ATLAS
of Biodiversity Risk

Edited by
Josef Settele, Lyubomir Penev, Teodor Georgiev, Ralf Grabaum, Vesna Grobelnik, Volker Hammen, Stefan Klotz, Mladen Kotarac & Ingolf Kühn

PENSOFT

Projected Climate Change Impacts on Biodiversity in Mediterranean Ecosystems

Josep Peñuelas, Marc Estiarte, Patricia Prieto, Jordi Sardans, Alistair Jump, José M. Moreno, Iván Torres, Blanca Céspedes, Eduard Pla, Santi Sabaté & Carlos Gracia

Figure 1. The picture shows the regenerating stand in Anchuras (Central Spain) in the wet year (2004). It was burnt in 2002. Photo: I. Torres.

The Mediterranean region presents a large variety of terrestrial ecosystems, many of them quite unique. Climate change will bring a series of direct and indirect effects on them which will be accentuated by the interaction with other components of the global change such as land use changes or pollution. Many of these ecosystems that are already at their ecological or geographical limit will be especially sensitive. Among them, the most vulnerable will be those located in islands in a broad sense (including edaphic islands and high mountain ecosystems) and in ecotones, the transition zones between ecosystems (Valladares et al. 2005). There is evidence showing that climate change affects the Mediterranean species phenology, their competitive ability, the interactions between them and finally the structure and composition of the communities (Peñuelas & Filella 2001) and generates species altitudinal and latitudinal shifts (Peñuelas et al. 2007a) along with extinction of local species. However, it is not known whether species will be capable of evolving and adapting to climate change in time (Jump & Peñuelas 2005). To gain knowledge on the impacts of climate change on Mediterranean biodiversity and ecosystems, there are at least three posible approaches: observations, experimentation and modeling.

Observations

The changes in the spatial patterns of species richness of two groups of annuals (grasses and legumes) during two consecutive years of very different precipitation rainfall in a burned *Cistus*-dominated shrubland of Central Spain offer an example of the observational approach. The area was burned in 2002 and measurements were carried out in 2004 and 2005, that is, during the 2nd and 3rd year of regeneration after fire. Measurements were made in a 180 × 90 m plot, and spatial techniques (kriging) were used to interpolate results with a resolution of 2 m. The hydrologic year 2003-2004 was practically normal, while 2004-2005 was well below average (total rainfall was about 30 % of the long-term average). Figure **2** shows the changes in species richness that occurred during these two consecutive years for two groups of annuals: grasses and legumes. While legumes virtually disappeared from the plot, their presence being restricted to small patches, grasses were able to maintain a number of species throughout the plot, hence being much more resistant to changes in rainfall. This example indicates that changes in patterns of rainfall will very likely affect the future species composition and diversity of Mediterranean shrublands.

Experimentation

A number of experiments have studied the potential effects of climate change on diversity of plant species in different types of plant communities. This experimental approach can be addressed by temperature or rainfall manipulations at stand level where the interactions between species assemblies and climate occur. However, the effects of climate change on diversity have been more rarely considered in relation to the successional process given the necessity for such long field experiments involving climate manipulation. Plant community recovery (species richness, diversity and composition) of a post-fire Mediterranean shrubland was monitored over a seven year period (1998-2005) under experimental drought and warming that simulated the environmental conditions projected for this area in the coming decades. Species richness and Shannon's Index were positively correlated with accumulated precipitation in the growing season and both variables were negatively affected by reduced water availability in drought plots. Species-specific responses to treatments were found. Drought and warming treatment reduced the competitive ability of the obligate seeder tree *Pinus halepensis* against native resprouter shrubs and consequently, the transformation from shrub to pine tree dominated vegetation was slowed down. Therefore, future drier and warmer conditions in

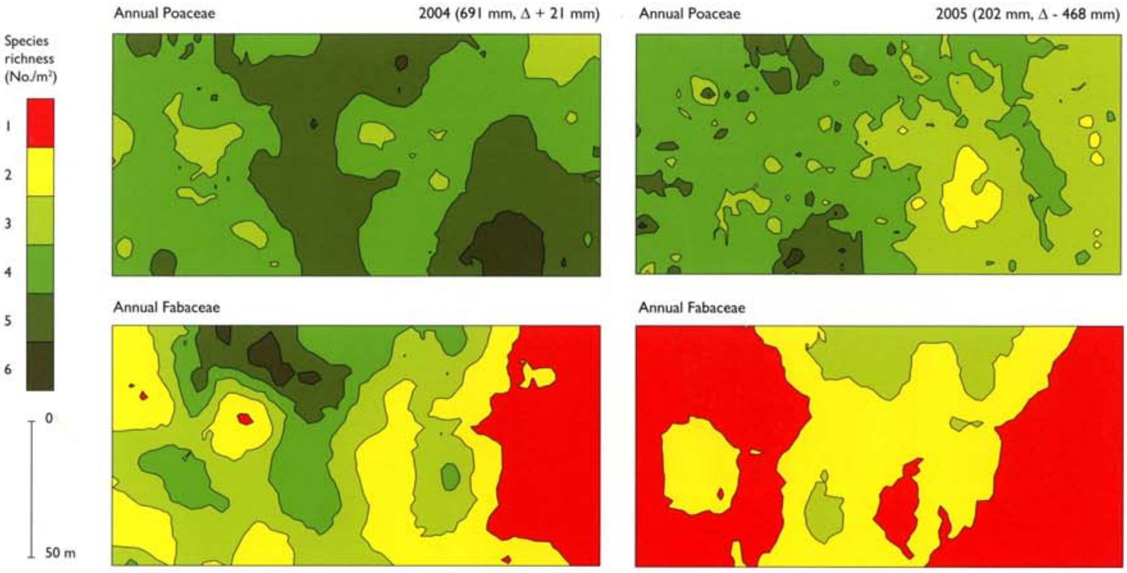

Figure 2. Species richness (Number m^{-2}) of annual grasses (upper panels) and legumes (lower panels) in a 180 × 90 m plot burnt by a wildfire in 2002 at Anchuras (Central Spain). The figure depicts the data for two consecutive years (2004, 2005) that differed very markedly in their total precipitation (2004 was normal; 2005 was very dry). Kriging was used to interpolate field data with a resolution of 2 m.

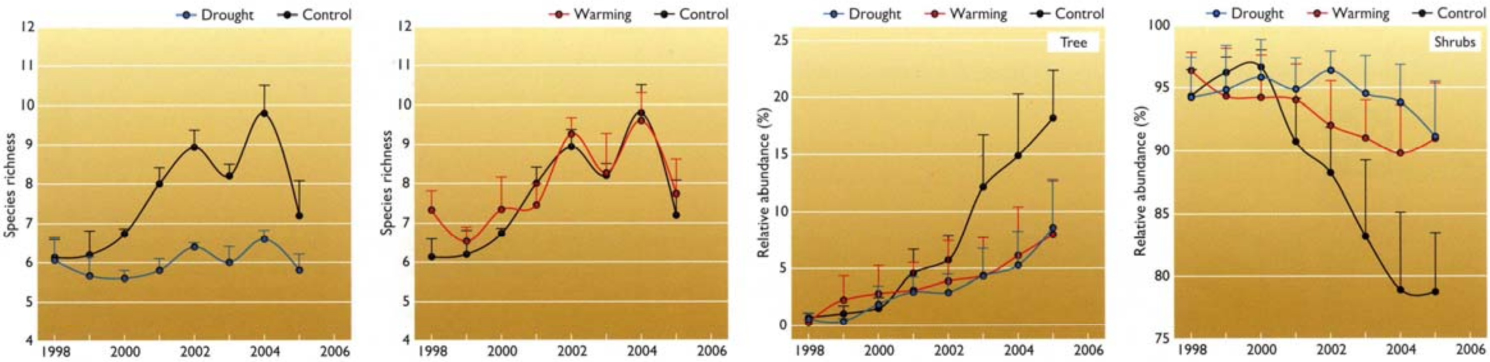

Figure 3. Number of species per 3-m transect in response to drought and warming treatments in 1998 (pre-treatment year) and in the years of the experiment (1999-2005) in a Mediterranean shrubland recovering from a fire in 1994. The pattern of relative abundances of life-forms (shrubs, trees) during the seven-year study period in control, drought and warming treatments is also shown. Bars indicate the standard errors of the mean (n=3 plots means). Modified from Peñuelas et al. (2007b) and Prieto et al. (2009).

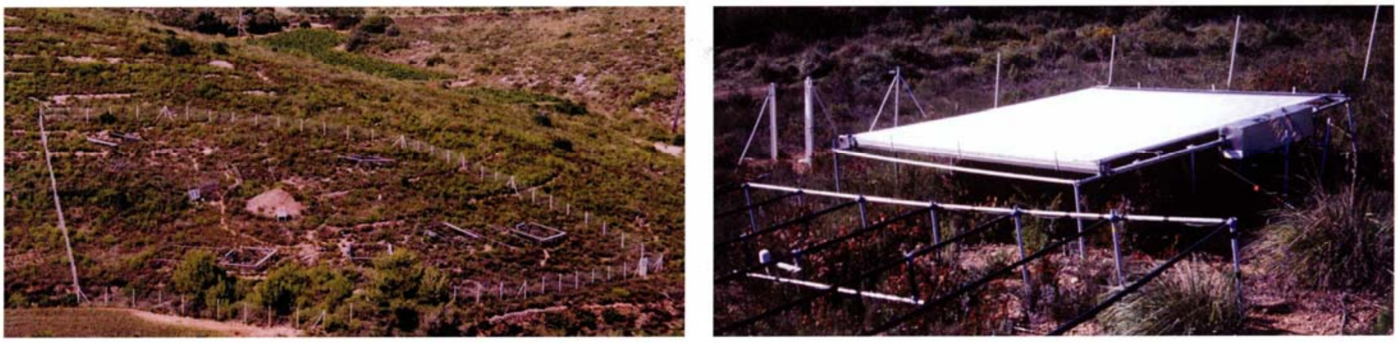

Figure 4. The pictures show the shrubland experimental site and a detail of one warming experimental plot. Photos: M. Estiarte.

Mediterranean areas may severely affect plant community recovery after a disturbance, due to the existence of both abundance-dependent and species-specific responses that may change interspecific competitive relationships. Drier conditions may seriously affect species richness and diversity recovery after fire due to lower levels of plant establishment and reduced growth rates. However, continued study in later successional stages is needed to monitor the changing species competitive relationships and assemblies.

Modeling

In an example of the third possible approach, a modeling exercise conducted within the ALARM project explored the effects of different climate change scenarios on Mediteranean forest carbon and hydrology balances and ultimately on species performance.
This approach was carried out using the process-based model GOTILWA+ (www.creaf.uab.cat/gotilwa+) for the whole European forest area. To supply the input data required for the model, an extensive database was built connecting diverse information sources at the European level. The database contains data related to forest functional types, forest cover, forest structure (tree density and size distribution), forest function (photosynthesis, respiration rates), soil hydrology, organic matter decomposition rates and management strategies. GOTILWA+ was thus run under different climate change scenarios. Mediterranean forests seem to be especially sensitive to the impacts of climate change. In some areas and under certain climate scenarios, carbon balances would be affected by increasing respiration rates, thus reducing their carbon sequestration capacity. Moreover an increase of water stress is expected. As a consequence, the frequency of the forest mortality events would increase with likely consequences on forest diversity.

References

Jump A, Peñuelas J (2005) Runnig to stand still: adaptation and the response of plants to rapid climate change. *Ecology Letters* 8: 1010-1020.

Peñuelas J, Filella I (2001) Phenology: Responses to a warming world. *Science* 294: 793-795.

Peñuelas J, Ogaya R, Boada M, Jump A (2007a) Migration, invasion and decline: changes in recruitment and forest structure in a warming-linked shift of European beech forest in Catalonia. *Ecography* 30: 830-838.

Peñuelas J, Prieto P, Beier C, Cesaraccio C, de Angelis P, de Dato G, Emmett B, Estiarte M, Garadnai J, Gorissen A, Lang E, Kröel-Dulay G, Llorens L, Pellizzaro G, Riis-Nielsen T, Schmidt I, Sirca C, Sowerby A, Spano D, Tietema A (2007b) Response of plant species richness and primary poructivity in shrublands along a north-south gradient in Europe to seven years of experimental warming and drought: reductions in primary productivity in the heat and drought year of 2003. *Global Change Biology* 13: 2563-2581.

Prieto P, Peñuelas J, Lloret F, Llorens L, Estiarte M (2009) Experimental drought and warming decrease diversity and slow down post-fire succession in a Mediterranean shrubland. *Ecography* 32: 1-14, doi 10.1111/j.1600-0587.2009.05738.x

Valladares F, Peñuelas J, Calabuig EL (2005) Ecosistemas terrestres. – In: Moreno JM (Ed.), Evaluación de los impactos del cambio climático en España. Ministerio de Medio Ambiente, Madrid. 65-112.

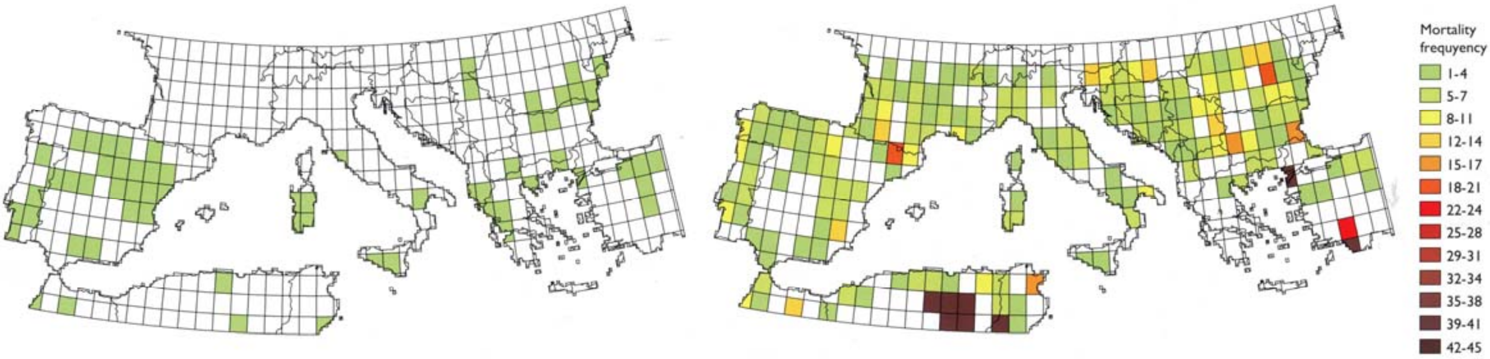

Figure 5. Comparision of mortality events frequency for evergreen broadleaved forests in south Europe for the 1990 time slice (1961-1990) and 2080 time slice (2051-2080) under de GRAS (A1FI scenario) and HadCM3 GCM. Spatial resolution 1° × 1°.