EFFECT OF CLIMATE MANIPULATIONS ON A GRASSLAND COMMUNITY

Purpose

- To examine the data and experimental techniques of an investigation into the effect of climate change on the growth of two grassland communities.
- To investigate the effect of rising temperature and changing rainfall patterns on plant growth.
- To show how the significance of differences within data is dependent on the degree of error within the experiment.

Effect of changing climate on plant growth

Research into the effect of changing temperature and rainfall patterns can be undertaken in the field using grassland plots with different treatments, or in a laboratory experiment to investigate the effect of changing conditions on plant growth. This activity is in two parts: in the first part you analyse data collected from field experiments and in the second part you plan and, time permitting, complete an investigation into plant growth.

Climate change field experiment

The Unit of Comparative Plant Ecology, University of Sheffield, exposed two different limestone grassland communities to simulated climate change in a five-year experiment.

One grassland was at Wytham, Oxfordshire. This area was arable farmland until relatively recently. The second site at Buxton, Derbyshire, by contrast, is an ancient, stable sheep pasture. At the start of the investigation the species richness at both sites (i.e. the number of different species present) was similar, although the species present were different.

The grassland plots used in the experiment were carefully chosen to be as similar as possible so that environmental variables were controlled as far as possible. The plots were 3 m × 3 m. Two levels of temperature treatment (normal or winter warming) and three levels of rainfall treatment (drought, normal or supplemented summer rainfall) were used.

The temperature of the heated plots was monitored using probes linked to a computer control system; 1000 W cables lying 5 cm apart at the soil surface maintained the winter warming plot at 3 °C above ambient temperature.

The summer drought was imposed by automatically operated, semi-transparent rain covers which slid over the plot at the onset of rain and rainfall was prevented from reaching the plot during July and August.

For the watered plots, water was added regularly through June to September to give 20% higher rainfall compared with a 10-year precipitation average for the area. A calibrated hose with spray nozzle was used.

Plot	Temperature	Rainfall
Winter warming	Winter warming	Normal
Summer drought	Normal	Summer drought
Supplemented summer rainfall	Normal	Supplemented summer rainfall
Winter warming + summer drought	Winter warming	Summer drought
Winter warming + supplemented summer rainfall	Winter warming	Supplemented summer rainfall
Control	Normal	Normal
Cable control	Normal (with unconnected heating cable in the soil)	Normal

Table 1 Simulated climate conditions used in the grassland plots.

The plots for the different treatments were arranged in a randomised block design, replicated five times. Each replicate block contained nine plots: one of each treatment (see Table 1), a control plot and a cable control (with ambient conditions and unconnected heating cables). There were two spare plots in each replicate block.

Questions

Q1 Sketch the layout of the experimental and control plots as described above for the five replicate blocks.

You can see plots being investigated at the Buxton Climate Change Impacts laboratory website. At the end of the season, the plots were cut to a height of 4–5 cm to maintain a short turf. The biomass produced was recorded. The results are summarised in Figure 1.

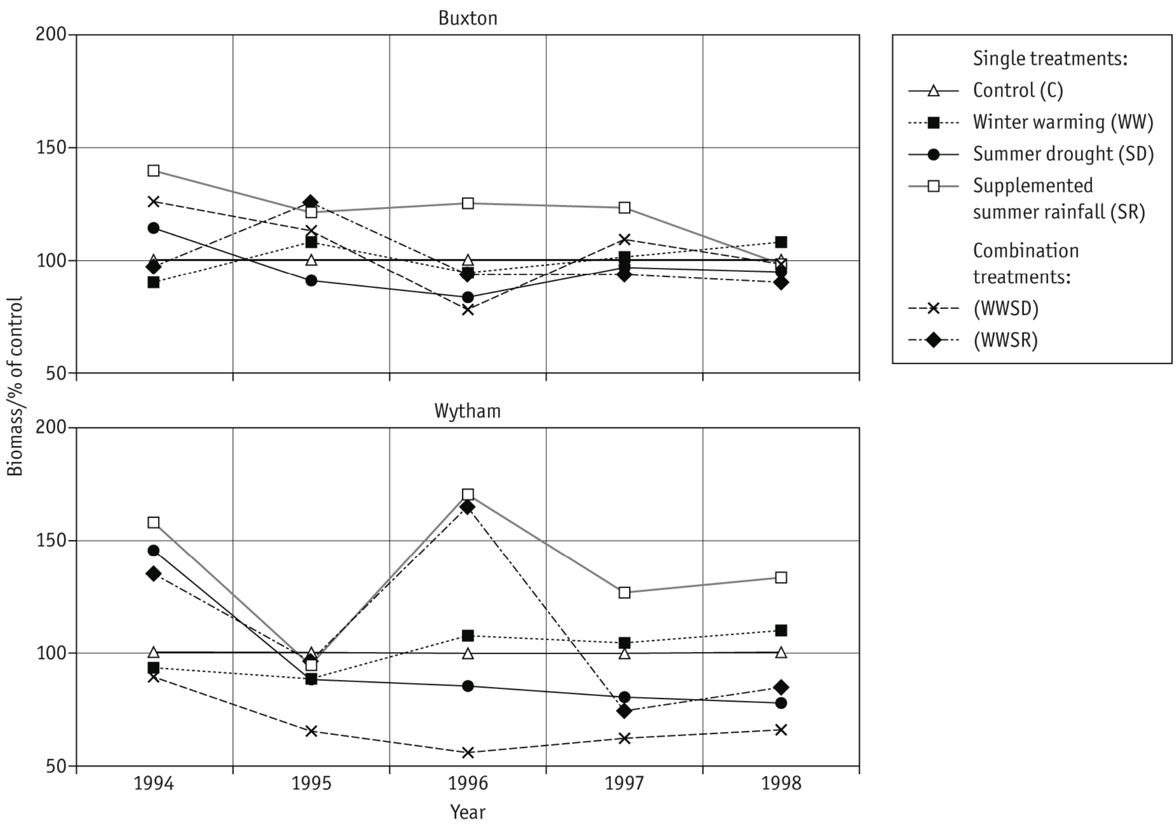

Figure 1 Mean biomass for each treatment plotted as a percentage of control biomass
Source: Grime, J.P., Brown, V.K., Masters, G.J., Hillier, S.H., Clarke, I.P., Askew, A.P., Corker, D., Kielty J.P. (2000) The response of two contrasting limestone grasslands to simulated climate change. *Science* 289, 762–765.

Q2 Suggest why the biomass for the treatments was plotted as a percentage of control biomass, rather than as the raw biomass figures for each year.

Q3 Identify treatments that **a** stimulated and **b** depressed biomass at the Wytham site in four or more of the five years.

Q4 What do these results suggest is the main limiting factor for growth?

Q5 The data in Table 2 give the mean values for each treatment over the five-year period. They also include standard error values for each of the means. These are calculated values of the amount of variation around the mean. Present these data in the most appropriate graphical format and add the standard errors to each value. This is done by drawing a bar above and below the value whose length represents the value of the standard error.

Treatment	Buxton mean biomass/g	Standard error/g	Wytham mean biomass/g	Standard error/g
C	181.6	12.8	212.5	20.7
WW	183.5	15.6	215.8	25.4
SD	175.4	18.8	199.6	23.0
SR	220.4	15.6	283.2	25.4
WWSD	192.9	21.5	145.6	16.8
WWSR	182.6	11.6	226.0	17.8

Table 2 Mean values of biomass for each treatment over the five-year period.

Look at the graph and compare the amount of variation for each mean with the differences between the treatments. Using the graph, explain whether or not you can be confident that the differences between the treatments are significant. Give reasons for your answer.

Q6 Two communities were studied in this experiment; a disturbed community (Wytham) and a mature community (Buxton). Which type of community was more responsive to the treatments?

Q7 Expanding human populations and associated changes in land use are replacing mature, stable ecosystems with more disturbed ecosystems. From the results of this experiment, is human impact likely to make the landscape more or less responsive to climate change? Explain your answer.

Figure 2 shows the results for the abundance of two grass species, *Festuca ovina* and *Agrostis vinealis*, from the droughted plots.

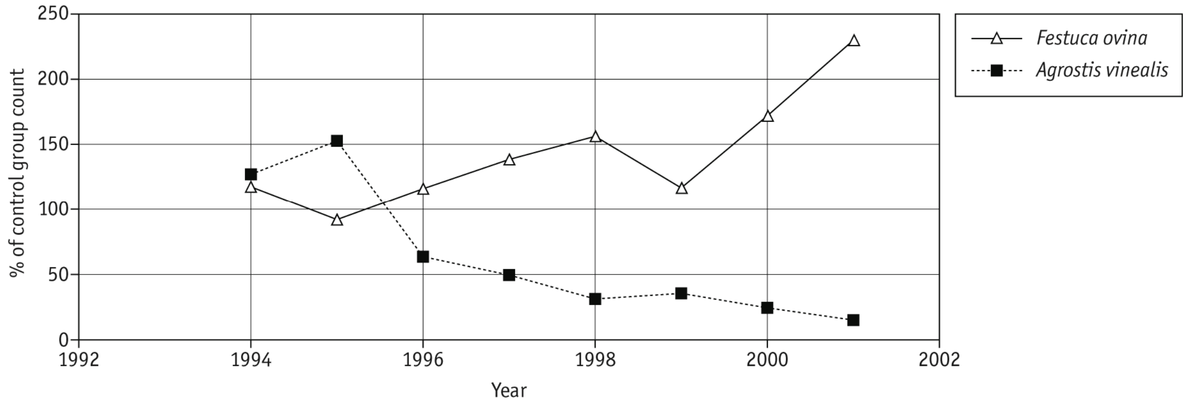

Figure 2 Mean biomass for each treatment plotted as a percentage of control biomass.

Q8 Deduce which species appears to be drought resistant. Justify your selection.

Investigating seedling growth in the laboratory

In addition to field experiments the effect of changing climate conditions on plant growth has also been investigated in laboratory-based growth experiments where conditions can be more carefully controlled. Extension 5.8 describes one such experiment that investigates changing carbon dioxide concentration. Design a laboratory experiment yourself that could be completed in school to explore the effects of temperature and drought on seedling growth in a similar way to the field experiments described above. Write a detailed plan that could be followed by another A level Biology student. If you need a reminder about what should be included in your plan have a look at the Developing Practical Skills Support material on SNAB Online.

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Notes on the procedure

The first part of this activity examines the data and experimental set-up of the climate manipulation experiments undertaken by the Unit of Comparative Plant Ecology, University of Sheffield (Grime, J.P., Brown, V.K., Masters, G.J., Hillier, S.H., Clarke, I.P., Askew, A.P., Corker, D. and Kielty J.P. (2000). The response of two contrasting limestone grasslands to simulated climate change. *Science* 289, 762–765). The Unit has kindly provided the data used in this activity.

The aim of the activity is partly to show students how environmental conditions can be controlled in larger-scale field experiments. It shows the effect of rising temperature and changing rainfall patterns on plant growth. It also introduces ideas about experimental design in terms of replicate block design. Variability within treatments and between treatments is also considered.

In part two, students are then asked to design a laboratory-based experiment to replicate the Sheffield investigation. This can be used as the core practical on seedling growth.

Answers

Q1 Figure 1 shows the layout of five replicate blocks, each with five randomly placed treatments plus C (control), CC (cable control) and two spare plots.

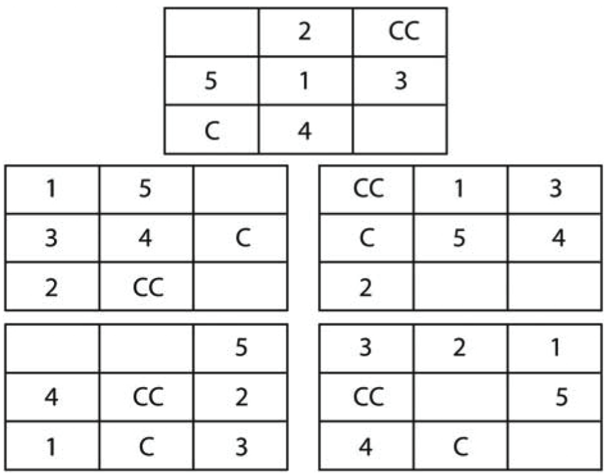

Figure 1 The possible layout of plots within the five replicate blocks.
Source: Buxton Climate Change Impacts Laboratory website.

Q2 To remove the effects of annual differences in weather, grazing, etc. that affect biomass.

Q3 **a** Supplemented summer rain.

b Summer drought. Combined winter warming and summer drought.

Q4 Volume/how much it rains in the summer.

Q5 The aim of this question is to give practice at selecting the appropriate graph and also to show how the significance of differences between data is dependent on the degree of error within the experiment. Students only need to appreciate the reason why standard errors are useful. They should produce graphs as shown in Figure 2.

Looking at the graphs, the students should see that they cannot be confident in the significance of differences between the means at Buxton where the error bars overlap. There does seem to be a difference between supplemented rainfall (SR) and the other treatments apart from winter warming with summer drought (WWSD). At Wytham the effects of supplementary summer rainfall are likely to be significant. The researchers report that at Buxton the various treatments had no consistent significant effects on plant biomass. The amount of variation between the replicate plots of each treatment was as great as any differences between the treatments. By contrast, temperature and rainfall manipulations significantly affected biomass at Wytham.

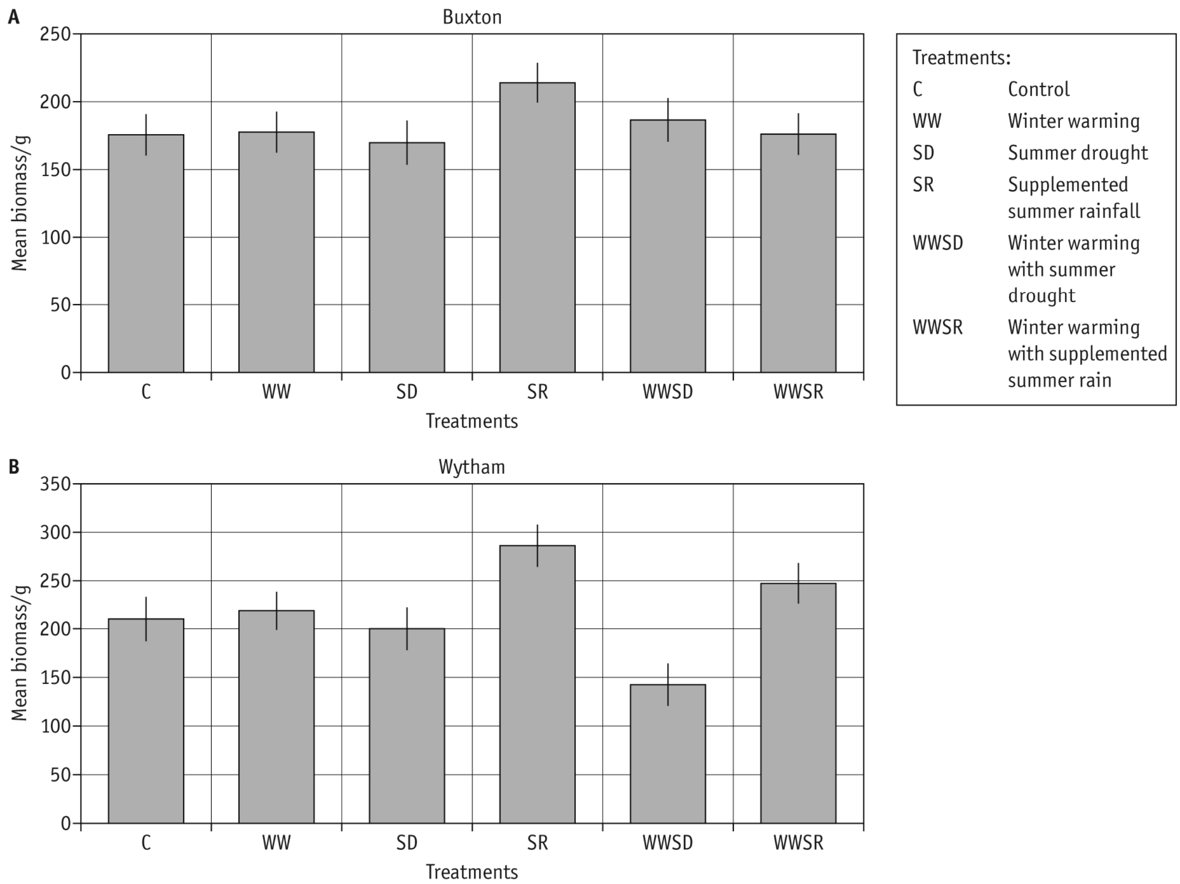

Figure 2 The effects of different conditions on the biomass of grassland plots.
Source: Buxton Climate Change Impacts Laboratory website.

Q6 The disturbed (early-successional) community at Wytham varied more in response to the treatments.

Q7 Human impact tends to cause disturbances to ecosystems and this will result in an increase in disturbed communities that are more sensitive to climate change.

Q8 *Festuca ovina*. The abundance of *F. ovina* as a % of control plot biomass increased in the drought conditions indicating that it is drought resistant. *A. vinealis* abundance decreased in the drought conditions indicating that it is drought sensitive or was out-competed by *F. ovina*.

Note: In the University of Sheffield study, abundance was measured as 'hits per m^2', using a point quadrat.

Investigating seedling growth in the laboratory

The effect of temperature on seedling growth is a core practical highlighted in the specification. In this activity students are asked to design an experiment to look at drought and temperature. This is because drought conditions have a greater effect on growth than changing temperature conditions and it also provides a link to the effect of changing rainfall patterns, which appears in the specification.

There is no detailed method sheet included; the method used will depend on time and resources available at a centre. There is no planning checklist included; at this stage in the course it provides an opportunity to check if students can recall the key features of a good plan, unprompted. Students are directed to the Practical Skills Support materials if help is required.

The laboratory experiment should include the following features:

- identical containers with the same growing medium for each treatment
- addition of the same amount of seed/same seed density to containers
- techniques for controlling light intensity and duration so that this is the same for all treatments
- suitable method for differential watering, e.g. measured volumes given to each container
- suitable method for controlling temperature, e.g. heated propagator
- suitable control for each species used, or range of treatment regimes
- suitable method for measuring growth, e.g. harvesting and weighing after stated time.

Treatments used might be:

- temperature – normal versus additional heating
- water – every day (normal) versus every three days (drought).

In order to compare the regimes it would be advisable to allow germination to take place before the different regimes are implemented. Seed trays should be identical, planted with similar density of seeds and the same growing medium should be used. It may be easier, and more accurate, to use capillary matting under the seed trays, rather than pouring water directly onto the growing medium. In this way, a measured volume of water can be added to a trough feeding the capillary matting. Nutrients should be in the growing medium, rather than added in the water. With planting in seed trays, the data collected could be increase in weight of seed tray (carried out at the same point in the watering regime) or height at set times after germination. Alternatively, biomass of samples could be determined. Collation of data from other groups would be useful to allow statistical analysis, as would comparison of results if different experimental procedures are followed.