The Buxton hub

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Across the world, science faces major challenges arising from the need to assess the impacts of a changing global climate. Many ecologists have devised models and experiments that allow predictions of the fate of particular plant or animal populations.

This "one species at a time" approach has obvious benefits for the conservation of vulnerable species and has attracted widespread support. However, in order to obtain a more comprehensive perspective, research should also be directed at larger scales including multi-species communities of organisms and, where possible, whole ecosystems. Twenty-two years ago, with some trepidation, a group of plant ecologists based at Sheffield University elected to follow this second path involving engagement with an entire ecosystem.

Buxton and Wytham

Early research developed and tested techniques by which to carry out controlled manipulations of temperature, rainfall interception, and supplementation. This work provided the basis for a five-year comparative experiment in which identical sets of climate manipulations (five combinations of winter warming, summer drought and supplementary watering) were applied simultaneously to two grasslands. The first, at Wytham near Oxford, was an ex-arable field colonised by robust perennials. The second site was an ancient unfertilised sheep pasture at Harpur Hill near Buxton in North Derbyshire. The two sites differed greatly in their rates of response to five years of continuous climate treatments: at Wytham, warming and alterations of water supply induced rapid shifts in functional composition of the vegetation, whereas in marked contrast, few changes were detected at Buxton[1].These results were in strong agreement with theoretical predictions of how plants with different potential growth rates, reproductive biology and length of life history are expected to differ in their responses to climate change according to the productivity and disturbance regime of each ecosystem.

Despite the technical and theoretical progress achieved at Buxton and Wytham, financial support was withdrawn first at Wytham and later at Buxton. However, we recognized that in the unprecedented conditions of change in the global climate it would be unwise to abandon the Buxton experiment. An immediate issue was our concern to explain why this site was so resistant to climate manipulation. A further consideration related to forecasting the exceptional and accelerating rate of climate change: future model outputs would need to be validated and refined by comparison against the results of field experiments, but there are remarkably few surviving long-term ecological experiments in the UK. Hence, if we are interested in the long-term consequences of climate change, experiments such as the Buxton Climate Change Impacts Study are a resource that will become ever more valuable with the passage of time.

Andrew Askew, Engineer and Site Manager at the Buxton Hub

Buxton 2002-2014

Despite a few difficult years in which the future of Buxton was uncertain, a number of organisations and individuals have made it possible for the experiments not only to continue, but also to expand into an international network of collaborating scientists. Without doubt the events most crucial to the development of the research programme were two successive awards from the National Science Foundation (USA) coinciding with the appointment of Jason Fridley (Syracuse University, USA) as Principal Investigator. And the determination of the researchers at Buxton to keep the climate manipulations going has paid off: Buxton is now one of the longest-running climate experiments in the world and, importantly, two decades of research have revealed changes in the grassland vegetation that were not apparent after 10 or even 15 years of climate treatments.

Ambient+ 3 degrees centigrade in February in the winter-warmed treatment

Mechanisms of resistance

A number of studies have investigated various mechanisms to explain the resistance of the grassland at Buxton to climate change treatments. A very revealing publication showed that fine-scale variation in soil depth at fine spatial scales within the Buxton experimental plots buffers community responses to the climate manipulations by allowing local relocation of species[2]. Some of this lateral movement is achieved by vegetative shoots but we suspect that seedling regeneration is also important,

particularly where bare soil is created by drought. As a first step towards assessing this, researchers at Sheffield University completed an exhaustive survey of the timing, intensity and duration of flowering in sixteen species after 20 years of climate treatments.

Three seminal publications[3-5] exposed the extraordinary amount of genetic variation in ancient calcareous grassland in North Derbyshire and pioneered techniques for its investigation. These pointed the way to characterise the nature and extent of genetic changes arising from the sustained manipulations of climate at Buxton. In 2014, a study of genetic variation in *Plantago lanceolata* provided convincing evidence that a trade-off between drought avoidance and competitive ability is driving genetic divergence between populations in drought and control plots at Buxton[6]. Several more studies of this kind are in progress.

Southern invaders and changes belowground

The Buxton facilities have also been used to examine the effects of climate manipulation on the ability of southern species to expand northwards. First experiments showed only minor benefits of warming and drought treatments to the performance of southern species, most of which failed to establish. This suggested a need for additional work with a wider range of grassland species and climate treatments. More recent experiments using *Brachypodium pinnatum* and *Bromus erectus* showed that both species are relatively insensitive to climate treatments[7] and concluded that in the fragmented landscapes occupied by these species, slow dispersal rather than climate limitation is restricting progress northwards[8].

Last but not least, the manipulations applied at Buxton provide an excellent basis for assessment of the impact of future climates on soil processes and function and work conducted at Buxton highlights the importance of considering both above- and belowground responses to climate change. Seven years of climate treatments altered the abundance of mycorrhizal fungi, which was partly attributed to changes in the relative abundance of particular plant species[9]. A more recent study (in review) demonstrated that shifts in soil microbial communities in response to the climate treatments are mediated by specific plant traits. Current projects include incubations to determine soil carbon stability, patterns of variation in soil microbial activity, and the release of soluble organic matter and mineral nutrients during the recovery phase after summer drought.

The future is bright

A landmark was reached in 2013 when we celebrated the 20th birthday of the main experiment and much has happened since. An increasing number of climate change researchers have sought access to the Buxton data or requested samples that have been subjected to climate manipulations for extended periods of time. Despite our need to limit damage to the plots, discussion has resulted in exciting new research involving scientists from ten institutions in seven countries, creating a 'hub' of climate change research centred on the Buxton plots.

The Buxton Site Manager, Andrew Askew has made major improvements to the site: the watering system is now fully automated and all rain-shelters have been upgraded. Staff from the Peak Park Authority are installing new gates, fencing and paths to ensure safe access within the experimental areas.

If the work now in progress at Buxton is to be useful for the future management of climate change impacts on the UK countryside, it is necessary to establish connections with the current processes of change that are already affecting Derbyshire grasslands. In the summer of 2013, North Derbyshire sites from an extensive survey in 1965 were revisited to collect new records and assess changes over almost 40 years. We suspect that, later this century, further surveys will allow comparisons with trajectories of floristic change currently detected in some of the Buxton plots. We are also learning from scientists working at warmer sites in Europe and continue to compare notes with our collaborators based in the slightly warmer conditions of Northern Italy.

Automatic retractable rain-shelters in position over fifteen drought treatment plots in July

Conclusions

Continuous application of modified climatic conditions in well-replicated large plots over a period of more than twenty years has created the basis for testing predictions of the relative susceptibility of ecosystems to global climate change. The presence of this unique research platform has attracted the attention of an international community of scientists and is providing exciting research opportunities for ecologists, geneticists, and soil scientists. Even after 22 years, continuing work at BCCIL has the potential to substantially advance our understanding of ecosystem function under long-term climate change. As the results of more climate change experiments become available it may eventually be possible to use sets of particular plant, animal and microbial traits to predict the rate and trajectory of response to climate change in each ecosystem[10] and to recognize priorities for conservation and management.

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