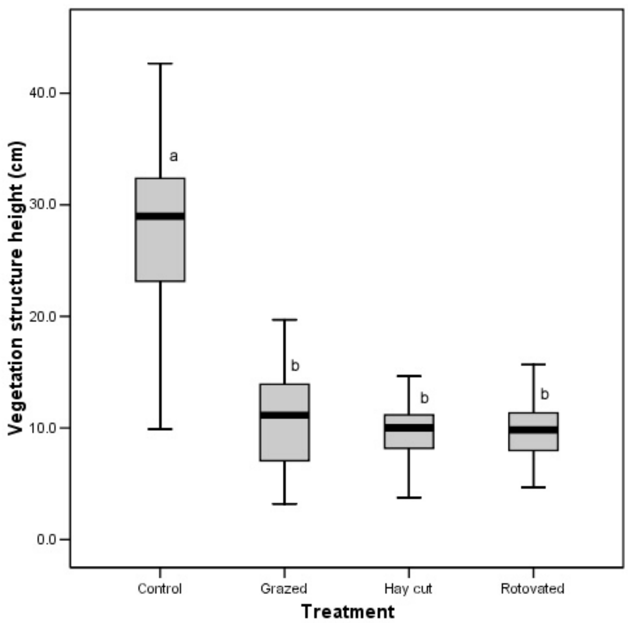


Figure 5.21 Boxplots for the variable average vegetation structure height (cm). Boxplots with the same letter do not differ significantly.

The effects of the treatments on the vegetation cover
The baseline study has already shown that significant differences existed between blocks in terms of several cover variables, and indeed “block” was found to be a significant factor for the variables % coarse grasses, % forbs and % scrub in the GLM analysis.
The factor “treatment” had a significant effect for the variables % coarse grasses, % forbs, % bare ground, % scrub and on the mean and standard deviation for vegetation structure height. The results are graphically presented in figures 5.22 until 5.25. For further data, see Borsje (2004b).

The percentage coarse grasses was lowest in rotovated plots, while grazed and cut plots also have lower coarse grasses cover than control plots. Percentage forb cover was highest in rotovated plots, with grazing and hay cutting having an intermediate position and control plots having lowest cover of forbs. The percentage bare ground was obviously a lot higher in rotovated treatments as opposed to the other three treatments. Scrub cover was highest in control plots, while scrub cover was significantly reduced by rotovation.

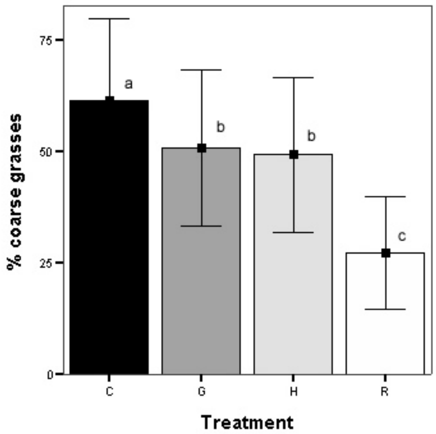


Figure 5.22 Bars represent mean % coarse grasses. Error bars show mean +/- 1.0 SD. Bars with the same letter do not differ significantly. $n_{control}$=64; n_{grazed}=64; n_{haycut}=128; $n_{rotovated}$=192. C=control, G=grazed, H=hay cut and R=rotovated.

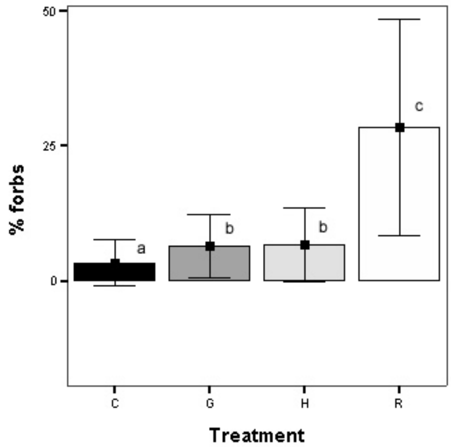


Figure 5.23 Bars represent mean % forbs. Error bars show mean +/- 1.0 SD. Bars with the same letter do not differ significantly. ncontrol=64; ngrazed=64; nhaycut=128; nrotovated=192. C=control, G=grazed, H=hay cut and R=rotovated.

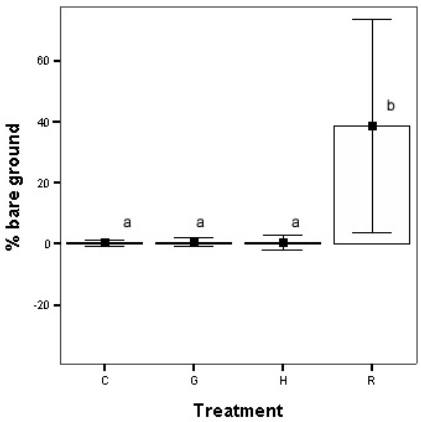


Figure 5.24 Bars represent mean % bare ground. Error bars show mean +/- 1.0 SD. Bars with the same letter do not differ significantly. ncontrol=64; ngrazed=64; nhaycut=128; nrotovated=192. C=control, G=grazed, H=hay cut and R=rotovated.

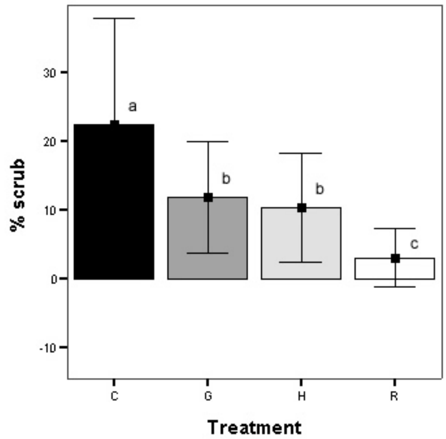


Figure 5.25 Bars represent mean % scrub. Error bars show mean +/- 1.0 SD. Bars with the same letter do not differ significantly. ncontrol=64; ngrazed=64; nhaycut=128; nrotovated=192. C=control, G=grazed, H=hay cut and R=rotovated.

In the GLM analysis, data for all blocks was analysed together. After the first year of the experiment, the effects of the treatments on the dependant variables might be not so strong and the initial differences between blocks might mask any increases or decreases in cover. Therefore, data is also presented per block. Figures 5.26 until 5.30 show the percentage cover of % coarse grasses, % fine grasses, % forbs, % Devil's-bit Scabious and % scrub as it was recorded during the baseline study, and as it was recorded in each of the treatments control, grazed, hay cut and rotovated in September.

In all blocks, the % coarse grasses seemed to have decreased in comparison to the control, with lowest percentages of coarse grasses in the rotovated treatments. Percentage fine grasses showed no consistent trend, although grazing and hay cutting seemed to be beneficial. The percentage forbs was high in rotovated plots, while it was higher for grazed and cut plots than for control plots, but not much. The percentage forbs seemed to have decreased since the baseline study for almost all treatments except under rotovation. No consistent pattern could be detected for Devil's-bit Scabious. The figure for scrub shows that no management (control) results in high scrub cover as compared to grazing and hay cutting, while rotovation resulted in lowest cover for scrub.

Application of rotovation treatment (March 2004).

Close-up of rotovated soil (March 2004).

Clonal growth in a rotovated plot (April 2004).

Vegetation in a rotovated plot (October 2004).

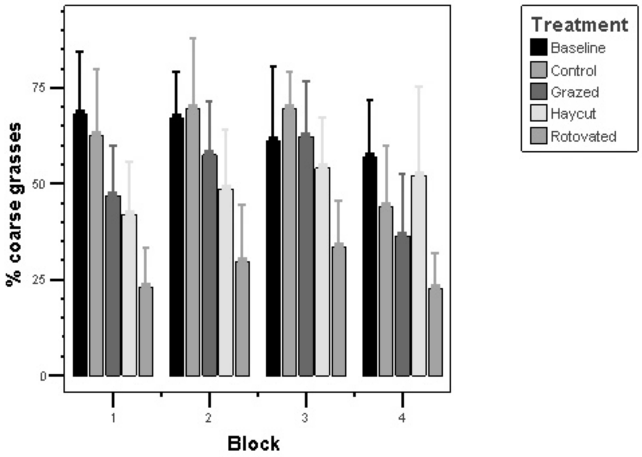


Figure 5.26 Bars represent mean % coarse grasses. Data is presented per block. Error bars show Mean +/- 1.0 SD. $n_{baseline}$=64, $n_{control}$=16, n_{grazed}=16, n_{haycut}=32, $n_{rotovated}$=48.

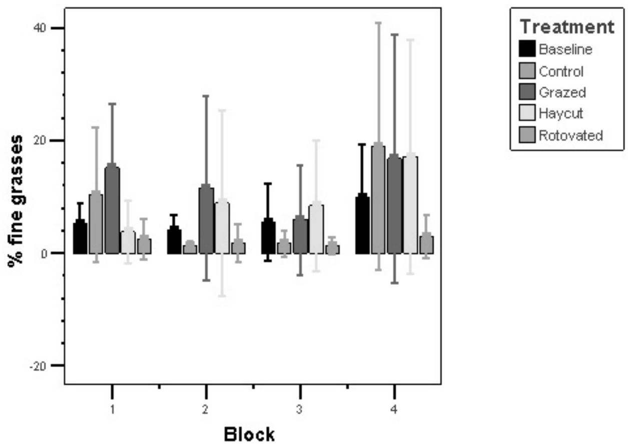


Figure 5.27 Bars represent mean % fine grasses. Data is presented per block. Error bars show Mean +/- 1.0 SD. $n_{baseline}$=64, $n_{control}$=16, n_{grazed}=16, n_{haycut}=32, $n_{rotovated}$=48.

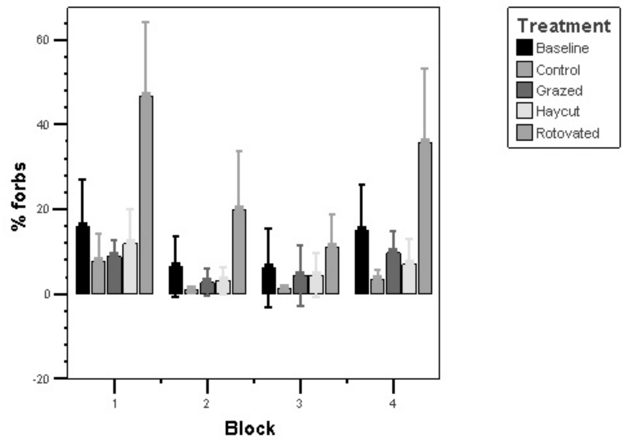


Figure 5.28 Bars represent mean % forbs. Data is presented per block. Error bars show Mean +/- 1.0 SD. $n_{baseline}$=64, $n_{control}$=16, n_{grazed}=16, n_{haycut}=32,

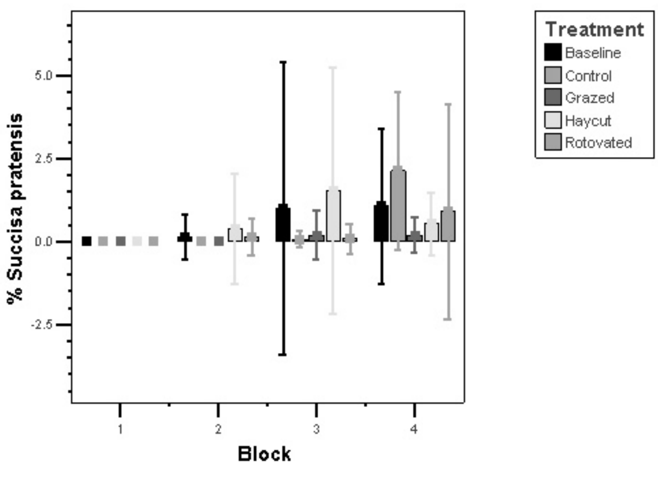


Figure 5.29 Bars represent mean % Devil's-bit Scabious (*Succisa pratensis*). Data is presented per block. Error bars show Mean +/- 1.0 SD. $n_{baseline}$=64, $n_{control}$=16, n_{grazed}=16,

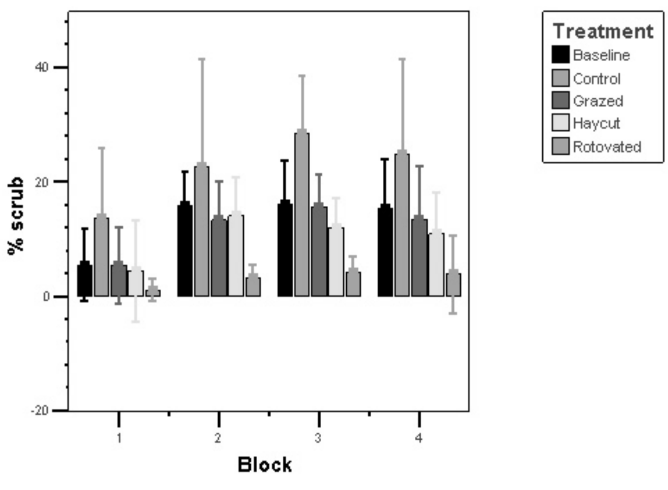


Figure 5.30 Bars represent mean % scrub. Data is presented per block. Error bars show Mean +/- 1.0 SD. $n_{baseline}$=64, $n_{control}$=16, n_{grazed}=16, n_{haycut}=32, $n_{rotovated}$=48.

Developments in the rotovated treatments
The plots that had been rotovated in March were quickly re-colonised; in June, still about 80% of the plots consisted of bare ground, while this percentage had dropped to about 40% in September (see figure 5.31). This was largely due to clonal re-growth from roots and plant parts. Especially Purple Moor-grass and Tormentil *Potentilla erecta* colonized large parts of the plots vegetatively, and clonal re-growth of Devil's-bit Scabious has also been observed. It was thought that the former standing vegetation would return quickly, and indeed the vegetation cover in the rotovated plots in June and September mirrors the vegetation cover as was recorded during the baseline study (compare figure 5.33 and 5.34). In the blocks where the percentage fine grasses, scrub, forbs and Devil's-Bit Scabious was high during the baseline study, relatively high percentages can also be found in the rotovated plots in those blocks in June and September.

Also the number of species found in the blocks reflects the former situation; the number of species was found to be higher in block 4 during the baseline study (see section 5.2) and the same accounts for the number of species recorded in the rotovated plots (see figure 5.32). Information about the species that germinated in the rotovated plots in the four blocks can be found in the next section that discusses the germination recorded in all treatments.

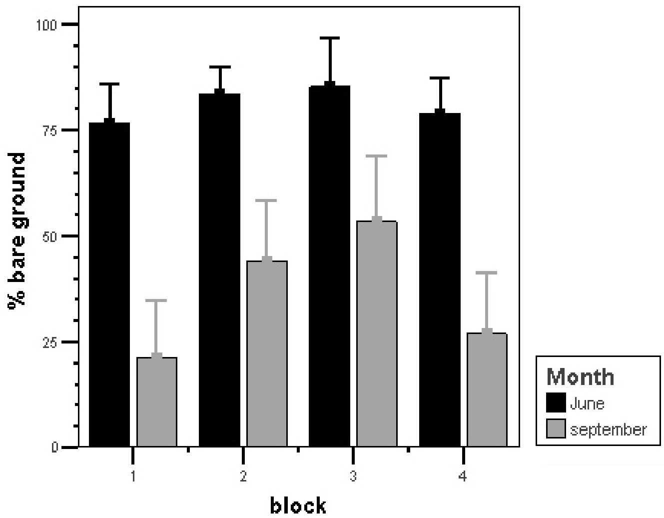


Figure 5.31 Bars represent % bare ground. Data is presented per block. Error bars show Mean +/- 1.0 SD. n_{june}=48 and $n_{september}$=48 for each block. Error bars show Mean +/- 1.0 SD.

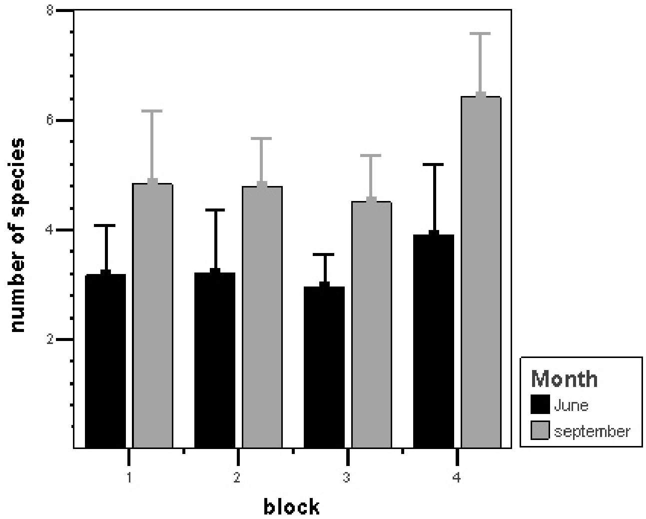
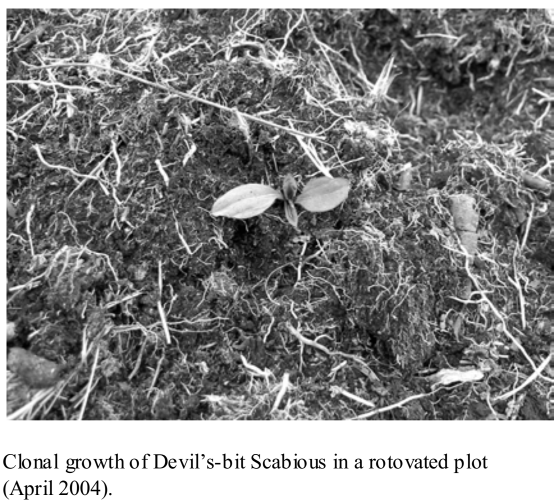
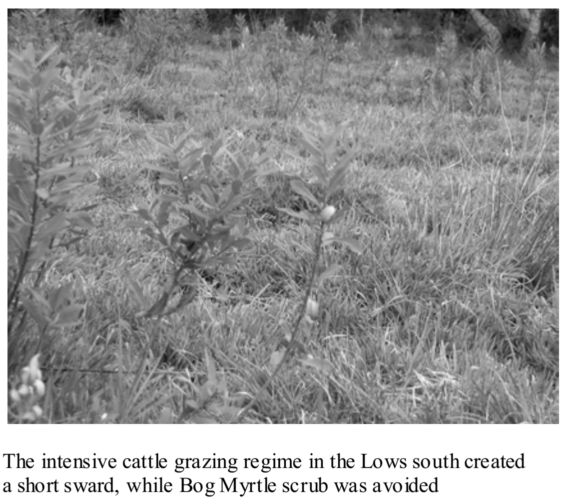


Figure 5.32 Bars represent the number of species recorded. Data is presented per block. Error bars show Mean +/- 1.0 SD. n_{june}=48 and $n_{september}$=48 for each block. Error bars show Mean +/- 1.0 SD.



Clonal growth of Devil's-bit Scabious in a rotovated plot (April 2004).



The intensive cattle grazing regime in the Lows south created a short sward, while Bog Myrtle scrub was avoided (September 2004).

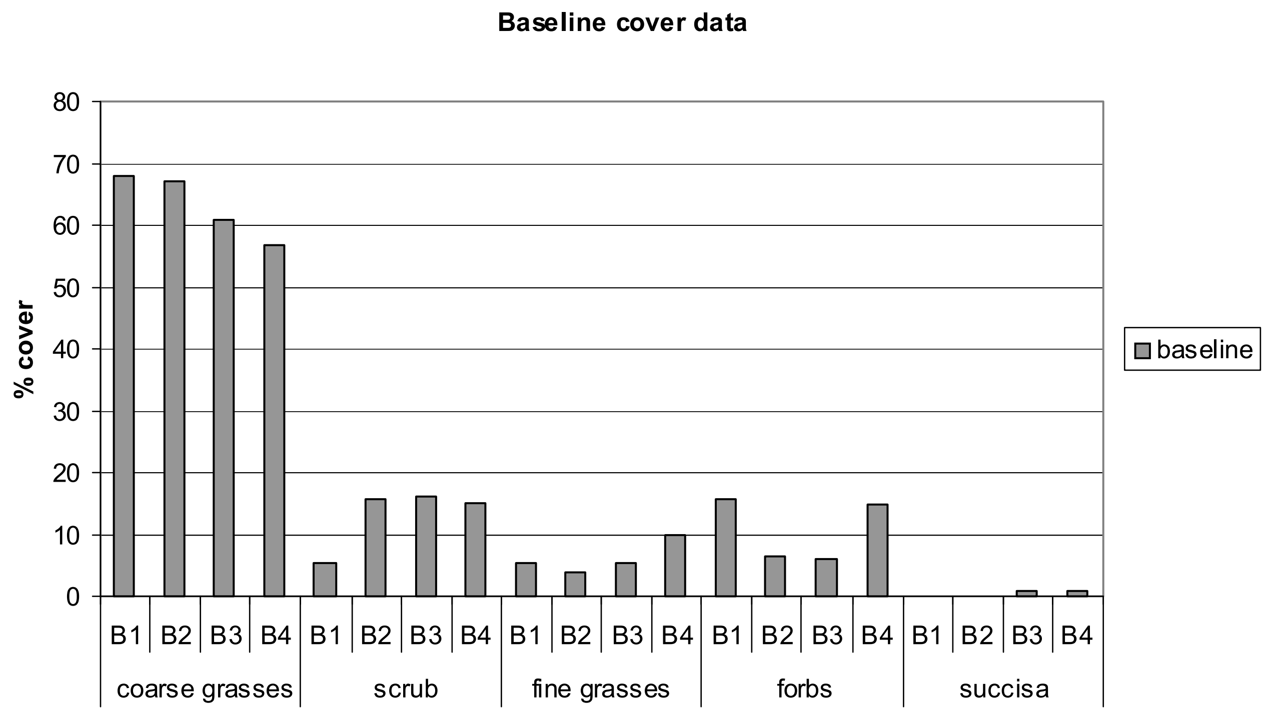


Figure 5.33 Bars represent percentage cover for coarse grasses, scrub, fine grasses, forbs and Devil's-bit Scabious (*Succisa*) as recorded during the baseline study in June.

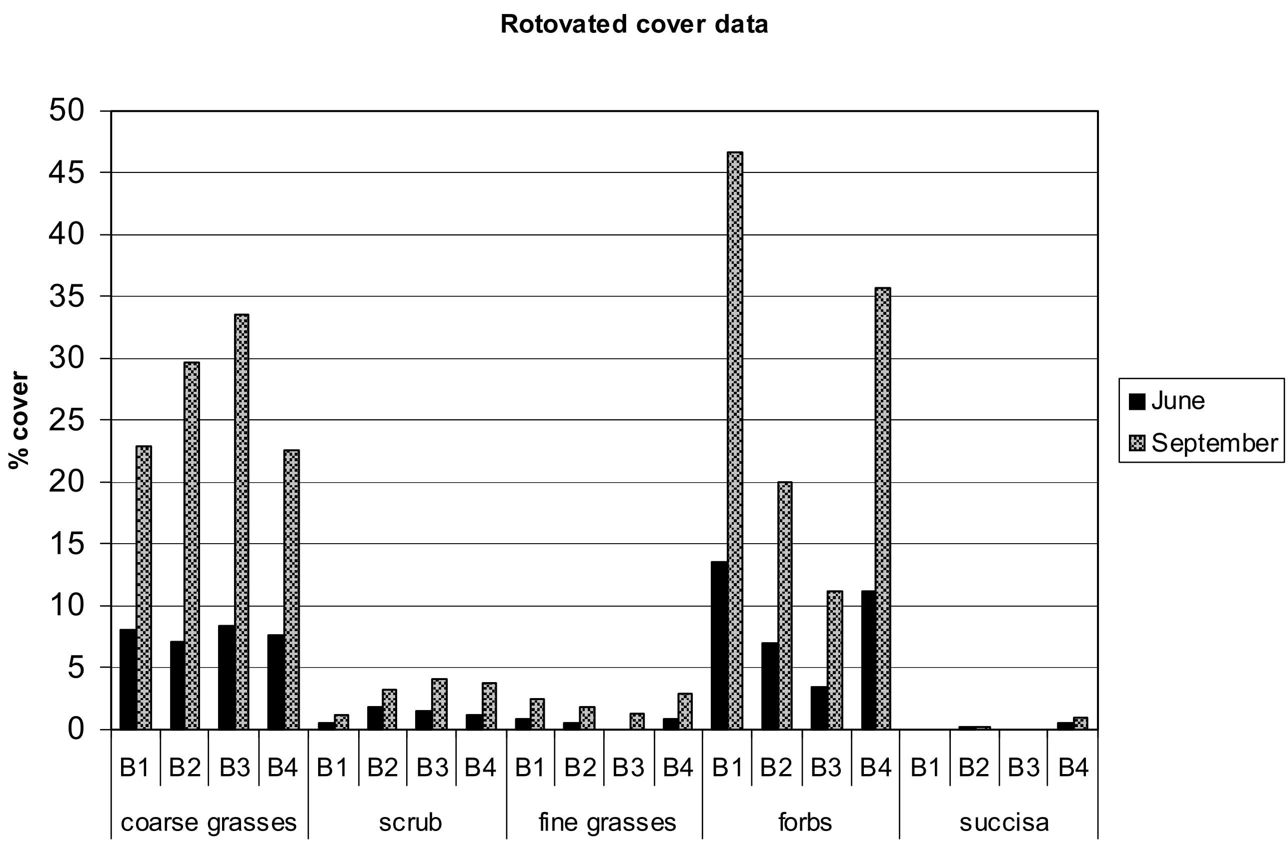


Figure 5.34 Bars represent percentage cover for coarse grasses, scrub, fine grasses, forbs and Devil's-bit Scabious (*Succisa*) as recorded in June and September in the rotovated plots.

Establishment of species under the different treatments
The mean number of established species was highest in rotovated plots, however, the differences between treatments were small and the mean number of species low with means not exceeding three species in any plot (see figure 5.35). The number of seedlings recorded was higher in block 1 and 4. Overall, establishment was higher in rotovated plots and in plots cut for hay than in the other treatments. The species that established in the different blocks are represented graphically in figures 5.36 until 5.39 on the next page.

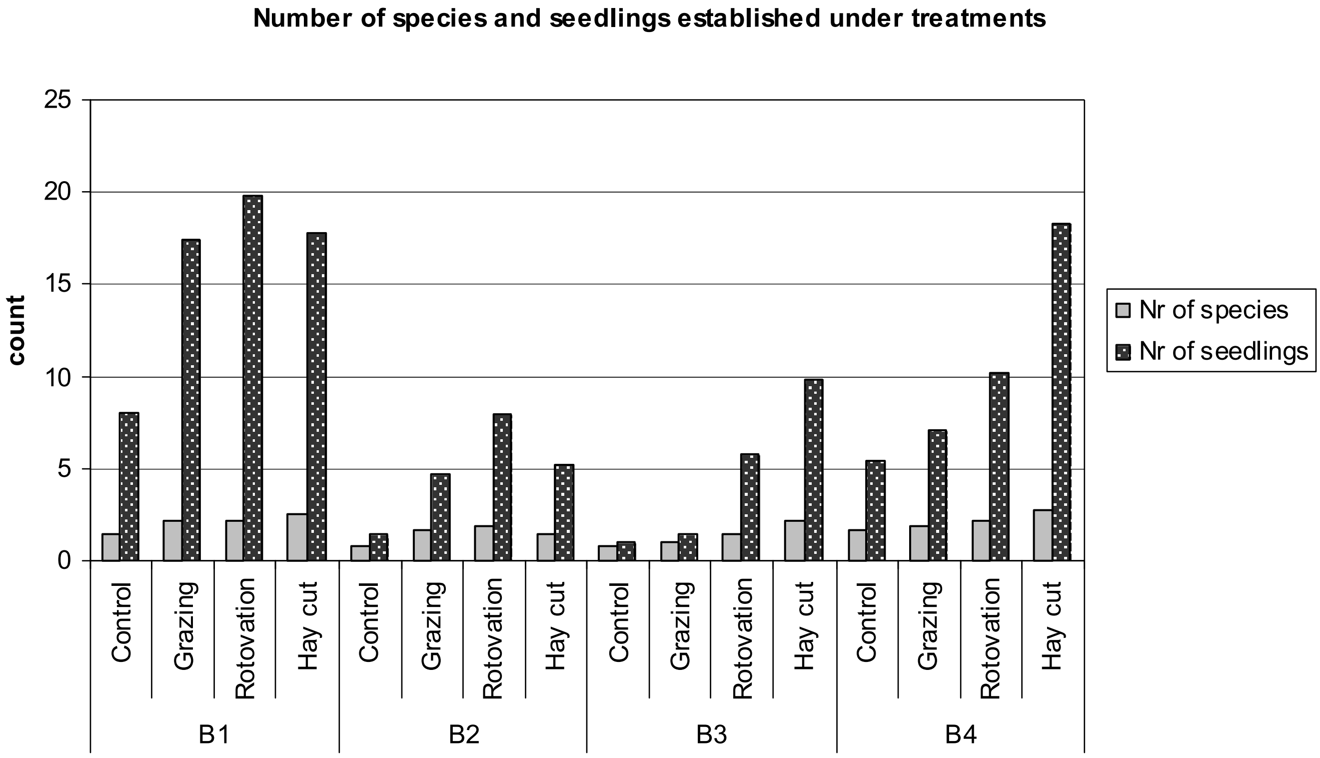


Figure 5.35 Bars represent the number of species and number of seedlings recorded in the treatments control, grazing, rotovation and hay cut. Data is presented per block.

Overview of block 2 and 3 with some rotovated plots in the foreground and the treatments haycut and control visible in the back (July 2004).

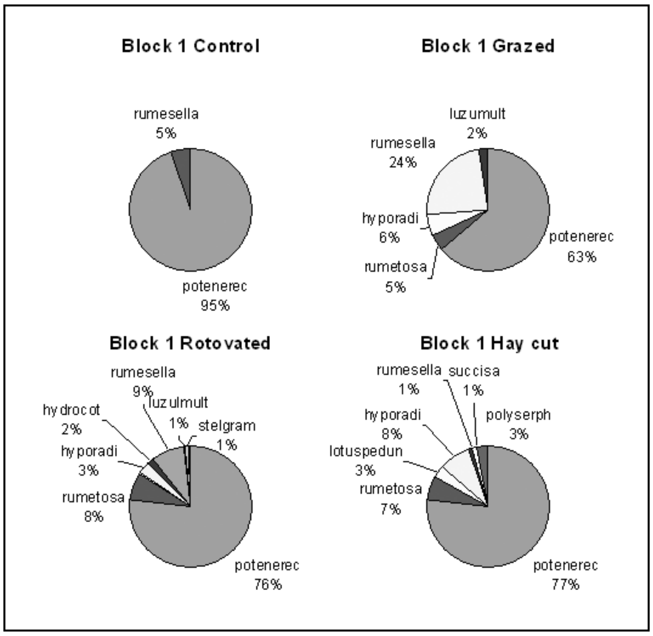


Figure 5.36 The established species in block 1 under the treatments control, rotovated, grazed and hay cut. Species are assigned by the first four letters of the Latin genus and species names, except for Common Sorrel *Rumex acetosa* and Sheep's Sorrel *Rumex acetosella.* These species are assigned by rumetosa and rumella respectively.

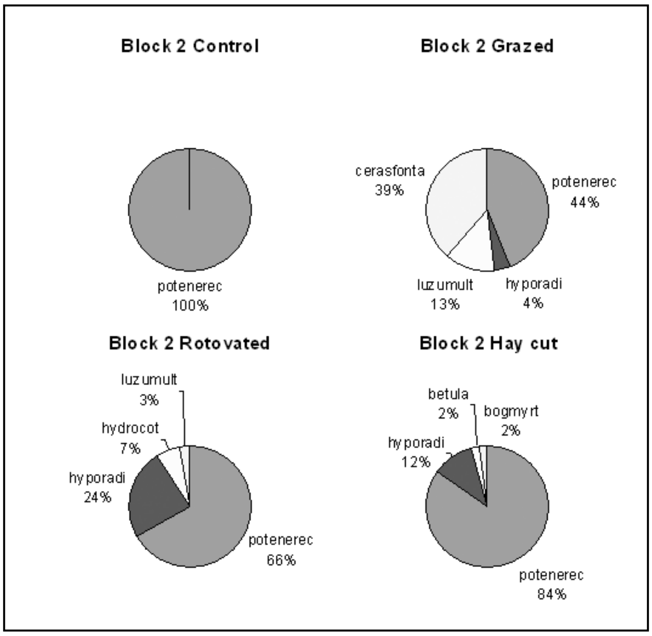


Figure 5.37 The established species in block 2 under the treatments control, rotovated, grazed and hay cut. Species are assigned by the first four letters of the Latin genus and species names, except for Common Sorrel *Rumex acetosa* and Sheep's Sorrel *Rumex acetosella.* These species are assigned by rumetosa and rumella respectively.

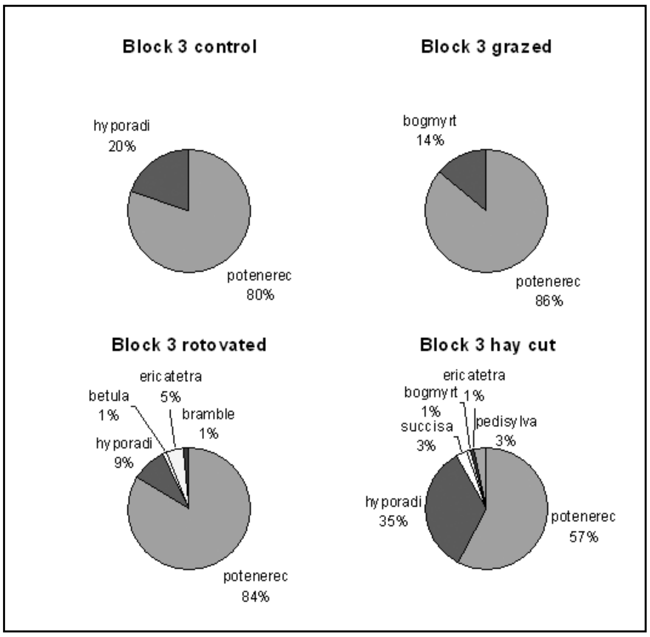


Figure 5.38 The established species in block 3 under the treatments control, rotovated, grazed and hay cut. Species are assigned by the first four letters of the Latin genus and species names, except for Common Sorrel *Rumex acetosa* and Sheep's Sorrel *Rumex acetosella.* These species are assigned by rumetosa and rumella respectively.

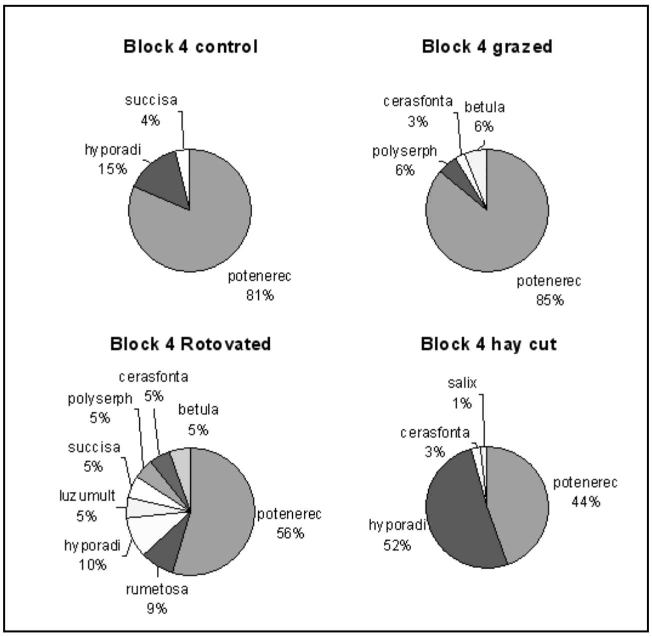


Figure 5.39 The established species in block 4 under the treatments control, rotovated, grazed and hay cut. Species are assigned by the first four letters of the Latin genus and species names, except for Common Sorrel *Rumex acetosa* and Sheep's Sorrel *Rumex acetosella.* These species are assigned by rumetosa and rumella respectively.

5.5.3 Discussion & Conclusion

The process of vegetation community restoration is often slow, as several studies have shown (eg Bakker 1989; Bakker and others 2002). Analysis of the results during the first year of the experiment is rather hasty, and any drawn conclusions would be premature. Therefore, most results in the former section have been presented graphically without testing for significance.

Comparison of the results at the end of the first growing season with the baseline study as carried out in June can easily result in wrong conclusions. For example, the data seems to suggest that fine grasses have increased in cover in comparison to the cover as recorded during the baseline study. It is however more likely that this increase in cover is due to leaf expansion and growth of the fine grasses during the growing season. Another example is the percentage forbs cover. The data suggests a decline in cover of forbs species in the grazed and cut treatments. The decrease in cover is probably the result of the grazing action of the animals and the removal of the vegetation during the hay cut, and does not reflect true changes in the cover of the herbaceous plants. True changes in vegetation cover can only be detected when comparing the baseline cover data (recorded in June), with cover data recorded in the same month in the coming years. Therefore, it is not possible to reject or accept any of the hypotheses at this moment. The results after the first year do however show some notable trends. Especially the low cover of Purple Moor-grass in most of the rotovated treatments is interesting. If subsequent vegetation management could prevent further increase in cover of Purple Moor-grass and provide appropriate conditions for establishment of fine grasses and forb species, this treatment could be very successful in achieving a reduction in cover of Purple Moor-grass and scrub species in favour of fine grasses and forbs.

The vegetation structure height in the control plots differed significantly from that in the other treatments. The vegetation was higher and there was more variation in vegetation height. This is probably caused by the fact that the vegetation was allowed to grow uncontrolled, resulting in large tussocks of Purple Moor-grass and Bog Myrtle dwarf bushes, with some lower species growing in between.

In this first year of the experiment, establishment of species in the rotovated treatments consisted mainly of Catsear *Hypochaeris radicata* and Tormentil. Some interesting species like Lousewort *Pedicularis sylvatica* and Heath Milkwort *Polygala serpyllifolia* established in block 4, in which the vegetation is generally more species-rich than in the other blocks. The vegetation in the rotovated plots is closing rapidly, but there is still substantial bare ground present. It is very well possible that this more sheltered environment will provide more safe sites for other species to germinate in the coming years. The environment as present during this first year just after the rotovation treatment had been applied might have been too harsh for germination and establishment of a lot of species.

The Lows comprises a fairly unproductive system, and there was not enough re-growth after the cut in July to allow a proper second hay cut in September. It is therefore recommended that in subsequent years of the experiment, the first hay cut is applied in June, just after monitoring of the vegetation is complete. Hopefully, this will result in more vegetation re-growth in September, which will justify the second hay cut and improve the treatment. Moreover, early cutting is thought to be most successful in reducing the dominance of Purple Moor-grass (Crofts & Jefferson 1999; Weeda and others 2003). For the same reason, it is recommended that grazing in the Lows south commences as early in spring as possible.