Opening Doors

Scientific workshops for young researchers

“UNDERSTANDING IMPACTS OF CLIMATE CHANGE ON TERRESTRIAL ECOSYSTEMS”

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CARMONA, SEVILLA

from 26 February to 2 March 2006
UNDERSTANDING IMPACTS OF CLIMATE CHANGE ON TERRESTRIAL ECOSYSTEMS

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Carmona (Sevilla), 26 February – 2 March 2006

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INTRODUCTION

The British Council in Spain, in collaboration with the Spanish Council for Scientific Research (CSIC) is organising a series of scientific workshops to provide opportunities for young researchers from the UK and Spain to meet face-to-face for the exchange of ideas, knowledge and information on priority topics and to explore future areas of research and collaboration.

This workshop on “Understanding the impacts of climate change on terrestrial ecosystems” was the fourth in the series.

PRESENTATION

At an increasingly faster rate, humans are modifying the spatial distribution and functioning of terrestrial ecosystems. This modification is occurring at local, regional and global scale so that, currently, the vast majority of ecosystems present a certain degree of degradation or alteration attributable to human activities. Furthermore, these activities are changing the biophysical properties of the atmosphere and of the climate, and there is now strong evidence that the ecosystems are responding to all these changes. Although much of this evidence is based on the responses of particularly sensitive species, there are more and more results that show effects at the level of the whole ecosystem. But these effects are not easily appreciable. Understanding the impacts of global change, and climate change, one of its main drivers, on the functioning of terrestrial ecosystems requires a critical analysis of our current knowledge and an extensive discussion on research agendas. This understanding is an international priority if we are to anticipate and mitigate the negative effects of such changes on the goods and services that terrestrial ecosystems provide to humankind.

Spain presents a large variety of terrestrial ecosystems, many of them unique, and all of them offering a wide range of goods and services. These ecosystems have been subjected to intense climate change in the past, but the rhythm of these changes has accelerated in an exceptional manner as a consequence of the anthropogenic emission of greenhouse gases. Accelerated climate change is bringing about a series of direct and indirect effects which are accentuated by the interaction with other motors of global change (changes in land use, pollution, biotic exchange). The effects are different for the ecosystems of the Atlantic region, limited by temperature, and for those of the Mediterranean region, limited by water. Whereas productivity could increase with climate change in the former, it might possibly be reduced in the latter. The rising awareness on these issues has led to their specific inclusion as relevant research lines in the Spanish National Program of Scientific Research (Ministry of Education and Science). The Ministry of Environment is also supporting research on impacts of climate change on ecosystems, with emphasis on the impact on protected areas, and it is coordinating the activities within both the national and international arenas by means of a Climate Change Bureau, directly attached to the Ministry (more information: http://www.mma.es/oecc/en impactos.htm. The Spanish Scientific Research Council (CSIC) is giving increasing priority to research on climate change and is planning a global trans-disciplinary strategy to address this environmental problem, taking advantage of its many institutes and research groups already tackling this topic from complementary angles.

In the UK, there is recognition that society is facing significant environmental challenges, and that more research and observations are needed before natural and human-induced impacts can be distinguished and environmental predictions improved. With this in mind, research councils such as the Natural Environment Research Council (NERC; www.nerc.ac.uk) have supported world-class research whose aims are to quantify impacts of climate on functioning of terrestrial ecosystems. Research has been supported in these three priority areas: (1) Earth’s life – support systems – water, biogeochemical cycles and biodiversity, (2) climate change – predicting and mitigating the impact; and (3) sustainable economies – identifying and providing sustainable solutions to the challenges associated with energy, land use and hazard mitigation. Collectively, such research will help society to preserve and promote environmental quality, human habitability, economic prosperity and the biodiversity of our planet. Key to achieving such tasks is collaborative research that is not bound by international boundaries; UK scientists are thus encouraged and supported to establish research links with top researchers in Europe and elsewhere. The workshop entitled “Understanding the impacts of climate change on terrestrial ecosystems” was thus an ideal forum to bring together several leading UK and Spanish research groups who have complementary and synergistic research programmes. Bringing together UK and Spanish scientists (the latter who have a well established track record in research into the effects of dry Mediterranean climates on ecosystem function) in such a forum was timely given the need for greater understanding of how expanding dry summer climates will impact on the functioning of UK terrestrial ecosystems.
**LIST OF PARTICIPANTS**

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**PROGRAMME**

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<td>9:00 Welcome</td>
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<td>Jon Lloyd</td>
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<td>John Farrar</td>
<td>Guided Tour of Carmona</td>
<td>Luis Santamaria</td>
<td>General Conclusions and Perspectives</td>
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<td>Fernando Maestre</td>
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<td>20:30 Welcome drinks and informal welcome dinner at the Parador of Carmona</td>
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<td>20:30 Dinner in a local restaurant</td>
<td>20:30 Dinner at the Parador de Carmona</td>
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**SUMMARY OF DISCUSSIONS**

The workshop provided a forum for discussions that, while being broad ranging in their content, provided tangible examples of specific cases where climate change is impacting on the functioning of terrestrial ecosystems. Over the three days of discussion, talks were presented that covered several areas identified as being of high priority for research in both the UK and Spain. Towards the end of the meeting, time was devoted to discussing in detail several areas identified as being of importance to scientists, government agencies and society in general. These included:

- The need for scientists and society at large to be critical and informed when assessing evidence of climate change. In the absence of an informed debate, there is a danger that biosensors of climate change (e.g., changes in butterfly distributions in the UK; bird populations in Europe; Pine Caterpillars in mountains of southern Spain; glacier melting in the tropics) may erroneously, in some cases, be used as evidence of climate change.
- Identifying high priority management goals necessary if the effects of climate change on terrestrial ecosystems are to be ameliorated. These include reducing soil erosion in semi arid areas, maximising carbon sequestration in the long-term as part of commitments in the Kyoto Protocol, increasing biodiversity, and preserving goods and services in environments where water availability becomes increasingly scarce.
- Determining the extent to which we can generalize from local/regional studies when predicting the impacts of climate change over large spatial and temporal scales. As part of this discussion, several participants questioned the utility of studies that were restricted to climate change factors of a local nature—it was agreed, however, that while not necessarily being useful for
large scale predictions, understanding how climate change impacts on small scale processes was often a high priority, particularly in areas of high scientific interest. To maximise the utility of collective research efforts, several participants argued for a coordinated, multi-faceted approach to the study of terrestrial ecosystem function. Within this discussion, examples from Montseny, Sierra Nevada, Pyrenees, Scottish Mtsns, and Moorland in Wales were addressed.

- Highlighting the extent to which scientific data provides sufficient resolution and accurate through time and space to enable accurate predictions to be made of future fluxes of important molecules through terrestrial ecosystems (e.g. carbon dioxide, water) and when predicting changes in distribution of plants and animals in a future, warmer world. As part of this discussion, Professor Jon Lloyd highlighted the need to incorporate population and community biology into large scale models. Although no answer was immediately forthcoming, the question of how this could be achieved was discussed in detail, with several areas of potential progress being announced.

- The issue of complexity was identified, in particular the risk that scientists all too often make predictions that are too linear in their outlook and as a consequence ignore many of the other biotic and abiotic factors that influence outcomes in terrestrial ecosystems. To deal with complexity, scientists in the UK and Spain will increasingly need to adopt a ‘systems biology’ approach to questions of ecological importance.

- The question of whether environmental change is occurring at a rate faster than the rate of adaptation was discussed. While of high importance, it was acknowledged that at present, our understanding of such factors was often hampered by a lack of experimental evidence. Research that deals with this deficiency was considered a high priority by participants from both the UK and Spain.

- The impacts of climate on soils was debated, with some questioning of the extent to which carbon turnover rates will be affected by climate change (abiotic and biotic factors). Given that carbon sequestration in soils is a crucial element of the Kyoto Protocol (under the Clean Development Mechanism), many of the participants viewed our deficiencies in knowledge of below-ground processes to be a research area in need of significant attention in coming years. The discussion then considered the extent to which heterogeneous soils are associated with higher productivity whether promotion of heterogeneous soils might be one route where by the negative aspects of climate change could be ameliorated.

- Finally, there was considerable discussion about what factors were responsible for changes in the efficiency of water use (i.e. the amount of CO2 fixed per unit water transpired). Factors such as changes in stomatal density, stomatal opening and air moisture were considered. Despite the considerable experience in this research area, it was not possible for the group to agree on some general, unifying factors responsible for the changes in water use efficiency; this highlighted the need for further well-planned research using agreed protocols.

Final conclusions

This workshop was the first of its kind to bring together a diverse range of approaches to understanding climate change impacts on terrestrial ecosystems. Rather than be limited to discussing the impacts of climate on plants and/or animals, the workshop brought together a broad range of scientists who’s research interests encompassed numerous biological taxa, and which covered a broad range of spatial and temporal scales of investigation. Importantly, the workshop also provided opportunities for scientists in both the biological and physical sciences to discuss the impacts of climate on terrestrial ecosystem functioning. In addition to increasing awareness of the research taking place in their respective countries, the workshop is likely to result in several of the UK and Spanish based research groups embarking on collaborative research in the coming years. Importantly, the workshop also provided opportunities for young scientists in both countries to gain valuable experience and exposure, thus increasing their chances of establishing themselves as independent researchers in the coming years.

COLLABORATIONS

Owen Atkin and Jon Lloyd have initiated a collaborative project with Fernando Valladares to investigate the impacts of climate on leaf carbon exchange in dryland forest ecosystems in northern Spain. Very recently (July 2006), NERC in the UK funded a large grant application that will see this collaboration continuing for the coming 3 years.

Owen Atkin also has remained in contact with Josep Peñuelas regarding the impacts of climate on leaf respiratory CO2 release, and has exchanged data sets with Andy Kowalski regarding light inhibition of leaf respiration and its interaction with climate. Future collaborations are likely with both individuals.

M. Teresa Sebastiá has planned to send one of her Ph.D students to start collaboration with Owen Atkin’s team. She is also planning to start a collaborative project with John Farrar.

Future collaborations would be great and I saw such a lot of potential from the meeting. I think my long term collaborations (connections is a more appropriate term) with Josep Peñuelas will continue, while I would like to develop some work with Fernando Valladares. (Ian Woodward)
ABSTRACTS

Teresa Sebastià - Ecosystem responses to climate and land use changes in the Pyrenees

Agustín del Prado - Interactions between climate change and grassland-based agriculture

Josep Peñuelas - Contrasting ecophysiological responses to climate change in Mediterranean ecosystems

Martín Garbulsky - Estimation of carbon fluxes between the vegetation and the atmosphere from approaches at different scales

Joana Zaragoza - Impact of growth irradiance on the temperature sensitivity of leaf respiration in long-lived, evergreen plant species

Silvia Matesanz - Influence of climate change on the performance of plants from gypsum soils: insights from experimental manipulation of precipitation

Fernando Maestre - Spatial heterogeneity in soil nutrient supply modulates nutrient and biomass responses to multiple global change drivers in model grassland communities

Laura Martínez - Mycorrhiza and climate change in arid ecosystems

Gracie Barrett - The effect of temperature on arbuscular mycorrhizal mediated plant nitrogen capture

Ian Woodward - Scaling up the impacts of environmental change on stomatal behaviour

Monica Mejia-Chang - Water use in epiphytic bromeliads: can we predict effects of forest fragmentation based on oxygen isotopic signatures

Hannah Toberman - The effects of summer drought on phenol oxidase activity and soluble phenolic carbon release in an upland Welsh heathland.

Andy Kowalski - Eddy covariance and (towards) understanding the functional behaviour of Mediterranean shrubland (matorral)

Teodoro Marañón - Global change and plant community ecology

Greg Hughes - Niche based and dynamic global vegetation models - Contrasting approaches to assess the impacts of climate change

Juan José Sanz - Impacts of climate change on bird biology: implications for their conservation

Colin Beale - Long and short-term weather effects on upland bird breeding success

Adolfo Marco - Vulnerability of reptiles to climate change

Jane Hill - Distribution changes during climate warming

José Antonio Hódar - Effect of global change on the population dynamics of the pine processionary moth Thaumetopoea pityocampa in Southern Spain

Sue Hartley - The impact of climate change on plant-herbivore interactions

Jorge Castro - Can climate change alter species composition of Mediterranean mountain forests? An experimental approach in Sierra Nevada (Spain)

Alberto Cruz - Anticipated effects of climate change in the regeneration ability after fire of Mediterranean-type shrublands

José Antonio Carreira - Relict, temperate-like, conifer forests in the Mediterranean region as experimental models to assess the impacts of climate change

Luis Sampedro - Ultimate effects of earthworms and their gut microbes at the ecosystem level. Sensitivity to new climate scenarios and implications for Global Change

Luis Santamaría - Forecasting the impact of climate change on the continental distribution of wetland plants. The importance of long-distance dispersal and local adaptation

Rachael Hickling - The distributions of a wide range of taxonomic groups are expanding polewards

Jennifer Smart - Sea-level rise: Are breeding redshank Tringa totanus caught between the sea-wall and the deep blue sea?

Greg McInerny - The shape of things to come: range dynamics and environmental change

Maria-Teresa Sebastià, Jordi Garcia-Pausas, Xavier de Lamo & Francesco de Bello

Ecosystem responses to climate and land use changes in the Pyrenees

There is general consensus that temperatures are increasing at the global level although the various models provide different future scenarios (Houghton et al. 2001). In addition to warming, many zones are expected to experience decreased rainfall under climate change (Watson, Zinyowera & Moss 1998). Most climate change scenarios project warmer and drier conditions in North-Eastern Spain (Liebøt 2005). Climate
change is expected to reduce biodiversity significantly (Thomas et al. 2004). In addition, strong changes in land use are occurring and models also predict important biodiversity losses as a consequence (Sala et al. 2000). Changes in climate and land use are expected to interact and affect plant species composition and the traits being selected with those, which in turn will affect ecosystem processes, and this will have consequences at the regional level (Chapin et al. 1997).

Several studies have been developed from the Laboratory of Functional Ecology and Climate Change at the Forest Technology Centre of Catalonia to investigate the consequences of climate and land use changes on ecosystem structure and function in NE Spain. A survey along climatic (five locations at altitudes from semi-arid lowland to cold-temperate subalpine upland) and land use (sheep grazing: intense, moderate, abandoned) gradients in that area showed that plant species diversity was lowest in water-stressed environments (arid locations and southern aspects) and increased with grazing, more markedly in humid locations (de Bello, Lep., & Sebastià 2005), but independently, showing that the same functional types cannot be used as indicators of land use under different climatic conditions. In addition, the functional consequences of these changes could be opposite than expected: although in moist locations vegetation used water less conservatively, plant strategies less conservative in water use were favoured with increased grazing intensity both in dry and in moist areas (de Bello, Buchmann & Sebastià 2006). In fact, we found decreased soil moisture with grazing in subalpine grasslands in the Pyrenees compared with abandoned areas (Vallecillo et al. 2006).

In addition to management, we found important shifts in plant diversity with biogeographical, regional, landscape, ecosystem factors. The number of species in 10 x 10 m plots increased with grassland patch size, and mixed grazing and cattle grazed areas favoured increased species richness over sheep-only grazing (Sebastià & de Lamo, 2006). Those studies were developed within an INTERREG-III A project.

In two transplanting experiments of subalpine grassland turves, we found an increased aboveground biomass in grassland sods transplanted to the lowland, suggesting that biomass production was more temperature-limited than water-limited (Sebastià 2006). The enhancement effect found in the upland sods following phosphorus addition supports the hypothesis of a strong limitation arising from reduced nutrient availability (Sebastià 2006). In addition, there were important shifts in plant species composition and guilds, suggesting strong compositional variations with climate change (Sebastià, Kirwan & Connolly in preparation). The counterintuitive effect of increased biomass with decreased water in the lowland was related to shifts in dominance from grasses to forbs, probably enabled by decreased nutrient availability under drought conditions (Sebastià 2006).

The above changes occurring at ecosystem, landscape and regional scales are expected to modify the goods and services ecosystems provide, both ecological and agronomical. Within the CARBOMONT and the CarboEurope projects we found that grazed areas presented higher soil carbon contents than abandoned, where carbon was accumulated proportionally less in grasses than in forbs and mosses (Casals et al. 2004). Changes in ecosystem functioning as a consequence of changes in management have also been found for soil carbon accumulation in grasslands within the CARBOPAS project, developed throughout the Pyrenees, were we found increasing soil active and organic C stocks with grazing by large mammals such as cattle (Sebastià et al. 2006). In addition to management, regional and landscape factors were also involved in determining soil C content.

Productivity and forage quality are agronomical goods and services that were addressed by our group within the Agrodiversity experiment, activity developed by the action COST 852 in more than 45 sites, most in Europe, some in Australia, Canada and the US (Sebastià et al. 2004). Applying an innovative design and modelling framework across 28 European sites, aboveground biomass of 4-species agronomic mixtures was consistently greater than that expected from monoculture performance and frequently exceeded the yield of the best monoculture (Kirwan et al. submitted). The additional performance of mixtures was driven by relative abundance more than species’ number (Kirwan et al. submitted). Additional studies developed in two sites, one run by our group, show decreased pest risk with increased plant diversity (Llurba et al. in prep.).

In summary, our studies show that: 1) Plant diversity responded to climate and land use changes, but the effect differed depending on the diversity component. 2) Functional type composition changed with climate and land-use change and the effects of environmental factors interacted in complex ways sometimes resulting in unexpected effects on ecosystem processes. 3) Changes at the regional scale affected processes at smaller scales, such as local species diversity decline through habitat reduction, feeding back on the primary components.

Agustín del Prado

Interactions between climate change and grassland-based agriculture

There is increasing evidence that the world’s climate is changing and that this rate of change is greater than
would be expected from natural variability alone. Not only will climate changes affect land uses and hence future agricultural systems but nowadays agricultural activities have also an important effect on other environmental (i.e: eutrophication) as well as ecological and socioeconomical issues. So far, although single mitigation measures are already available for mostly any of these issues (i.e: N2O abatement measures through use of nitrification inhibitors), these measures do not often lead to win-win situations (i.e: application of manures sequesters C and improves fertility of the soil but generally increases N2O, NH3 and NO3-leaching). Due to the complexity of the interactions in these systems modelling allows this complexity to be integrated. The development of a new modelling framework is described in this seminar. This modelling framework comprises 2 main sub-models: one sub-model optimizes (through a weighted multicriteria) the management of a UK dairy farm in order to produce sustainable farming systems on the basis of environment (emissions of GHG, NH3, NOx, N losses to waters and P losses to waters), ecology (biodiversity), soil quality, landscape, animal welfare and economic viability and a second sub-model which predicts farm adaptations to achieve sustainable farms in a climate-changed future scenario (using the same criteria as a basis). This work is still in progress and modifications will be made in order to simulate the effect of climate change on processes which control plant growth (N fixation, partition between shoot: root and N: C ratio), plant water use efficiency, soil & manure & excreta mineralization, soil nitrification, soil denitrification, plant roots and stubbles decomposition, NH3 volatilization and animal performance & welfare.

Martin Garbulsky, Josep Peñuelas and Iolanda Filella

Estimation of carbon fluxes between the vegetation and the atmosphere from approaches at different scales

Estimates of carbon uptake at the regional scale are needed as the role of countries and biomes as net sinks or sources of carbon gains political and economic importance. Global changes affect the carbon balance of terrestrial ecosystems and different approaches have tried to determine the geographical distribution and magnitude of terrestrial carbon fluxes.

During the past decades, detailed remote sensing work evidence that the radiation use efficiency (RUE) could be estimate from remote sensors by the Photochemical Reflectance Index (PRI). Today, the availability of CO2 fluxes data derived from eddy covariance towers for different biomes and remote sensing data at higher spectral, temporal and spatial resolution and coverage, allow developing new approaches to estimate primary productivity. Thus, we propose that using MODIS channels 11 and 12, a regional estimation of RUE will be possible to include in PPN estimations from the Monteith’s model.

The use of PRI at a wide range of vegetation types and climatic situations will provide a better background to generate new primary productivity estimations. Primary productivity estimations will benefit from the increasing of better spatial and temporal resolutions. PRI derived from MODIS could increase both of them for a 6 year period (2000-05). In Mediterranean forests, short term water availability controls the RUE, and this feature could be gathered by the PRI. From our analysis, we concluded that the PRI appears as a promising tool to track photosynthetic capacity of vegetation at regional scales and that could improve the evaluation of the impacts of climate change on vegetation function.

Josep Peñuelas, Alistair Jump, Jordi Sardans, Francisco Lloret, Iolanda Filella, Marc Estiarte, Romà Ogaya, Joan LLusià, Roger Seco, Martin Garbulsky, Giorgio Alessio, Jenny Hunt, Sue Owen, Dolores Asensio, Patricia Prieto, Angela Ribas, Salvador Blanch

Contrasting ecophysiological responses to climate change in Mediterranean ecosystems

We presented contrasting biological responses to climate change taking as pilot field site the Montseny mountains (Barcelona) which constitute an ecotonic area between the wet temperate and the Mediterranean biome. We presented the species contrasts in phenological responses to current warming, an the spatial and temporal contrasts in growth responses of beech trees from the higher tree-line to the lower forest limit, and from several decades ago to nowadays. We then passed from phenotypic responses to genotypic responses and microgeographic differentiation of individuals (adaptation). Finally, we presented data on beech migration resulting from amelioration in the higher altitudinal-latitudinal ranges and replacements in the lower altitudinal-latitudinal ranges. We also presented interactions of the climate change effects with those of other components of global change with an example of fragmentation of the beech forest. As a result of the contrasting responses, significant changes in ecosystem structure and functioning are expected. We have already observed many of these changes in experimental studies that, for example, show biodiversity losses in response to drought and warming. At the end, though, we reminded that change is consubstantial to life in Earth.
J. Zaragoza Castells, D. Sanchez Gomez, F. Valladares and O.K. Atkin

Impact of growth irradiance on the temperature sensitivity of leaf respiration in long-lived leaves, evergreen plant species

Understanding the effect of temperature on plant respiration (R) is fundamental to predicting the impact of global change on the biosphere. Although R has been shown to be sensitive to short-term changes in temperature (i.e. Q10), the impact of long-term temperature changes depends on the degree of respiratory acclimation. The work presented here investigated the impact of growth irradiance (full sun and permanent shade environments) on the sensitivity of R to short- and the long-term changes in temperature under controlled conditions and also in the field where other abiotic factors also varied. Our test species was a Mediterranean dry-land evergreen plant with long-lived leaves (Quercus ilex). The results demonstrate that sun and shade leaves of Quercus ilex are capable of approaching full acclimation to changes in the growth temperature. We observed seasonal changes in the Q10, with higher values in winter than in summer. However, while irradiance affected photosynthesis, it had no effect on the Q10 of leaf R although rates of leaf R were lower in shade-grown leaves than their high-light grown counterparts. Nevertheless, we observed that plants under shade can manifest respiratory thermal acclimation. In addition, in the field, we observed dynamics shifts of temperature response curves through the year under both sun and shade providing further evidence that these plants can acclimate. Consequently acclimation must be taken into account in order to establish accurate leaf gas exchange models in these Mediterranean systems with very low carbon input.

Silvia Matesanz, Fernando Valladares & Adrián Escudero

Influence of climate change on the performance of plants from gypsum soils: insights from experimental manipulation of precipitation

There are several main drivers of global change causing changes in biodiversity and ecosystems. In Mediterranean ecosystems, the impact of fragmentation (habitat change), climate change, and degradation of the habitat is increasing very quickly. To understand and predict the response of plant communities to these changes, it is crucial to assess the impact of both the factors separately and their interactions. To address this objective, we set a factorial experiment (factors: fragmentation, degradation and drought) in a semiarid area of strong agricultural tradition on gypsum soils, in which there are remnants of natural vegetation of different sizes and connectivity. We monitored different morphological, physiological and phenological traits of individuals of the target species, Centaurea hyssopifolia, endemic of the area during 2005 and 2006. We found different results in relation to the studied variable, but in general terms, the three factors had negative effects on the performance of the plants (e.g.: survival, photochemical efficiency or growth). Also, we found significant interactions among the factors, so that the effect of climate change tends to worsen the effects of fragmentation and degradation in the plants. Our results highlight the importance of identifying the main drivers in each system to integrate their effects on plant communities and predict their response in future climate scenarios.

Fernando Maestre & James F. Reynolds

Spatial heterogeneity in nutrient supply drives plant nutrient and biomass responses to multiple global change drivers in model grassland communities

The spatial pattern of nutrient supply (nutrient heterogeneity) influences the productivity of plant communities, but it is virtually unknown how nutrient heterogeneity and global change drivers interact to affect plant performance and ecosystem functioning. We conducted a series of microcosm experiments to evaluate the effect of simultaneous changes in the atmospheric concentration of CO2 ([CO2]), nutrient heterogeneity, nutrient availability and biotic diversity (species composition, richness and evenness) on the biomass and nutrient content of grassland assemblages. Nutrient heterogeneity modulated the effects of nutrient availability and [CO2] on biomass production and aboveground nitrogen content, and those of species composition on biomass production. Our results show that nutrient heterogeneity has the potential to influence the response of plant assemblages to simultaneous changes in [CO2], nutrient availability and biotic diversity, and suggest that nutrient heterogeneity is an important environmental factor to interpret and assess plant assemblage responses to global change.

Laura Martinez

Mycorrhiza and climate change in arid ecosystems

Climate change models predict for Spain an increase of temperature and changes in rainfall patterns inducing heavier events in winter and longer drought spells. These changes may affect mycorrhizae communities in several ways, having implications for terrestrial ecosystems. Being water the most limiting factor in arid environments, it is important to understand the effect of further water shortages on mycorrhizal activity.

Previous studies on this subject were conflicting. In several experiments it was observed an increased in colonization...
as water became limiting but in others the opposite effect was true. However, most of these experiments were done with inoculated plants of agricultural importance, and therefore, information on water variability on native populations in the field is scarce.

Regarding this lack of information, we want to analyze the response of mycorrhizae to decreasing water availability, monitoring the effect of two different watering levels on root colonization by native population of arbuscular mycorrhiza. In the field, we will look at mycorrhiza variability along a drought gradient, expecting changes in root colonization and species composition depending on environmental conditions.

**Monica Mejia-Chang, Brent Helliker, Klaus Winter and Howard Griffiths**

**Water use in epiphytic Bromeliads: can we predict effects of forest fragmentation based on stable oxygen signatures?**

Epiphytic bromeliads are subjected to intermittent precipitation inputs, such as rainfall and fog, which can be exploited over varying timescales, depending on seasonality, growth form (tank vs. atmospheric species), metabolism (CAM vs. C3) and exposure within the canopy. Our study utilises epiphytic Bromeliads along an altitudinal gradient that includes mesic and montane forest in Panama. With plants effectively isolated from ground water sources, we hypothesized that oxygen isotopes in water sources would provide a signature related to altitude or seasonality in precipitation, as well as dewfall or fog inputs. In addition, we anticipated that the 18O in leaf water and organic material would provide a marker for the degree of evapotranspiration. Rainfall patterns and precipitation inputs were mirrored in tank water and leaf water enrichment for C3 plants. The more succulent CAM bromeliads, in contrast, were buffered against changes along an altitudinal gradient. Conversely, δ18O values of organic matter suggest that plants, independent of photosynthetic metabolism, preferentially fix carbohydrates during the rainy season, when water is not a limiting resource.

Subsequently, a series of laboratory-based measurements have been undertaken to explore the uptake and utilisation of liquid water and fog, by manipulating water sources isotope signal and following the shift in leaf water enrichment. The results confirm the notion that epiphytic bromeliads have a high dependence on atmospheric water inputs, suggesting that they are sensitive indicators of climate changes resulting from altered precipitation patterns and or habitat fragmentation in tropical forests.

**Hannah Toberman**

**The effects of summer drought on phenol oxidase activity and soluble phenolic carbon release in an upland Welsh heathland**

The Intergovernmental panel on Climate Change (IPCC) has predicted that global warming may result in a greater...
frequency of summer droughts at higher latitudes. Whilst previous studies in deep peatlands have found drought conditions to stimulate soil phenol oxidase activity, little work has been carried out to see whether this stimulation is found in shallow peats. Retractable transparent roofs have been used to simulate repeated summer drought in a natural stand of upland Calluna heathland in north-west Wales, characterised by a shallow peat horizon (~10 cm deep). This study looks at the effects of these summer drought events upon litter and peat phenol oxidase activity at the site, and the concentrations of water soluble phenolics present in the litter, peat and water draining from the peat horizon. The summer drought 2005 reduced soil moisture levels by 52% compared to the controls, and was found to significantly reduce peat phenol oxidase activity (P = < 0.001). Thus it appears that in shallow peats with high sensitivity to substantial drying over short periods of restricted rainfall drought may in fact inhibit soil phenol oxidase activity as a result of water limitations. Litter phenol oxidase activity was not significantly affected by the drought (P = 0.41), the litter tending to rapidly re-wet in the short periods of incoming rainfall received as the roofs close in response to rain events. The 2005 drought resulted in lower phenolic concentrations in the water draining from the peat horizon in the drought plots compared to the controls (P = 0.07), a trend followed by the lower phenolic concentrations in the droughted peat itself (P = 0.004). It remains to be investigated whether this resulted from lower leaching of phenolics from the litter in the drought plots or is related to the changes in peat phenol oxidase activity. Results for litter phenolic levels were not conclusive, showing significant deviation amongst the drought plots. Phenolic concentrations in the water draining from the peat horizon throughout the non-droughted months of the year from the summer droughted plots were consistently higher than the controls (P = 0.001). This being in contrast to a large spike in phenolic washout that may be expected from the drought plots upon re-wetting if phenolic outputs in the plots were being affected by leaching dynamics alone, and suggests that the summer drought events may indeed be having an effect on key soil biological processes involved in the processing of polyphenolic material. A preliminary look at leaf tannin concentrations was also carried out for Calluna vulgaris and Vaccinium myrtillus in the plots. Both species were found to have higher (Calluna P = 0.07; Vaccinium P = 0.15) leaf tannin contents in the droughted plots, suggesting that plant stress responses to drought may also be playing a role in the trends in soluble phenolics.

Andrew S. Kowalski

Eddy covariance and (towards) understanding the functional behaviour of Mediterranean shrubland (matorral)

The eddy covariance technique is presented as a tool for addressing ecosystem functional behaviour and long-term carbon exchange.

Turbulent transport is outlined, with emphasis on vertical transport by “random” eddies acting on vertical gradients established by surface interaction. The concept of heterogeneity scales at the surface is presented, along with its implications for necessary tower height and (homogeneous) ecosystem size, or fetch. Some limitations of the technique are identified, including nocturnal lack of turbulence and various corrections that are necessary as a function of the type of gas analyser used. Examples of the resultant data are also presented, including hourly variability, typical missing data problems, and the (empirical, ecophysiological) modeling tools that can be used to cope with such challenges in order to achieve annual-scale data. Finally, some examples are given of recent measurements over dryland ecosystems Andalusia, with apparent influence of abiotic pedological processes which complicate the interpretation of the net carbon dioxide flux as “ecosystem exchange”.

Teodoro Marañón

Global change and plant community ecology

Socio-economic factors influence greenhouse gases, which are related to climate factors, and those with land use. Also there is a direct relation between socio-economic factors and land use. All those are the main drivers of Global Change.

Recent studies have predicted for the Iberian Peninsula a temperature increase of 2-3 °C and a rainfall decrease of 14-17 %, that for the “optimistic” environmental scenario, whereas for the “pessimistic”, economy-focused scenario, the predictions are 3-4 °C increase and 22-27% decrease of rainfall. Mediterranean region is particularly vulnerable to global change, to increased temperature and strongly to reduced rainfall.

To investigate the impact of climate and global change on terrestrial vegetation we can use several, complementary approaches, such as species distribution and climatic variables, phylogeographic analyses, historical vegetation records, experiments in areas of contrasted climate, and experiments under controlled conditions simulating changes. Here I present results from five studies carried out in southern Spain.

1) Rhododendron ponticum is a native Mediterranean plant which has invaded the forest understorey of temperate Europe. In its native habitat it is restricted to riparian forests where it has very poor regeneration by seeds, probably associated to a historical decrease of late spring rainfall during the last 100 years. In contrast, in Britain and Ireland is considered a “killer of the countryside”, colonizing the forest understorey easily from seeds and causing severe ecological impacts on native biodiversity. Thus, climate change can threat a relict plant species in South Europe, while favouring the invasion by the same species in the North-West.
2) Deciduous and evergreen oaks are currently coexisting in many forests of South Spain. According to pollen records, deciduous oaks were dominant until about 3000 years ago, when they were replaced by evergreen oaks, associated to charcoal in sediments and so probably favoured by man using fire. The analysis of present distribution of five oak species in South Spain (using data from the National Forest Inventory) shows patterns, which can be explained by climate, topography, soil and three millennia of human intervention. In the climatic space (based on a PCA of climatic variables) we can predict that increasing temperature will affect more to species such as Q. pyrenaica, associated to higher altitude. While decreasing rainfall will affect more to species, such as Q. canariensis, restricted to the moister areas.

3) The effects of climate change can be evaluated indirectly by experiments of common protocol, but in sites with contrasted climate. To simulate the effects of a decreasing rainfall, we planted seeds of two oak species (Q. suber and Q. pyrenaica) in Aljibe (with average rainfall of 950 mm) and in Cardeña (average 530 mm). In the drier site we found a general decrease in seedling survival after summer, from 40% to 17%, and a general lower growth of seedlings (about a 30% reduction). The deciduous species Q. pyrenaica seems more vulnerable to the drier environment.

4) The effects of climate change can be studied directly by simulating different conditions in greenhouse experiments. We cultivated seedlings of four oak species under contrasted soil moisture conditions. Analysing the performance of 18 physiological and structural variables, we found a stronger response to drought for the physiological variables. For example, droughted seedlings had lower stomatal conductance, to diminish water loss, and there was no significant differences among oak species.

5) The use of historical records of vegetation, such as forest inventories during the last 100 years, can allow detecting changes in forest composition. As a first hypothesis, we can relate the increasing proportion of Q. suber during the last 100 years with a decreasing trend of rainfall. As alternative hypothesis, we can explore the socio-economic changes in the forest region, such as changes in the use of forest resources (from tannin to cork), increasing price of cork, Civil War and economic isolation, change in energy source (from wood to butane gas), and changes in conservation policy (Park since 1989). In the recent history, we can conclude that socio-economic factors were main drivers of forest change. However, in the present scenario of forest conservation policies, climate change can be important.

As general conclusions, a) we need complementary sources of evidences to understand the changes in the past and to predict the changes in the future; b) we need to act urgently to reduce anthropogenic changes and to mitigate their impact on biodiversity; c) but also we should have in mind that (quoting Petit et al., 2005) “the present-day tree flora of the Mediterranean Basin is made up of very resilient taxa that have already experienced many abrupt and intense climate changes in the past”.

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**Greg Hughes**

**Niche based and dynamic global vegetation models - Contrasting approaches to assess the impacts of climate change**

Niche based and dynamic global vegetation models are two modelling techniques used to assess the impacts of climate change on biodiversity and vegetation structure/function. These two approaches are, however, seldom employed together. Using a projected future climate for 2050 for a case study area, Namibia, the impacts of climate change on the flora, vegetation structure and ecosystem function were assessed. Niche-based models were used to evaluate the sensitivity of 1020 plant species, of which 159 were endemic, to climate change and a dynamic global vegetation model to assess the impacts of climate change on vegetation structure and ecosystem functioning. Comparison of the results from the two approaches is complicated by the different scales and aspects that each methodology addresses yet it is clear that their complementary use provides additional insights into the potential response and vulnerabilities of ecosystems and species.

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**Juan José Sanz**

**Impacts of climate change on bird biology: implications for their conservation**

Among birds, many biological features such as migratory phenology, breeding performance, fitness components, population dynamics or geographical distribution had been related to climate change demonstrating significant links. Future political measures on bird conservation should be adapted to the climate change scenario. For example, we have some evidences that some birds are actually wintering in southern Europe. Therefore, in southern Europe, we will probably have new species to protect. For birds, plenty of evidences exists demonstrating that range boundaries are correlated with climatic factors. The poleward extension of bird distributions has been documented for several species and geographical areas (Europe, North America). For example, Thomas & Lennon (1999) analysed the northern and southern edge of the range of birds in Great Britain. They showed that northern range boundaries of 59 out of 101 southern species moved on average 18.9 km towards the north. We have also several examples of
invasions by different bird species, formerly restricted to Africa or Asia (‘exotic species’). On the other hand, climate change may reduce the reproductive success of populations already fragmented by habitat loss, and so may further reduce the viability of those populations. Reduction in population size may result in reduced genetic diversity. Change in land-use and human activity, such as agriculture, related to climate change, may also indirectly impact on bird species. If rainfall decreases, the distribution of several groups of birds is expected to contract towards the higher rainfall regions. These impacts on abundance are difficult to disentangle from those of other processes such as habitat loss. For migratory birds, the timing of arrival on breeding and wintering areas is a key determinant of reproductive success, survival and fitness. Short distance migrants may benefit by breeding earlier, by shortening their migration distance and by experiencing better conditions in the breeding area after the breeding season. Resident birds may benefit from warmer winters and impose increasing competitive pressure on migrants. Therefore, it is likely to be considerable asymmetry in the effects of climate change on long- and short-distance migrants, with an increasing advantage for short-distance migrants. Finally, we should be able to propose some measures to improve opportunities for bird biodiversity to adapt to the actual climate change.

Colin Beale

Long and short-term weather effects on upland bird breeding success

Assessment of the impacts of climate change is often complicated by the difficulty of distinguishing between climate and weather effects. For many species (in Europe particularly northern and western species), warmer and drier weather results in an increase in productivity and survival, yet global warming is considered a significant conservation concern. I describe a method that allows the simultaneous identification of immediate and long-term impacts of current climate and weather variability on a suite of nine rare birds breeding in the north and west of Britain. I show that breeding success of all studied species was higher in warmer years, but for two species, I found that this effect was significantly negated by longer-term impacts of a warmer climate at the same time of year. I suggest that this approach offers an important tool in the assessment of sensitivity to climate change.

Adolfo Marco

Vulnerability of reptiles to climate change

In Mediterranean areas, climate change models predict increasing temperatures, severe droughts and more intense, deeper and earlier soil desiccation. Though these changes may permit some thermophilic species to benefit by breeding earlier, by shortening their migration distance and by experiencing better conditions in the breeding area after the breeding season. Resident birds may benefit from warmer winters and impose increasing competitive pressure on migrants. Therefore, it is likely to be considerable asymmetry in the effects of climate change on long- and short-distance migrants, with an increasing advantage for short-distance migrants. Finally, we should be able to propose some measures to improve opportunities for bird biodiversity to adapt to the actual climate change.

Jane K. Hill

Distribution changes during climate warming

During the past few decades, global temperatures have been warming and some species have responded to these changes by shifting their European distributions northwards to track climate. Our research group has focused on European butterflies because there are excellent long-term and fine-scale distribution records available in Britain where many species reach their range limits. In addition, the high reproductive rate and dispersal ability of butterflies means they are likely to respond quickly to climate changes. There have been two intensive periods of recording of butterflies in Britain during recent climate warming; 1970-1982 and 1995-99. During this period, several southerly-distributed species have expanded northwards. However, because of the widespread loss of breeding habitats, expansions of the widespread loss of breeding habitats, expansions...
generally have been restricted to generalist species and most specialist butterflies have declined. For these generalist species, the availability of habitat affects the rate of expansion. Evolutionary increases in dispersal occur in expanding range margin populations that may increase the likelihood of colonisation success but this is balanced by reduced fecundity in these new populations which are therefore likely to have reduced population growth rates. Reduced genetic diversity has been observed in some species during expansion and this may affect their ability to adapt to novel environments in the future. There is also evidence that the rapid range expansion of some polyphagous species is associated with altered larval host plant performance and the incorporation of more widely-available host plants in to the diet. Overall, the evidence that most butterfly species are failing to respond to climate indicates that the composition of communities is likely to be greatly altered in the future, with communities dominated by widespread generalist species and specialist species continuing to decline.

José A. Hódar and Regino Zamora

Effect of global change on the population dynamics of the pine processory moth Thaumetopoea pityocampa in Southern Spain

The pine processory moth (Thaumetopoea pityocampa) is one of the main plagues both natural and afforested pine woodlands of SE Spain. Since 1997 we study the population dynamics of the pine processory caterpillar in the National Park of Sierra Nevada (SE Spain), as well as the negative impact of the plague on the growth and reproduction of affected pines. Our results reveal that the eruptive phase of the plague coincides with mild winters, which are increasing its frequency as a consequence of global warming. In fact, we found a significant relationship between the negative phases of the NAO and years of high incidence of defoliation by the pine processory moth, and this relationship is stronger for pines living at mid-high altitudes in Andalusia, and weak or inexistnet for pines at lower altitudes. This is especially dangerous for the populations of Pinus sylvestris nevadensis, a relict variety of Scots pine living in Sierra Nevada and Sierra de Baza mountains. We propose that damage by pine processory moth plagues can be tempered by the appropriate management of the forest structure.

Sue Hartley

The impact of climate change on plant-herbivore interactions

Professor Hartley’s presentation addressed the impact of climate change on the allocation to plant defences and hence on their palatability of insect herbivores. The impact of elevated CO₂ on the biosynthesis of phenolic compounds was considered in detail and a new model of defence allocation, based on precursor competition between protein and phenolic synthesis. Winter moth feeding on a range of host plants was used as a case study to illustrate the impact of climate change on insect performance and to demonstrate that these effects were dependent on the effect on plant chemical composition—winter moth feeding on host plants that were more responsive to climate change in terms of their nutrient and secondary compound content were in turn more affected by climate change. Lastly the presentation considered how shifts in plant community composition in response to climate change could cause changes in the composition of the associated insect herbivores.

Jorge Castro and Regino Zamora

Can climate change alter species composition of Mediterranean mountain forests? An experimental approach in Sierra Nevada National Park (Spain)

Summer drought is a major factor constraining seedling establishment in Mediterranean-type ecosystems. The Mediterranean climate has pronounced rainfall seasonality, with dry and hot summers, plus high between-year variability, as only scattered years have wet summers. Therefore, wetter summers are thought critical for establishment of seedlings of long-lived woody species and hence, for forest regeneration. However, with global change, summer rainfall may be rarer in these ecosystems, affecting forest species differently given the variable summer-drought tolerance of Mediterranean flora. We are currently performing several experiments in Sierra Nevada National Park (SE Spain) to assess the role of water availability on the recruitment of seedlings of the main woody species present in these forests. We consider both i) the impact of eventual rainy years (simulating a wet summer with irrigation experiments) and ii) the impact of an increase of drought stress under a predicted scenario of global change (experiment with water addition, control, and partial rainfall exclusion).

Preliminary results show that summer drought is critical for the survival of seedlings, which is boosted under a simulation of higher rainfall. However, the response of the species that forms the mature forest differs largely. For instances, boreal species such as Pinus sylvestris or Taxus baccata are extremely dependent on a wet summer for seedling establishment, but Mediterranean species (e.g. Quercus ilex, Pinus nigra) are less drought sensitive. The responses is also affected by the type of habitat, with a wet summer being more critical for establishment in areas of bare soil than under the canopy of shrubs or woodlands. The differential impact of summer drought across habitats and species may affect the patterns of recruitment in these forests.
Under a scenario of increase in aridity and irregularity of precipitations (as expected for the Mediterranean region according to climatic models) forest composition is expected to change in favour of more drought tolerant species. Tree recruitment might be even blocked in favour of shrubby species under some circumstances, altering therefore the patterns of succession. Current ongoing projects will help to model forest composition and to unravel the possible successional trajectories under several scenarios of water availability.

Anticipated effects of climate change in the regeneration ability after fire of Mediterranean-type shrublands

Fire is an essential component in the ecology of Mediterranean-type ecosystems, affecting in a great extent to shrubland communities. Mediterranean-type shrublands are highly resilient to fire, and plant species recover its cover by establishment of new seedlings or by resprouting. This resilience is based in the existence of persistent soil seed banks, which not depend on current year seed production, and vigorous resprouting plants, which have a favorable root:shoot ratios during the first stages after fire. Climate scenarios for XXI century in Spain include increased potential evapotranspiration and higher probability of extreme drought events. It has been predicted an increase in fire hazard, being fires in the future climate not only more frequent, but also more intense and extended to broader seasons. The resilience of Mediterranean-type shrublands to fire may be altered in the future climate scenarios. The UCLM research group on fire ecology is currently working on analyzing the effects of altered rainfall patterns in the emergence of seedlings from soil seed banks, in the survival of established seedlings, and in the allocation of resprouting plants to carbon reserves and bud banks.

Relict, temperate-like, conifer forests in the Mediterranean region as experimental models to assess the impacts of climate change

One of our main research lines deals with the C & N biogeochemistry of relict, temperate-like, conifer forests growing in the Mediterranean-type climate region of southern Spain. We are using these remnant ecosystems as suitable experimental models to assess the effects of climate change on typical temperate conifer forests. Endemic Abies pinsapo stands (less than 2000 ha in total currently growing at Sierra de las Nieves and Serranía de Ronda (Malaga-Cádiz), but also isolated Pinus sylvestris and Pinus nigra patches occurring at high altitude in some mountains in the Granada-Jaén provinces, are remnant populations of temperate-like conifer species that were more widely distributed throughout the region during the last glaciation periods. As climate warmed following the last ice-age, and instead of migrating north as the main populations did, some others stayed in the South, retreating to top positions on N-facing slopes, where they got isolated and are subjected to the constraints of the Mediterranean-type climate. Thus, we are using these relict forests as experimental models of “already warmed” temperate forests, both for the screening of possible effects on typical temperate forests, and as early warning indicators, of global warming. For instance, How does a (Abies pinsapo) fir-forest behave, in stand productivity and biogeochemical terms, when it is subjected to a typically Mediterranean seasonality?

We have already conducted several research projects on these issues, including projects PB1998-0309 and BOS2000-0897 funded by the Spanish Ministry of Science, and a british-spanish collaborative project (HB1999-0172), partly funded by the British Council, in which the Soil Ecology Group (A.F. Harrison) at Merlewood Research Station (CEH-NERC) acted as our partner. We are now (2004-2006) working on the project REN2002-09509 “Effects of climate change on the liability of temperate forests to nitrogen deposition: using relictic, pinsapo-fir (Abies pinsapo, Boiss.) forests from southern Spain as an experimental model”. We have found that Abies pinsapo stands growing near the industrialised area of Gibraltar show acute symptoms of N saturation, even though measured atmospheric bulk N deposition inputs are not too high (around 10 kg N/ha*yr in the interval 2000-04). This led us to hypothesized that current climate change would reduce the efficiency of N retention mechanisms in conifer forests of temperate regions, both through alteration of the mineralization/immobilisation balance and decoupling of retention/loss mechanisms in the soil, and by changes in the rates of N uptake and accumulation in plant biomass. Thus, under a climate warming scenery, the liability of temperate forests to develop N saturation symptoms would increase even though N deposition rates remain unchanged. Particularly, we predict that the lag-period in which N-limited forests respond to N inputs by accumulating N will be shortened, the N saturation phase will be reached earlier, and forest decline will be more likely to occur. To test for these hypotheses, we are conducting N fertilisation and N15 labelling experiments in several Abies pinsapo plots distributed along a combined altitudinal and N deposition geographic gradients. Preliminary results show that N retention within the ecosystem is less efficient, and that onset of high rates of nitrate leaching through the soil develop earlier, than shown in the literature for typical temperate conifer forests (e.g. UE-Nitrex project).

We are now beginning a collaboration with the Global Change Ecology Group at University of York (Prof. P. Ineson), who has developed a novel multiplexer Li-Cor system combined with soil treatments that allow...
for the separation of the different components of soil respiration (heterotrophic, mycorrhizal, and autotrophic). Through a 6-month stay at York University, we have been continuously monitoring in the field soil respiration in a Pinus sylvestris forest and have found that the mycorrhizal component accounts for up to 30% of total soil respiration, and that this component show very little sensitivity to temperature changes but respond strongly to low soil water potentials. We are now planning to apply the methodology in a relict P. sylvestris forest from South Spain, in order to assess how climate change might affect soil respiration in boreal forests.

Finally, we are using Abies pinsapo fir-forests as early warning indicators of climate change. These forests show acute decline symptoms in areas below 1300 m asl. Through a combination of multitemporal comparison of aerial ortophotos, dendroecology, and field-monitoring of water use by trees along the altitudinal gradient, we demonstrate that increasing between-years variability in precipitation through the last six decades is in the base of the observed decline symptoms.

Luis Sampedro

Ultimate effects of earthworms and their gut microbes at the ecosystem level. Sensitivity to new climate scenarios and implications for Global Change

Earthworms ingest tons of soil yearly interacting with soil microflora and influencing soil properties and biochemical cycles as they are considered ecosystem engineers. Identified ultimate effects of earthworms in ecosystem function include those related to burrowing and casting activity, mixing soil layers, modifying soil aggregation and porosity in long term, and enhancing water infiltration and solute transport to deeper soil layers. On the other hand, the effects derived from the gut associated processes (GAP) of the earthworms can be considered as proximal effects. The knowledge of the earthworm digestive activity is scarce, and the earthworm gut remains as a black box. The earthworm gut may be considered as a fermentative anaerobic digester where strong interactions between earthworm and microbes take place. Some of these GAPs have the potential to ultimately affect Global Change. Specifically, (i) earthworms directly stimulate litter decomposition, (ii) earthworms may improve the protection of particulate organic matter in macroaggregates into macroaggregates, and (iii) the earthworm gut constitutes microsites for N2O production due to denitrifying activity of soil microbes activated passing through the anoxic gut. We review these processes and we discuss how the earthworm activity, and specifically the proximate effects resulting from their digestive function, may have consequences for global change. We present the results from a series of microcosm experiments studying the effect of earthworm density and mineral nitrogen availability, analyzing CO2 and N2O evolution, both natural and acetylene blocked to quantify the N2O emission derived from the earthworm activity. We found the natural N2O flux to be density dependent and responsive to increased nitrate availabilities, and to CO2 concentrations only when earthworms were present. Earthworms were identified as key regulators of denitrification associated to the decomposition of organic substrates, and our results indicated that earthworms should be considered by itself for potential emission of this important greenhouse gas. This process needs to be urgently quantified and factors influencing this activity and the occurrence in natural conditions should be addressed. Terrestrial habitats are supposed to be responsible for approximately 70% of the N2O that is produced globally. Actual evaluations of total N2O emission from soils already accounted for the earthworm-derived N2O, however the total N2O emission from soils under new scenarios of modified temperature and precipitation regimes could be different than the expected taking into account only free soil microbes, due to differential sensitivity of earthworm-derived N2O emission to climatic factors. We propose as new challenges (i) to quantify earthworm-derived N2O emission in target ecosystems: agroecosystems and grasslands; (ii) modelling response to temperature, nutrient content and litter inputs; (iii) to study the effects of different crop management in N2O emission and mitigation; and (iv) to get insight on the adaptive significance and physiological regulation of this process. Furthermore, increased human activity and changing climate will affect earthworm species distribution and activity.

Luis Santamaría

Forecasting the impact of climate change on the continental distribution of wetland plants. The importance of long-distance dispersal and local adaptation

Global warming is forecasted to result in important changes in the distribution of species and genotypes. To cope with these changes, they will have show migration speeds that match the speeds of changes in local environments. Species with broad distributions will be best prepared to cope with the effect of climate change, since they generally have broad ecological tolerances and great dispersal capabilities. Therefore, the study of these species, in the framework of future climate change, can teach us how to manage the most resilient component of ecosystems and how to support more sensitive species. A traditional example of broadly distributed species are freshwater plants and invertebrates. For example, freshwater plants typically show broader distributional ranges than terrestrial plants. Modelling studies show that the expected impact of climate change is much smaller than on terrestrial plants: under the most severe scenarios, average changes in European distributions will range from a slight increase to a moderate decrease (-18% to +6% for unlimited dispersal ranges, -6% to –31% with dispersal constrained to postglacial expansion rates).
Though the classical explanation for the generalization of cosmopolitism among aquatic plants poses that it relates to the homogeneity of the aquatic environment, a review of existing evidence shows that such environment shows considerable geographic variation. However, aquatic plants tend to respond within-species, rather than among-species variation; and this variation is largely based on plastic responses, rather than variation among population or genotypes. As a result, reciprocal-transplant experiments across broad geographic ranges (such as Potamogeton pectinatus) show that most individuals can live and reproduce across the complete distributional range of the species, though centre-periphery gradients and local adaptation result in sharp gradients in performance in the latitudinal range limits of the species. An important factor to understand the specific characteristic of aquatic organisms is their high dispersal capacity, mediated by migratory waterfowl and waders, which can span thousands of kilometers. Though compounded by priority effects, long distance dispersal have lasting effects on the genetic structure of aquatic plants and invertebrates along the migratory flyways of their bird dispersers. These patterns are likely to have an important bearing on the capacity of these species to adjust to climate change. In summary, even for broadly distributed species with high dispersal capacities, predicting the impact of climate change will require detailed knowledge of the geographies scales at which dispersal, local adaptation and priority effects affect local population characteristics and metapopulation connectivity. Two important consequences for management policies follow. Firstly, long-term management should focus on ensuring future ecosystem resilience, rather than conserving pseudo-pristine ecosystems than largely belong to the past. Secondly, management emphasis should shift from selecting and conserving highly-diverse localities or large local populations, to preserving the connectivity of population networks, which is largely mediated by waterfowl and wader flyways.

Rachael Hickling

The distributions of a wide range of taxonomic groups are expanding polewards

Evidence is accumulating of shifts in species’ distributions during recent climate warming. However, most of this information comes predominantly from studies of a relatively small selection of taxa (i.e. plants, birds and butterflies) which may not be representative of biodiversity as a whole. Using data from less well-studied groups, we show that a wide variety of vertebrate and invertebrate species have moved northwards and uphill in Britain over approximately 25 years, mirroring, and in some cases exceeding, the responses of better-known groups. Given the wide variety of species showing a similar northward shift, we believe that climate change is the most parsimonious explanation.

Jennifer Smart

Sea level rise: Are breeding redshank Tringa totanus caught between the sea wall and the deep blue sea?

Patterns of breeding density for redshank in the UK show that the highest densities are achieved on saltmarshes. This could be interpreted as evidence that saltmarsh might be the highest quality breeding habitat for redshank. However, breeding densities may not accurately reflect habitat quality, particularly in habitats that are undergoing environmental change.

Rising sea levels are the most certain of climate change impacts, and for low-lying coastal areas the threats are particularly severe. The key implications of SLR are a loss or decline in the availability or suitability of saltmarsh and potential losses of other coastal habitats. Mitigation may not be possible in the coastal zone, and so inland habitat creation may be important. However, the relative quality of these different habitats for breeding wader species is not known, making effective mitigation strategies difficult to devise.

East Anglia is both low-lying and has important breeding populations of redshank. Their habit of breeding on both coastal and inland habitats makes this an ideal species for a comparative study of habitat quality. Here, we present a comparison of redshank breeding success on saltmarsh and coastal and inland grazing marshes and discuss these findings in relation to the production of high quality mitigation habitats to replace future losses of coastal habitats.

Greg McInerny

The shape of things to come: range dynamics and environmental change

Projected responses of species’ to climate change have so far centred on correlative relationships between the biota and climate, ignoring the interactions of landscape, dispersal and evolution in determining species distributions. Here we take a heuristic approach to develop hypotheses for spatial responses to climate change. Using an individual based model we investigate the evolution of a trait along an environmental gradient, which is at first static and then experiences a period of environmental change. The model demonstrates that as gene flow becomes increasingly contrary to the direction of environmental change there may be considerable convergence of ecological and evolutionary responses. Furthermore we show that through frequency dependent selection, simple heterogeneity in carrying capacity of patches causes considerable dynamism in ranges; including shifts, contractions, expansions and divisions. We discuss how an explicit consideration of spatial patterning and processes can add considerable complexity to biotic responses to climate change.
EVALUATION QUESTIONNAIRE
QUALITY IMPACT CONTROL

ABOUT THE WORKSHOP

1. What benefit did you expect to get from this workshop? To what extent did we meet your expectation?

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<th>Benefit met</th>
<th>Exceeded</th>
<th>Met</th>
<th>Partly met</th>
<th>Hardly met</th>
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2. Overall, how would you rate the quality of our service?

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<th>Good</th>
<th>Neither good nor bad</th>
<th>Bad</th>
<th>Very Bad</th>
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3. It was a well balanced programme

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<th>Fully agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Fully Disagree</th>
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<td>2</td>
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4. All relevant topics were covered

![Bar chart showing responses]

5. The length of the workshop was correct

![Bar chart showing responses]

6. The mix of participants was good

![Bar chart showing responses]
7. The facilities were adequate

8. The venue chosen was appropriate

9. The standard of accommodation was good
### Results of Event Evaluation Questionnaires

#### General data

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<td>Number of questionnaires received</td>
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<td>Percentage</td>
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<td>Participants from Spain</td>
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</tr>
<tr>
<td>Participants from Britain</td>
<td>15</td>
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GENERAL COMMENTS

- Excellent experience. Thanks for the opportunity (Jen Smart)

- Overall an excellent meeting. I gave the top assessment in all cases and my only comment was about abstracts. I suggest that it would be great to have these from all speakers before the meeting - in the pre-meeting information packs. (Ian Woodward)

- There were definite biases in the topics covered that could perhaps be addressed by getting organisers from different (i.e. range) of scientific areas. I suspect network opportunities would improve and lasting collaborations formed if more participants were in the post-doc area, rather than PhD students who may not remain in science or the research area

- Might be a brief resume about each participants previously to the conference, to help to focus on new projects and joint actions (Luis Sampedro)

- Perhaps splitting up into smaller discussion groups for the final roundup session would have given those at the workshop less experienced and confident at large group discussions, a chance to better discuss and communicate their thoughts and ideas (Hannah Toberman)

- Provision of abstracts for talks beforehand would have allowed us to identify people to talk to earlier in the workshop. Break out sessions would have aided interaction, discussion and final reporting. A very well run and worthwhile workshop. Thank you for inviting me to attend. (Greg Hugues)

- Follow like this. Excellent service (Josep Peñuelas)

- It was perfect!
ACKNOWLEDGEMENTS

Many thanks to the British Council and the Consejo Superior de Investigaciones Científicas (CSIC) for the opportunity to organise this workshop. We are especially grateful to Chris Hickey (Director British Council Spain), Carlos Martínez (President CSIC), and Rafael Rodríguez (Institutional Coordinator in Andalusia, CSIC) for their support.

We would also like to thank Belén Fortea (Co-ordinator Science & Society, British Council) for an efficient organisation and a great, positive attitude that significantly contributed to the overall success of the meeting.
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