Human impact – the last nail in the coffin for ancient plants?

Connor, S.E.

This is a draft version of a manuscript published in *Journal of Biogeography* 36: 485-486 (2009). Please note that there may be differences between this version and the final published version. The author will be happy to provide copies on request.

Article type: Commentary

Article title: Human impact – the last nail in the coffin for ancient plants?

About two million years ago the Earth's climate entered a new and restless phase. The onset of the Pleistocene glacial periods or 'ice ages' rapidly reorganised landscapes and biota right around the globe. During each glacial period, solar radiation weakened, mountains heaved with glaciers, and sea levels fell as giant ice caps blanketed the northern parts of Europe and North America. The climate of temperate regions became colder, drier or more variable. Accustomed to the relative warmth and stability of the preceding Tertiary period (65–2 million years ago), some plants and animals responded to their new environment in a most decisive way – they became extinct.

Fossil records show that at least 20 tree genera disappeared from Europe and North Africa through the Pleistocene. They include *Carya*, *Halesina*, *Liquidambar*, *Magnolia*, *Nyssa* and *Sassafras*, genera that are still alive and well in the forests of other continents. Europe's Pleistocene extinctions illustrate how climatic changes of global extent can lead to starkly different outcomes in different regions.

Why was Europe's flora disproportionately affected by the glaciations? Part of the answer is to do with Europe's unique geography: Europe is warmed by the Gulf Stream, the ocean current that keeps that continent's climate much milder than it otherwise would be. The Gulf Stream weakens during each glacial period, making Europe's climate cold and continental. For plants intolerant of low temperatures, the mountain chains of the Alps, Balkans, Pyrenees, Carpathians and Caucasus, as well as the Mediterranean Sea itself, all present geographic barriers to migration (Svenning, 2003).

There is, however, a group of plants that remained in Europe and North Africa, surviving the long, cold winters of the glacial periods and flourishing briefly during the warmer periods between. Tertiary-relict plants are the last survivors of the forests that prevailed in Europe and other parts of Eurasia from the late Cretaceous until the late Pliocene. Two main categories of European Tertiary-relicts are recognised: the 'Palaeotropical' elements descended from Tertiary evergreen tropical rainforests, and the 'Arcto-Tertiary' elements from Tertiary warm-temperate deciduous forests (Mai, 1989).

Tertiary-relict plants have fascinated biogeographers for many years. They are, if you like, living dinosaurs of the plant world. The questions they raise have a similar resonance: What triggered the extinctions? Why have some species been able to endure two million years of climatic change, while others could not? Is it luck, or survival of the fittest? How do these plants cope with glacial conditions? Do they hide in sheltered locations ('refugia'), or does their physiology allow them to adapt? How do they react to the warmer climates of the interglacials? Why is their present-day distribution so limited and fragmented? Can we predict how Tertiary-relict species will respond to future environmental change?

A recent study has shed valuable light on these questions by tracing the extinction of two Tertiary-relict plants in an island ecosystem. Lea de Nascimento and colleagues (2008?) looked at pollen fossilised in lake sediments on Tenerife, one of the Canary Islands off the northwest coast of Africa, to understand how the vegetation of the island had changed in recent times with the arrival of humans. Tenerife is home to

several Tertiary-relict plants that became extinct long ago in southern Europe, surviving on the Canary Islands because of their mild, oceanic climate. The pollen reveals the extinction of two important Arcto-Tertiary species from Tenerife's forest ecosystems: oak (*Quercus*) and hornbeam (*Carpinus*). The results are surprising because no-one had previously found any evidence that they existed on Tenerife. Hornbeam is particularly unexpected, since these trees are all but absent from North Africa and the Iberian Peninsula today. If the pollen represents *Carpinus betulus*, its nearest living population is 2000 km from Tenerife.

Oak and hornbeam began to decline around 2000 years ago, coinciding with the first human settlement of the island. In the absence of any other 'smoking gun', the study's authors argue that humans – through burning, grazing, selective felling and agricultural development – were ultimately responsible for the extinctions.

Island ecosystems are, of course, much more vulnerable to extinctions than their mainland counterparts. Or are they? The past, present and future of a Palaeotropical Tertiary-relict, Portuguese Laurel (*Prunus lusitanica*), is the subject of a detailed analysis by Juan Calleja and colleagues (2008?). Along with the Canary Islands, this evergreen tree species is found on the Azores and Madeira, in Morocco, Spain, Portugal and southwest France. The authors counted every living Portuguese Laurel on the Iberian Peninsula: 31076 individuals in total. Such hard-won results show just how fragmented laurel's area is: some populations have as few as two trees and over half of the populations are less than 50 individuals each, often separated by hundreds of kilometres. In effect, these populations are islands in the Iberian landscape.

How did laurel populations become so isolated, fragmented and small? To answer this question, the authors used a sophisticated modelling technique based on the climate of laurel habitats. It shows that laurel trees today cover an area of 301 km², a mere 1% of their potentially suitable range. Human activities, now and in the past, have almost certainly contributed to laurel's habitat fragmentation. The history of the species may also be important. During the coldest phase of the last Pleistocene glaciation (about 21000 years ago), Portuguese Laurel probably survived in isolated refugia scattered along the Atlantic coast. Relying on birds to disperse its seeds, laurel must have migrated from these locations into the mountains to arrive at where it is today.

Calleja predicts that the future distribution of the species, under climatic conditions simulated for the year 2080, will differ substantially from today's. Portuguese Laurel's main population in Portugal is expected to decline, leaving behind a sprinkling of suitable habitats in the mountains of central and northern Spain. Already laurel's southernmost populations are showing signs of the drought-stress predicted to accelerate in coming decades. The species' long-term viability will depend on its ability to migrate or adapt quickly, an ability that may well be hampered by human activities.

Human impact is a common theme in both of these new studies. So will it be us humans who put the last nail in the coffin of Tertiary-relict plants?

Before we make any bold predictions, we must look carefully at the role humankind has played in long-term environmental change. To return to the example of the Portuguese Laurel, if it were so badly affected by humans on the Iberian Peninsula, one could expect a similar outcome on the Canary Islands. Instead, it seems laurel increased on Tenerife after humans arrived there. Iberian laurel populations were

perhaps more susceptible to human activity because of drought stress. Likewise, oak-hornbeam forests on Tenerife may have been at risk because they existed outside their optimal ecological conditions. Yet, in the absence of a firm understanding of what 'human impact' constitutes, such conclusions are difficult to assess rigorously. Human impact remains a vague concept, encompassing many different processes, rates, scales and ecological outcomes (Head, 2008).

The danger is that a concept as fuzzy as 'human impact' could be used uncritically – as a kind of ecological gap-filler. Of course this does not mean that we can ignore human agency altogether. There is now abundant evidence from around the globe showing that humans have been pervasive in environmental change for long periods of time (Roberts, 1998). The studies above (Calleja *et al.*, 2008?; de Nascimento *et al.*, 2008?) must be applauded for recognising that factors other than climate are important in the history and distribution of plants. Our problem now is how to *measure* the anthropogenic effect in the long term. This is no mean feat when we consider the enormous variety of human interactions in ecosystems today. Can we really work out what our ancestors were doing in their environment? As difficult as this will be, to fail to integrate humans into our understanding of Nature is to fail to understand Nature herself.

The way forward in illuminating past human interactions with ecosystems could be considered to have two fronts: data calibration and ecosystem modelling.

The first is in improving the data that are used to reconstruct past environments. Much has already been done. Charcoal pieces fossilised in sediments can reveal the occurrence of fires in the past. Certain fossil spores can indicate the presence of grazing herbivores. Some types of fossil pollen tend to be associated with human activities. The great challenge is to calibrate these data to produce estimates of environmental conditions in the past. Can we match charcoal quantities with the area and intensity of a fire? Can we use spores to measure grazing pressure? Can we determine the nature and extent of past human activities using fossil pollen? We must find ways to answer 'yes' to these questions if we wish to improve our understanding of past human–environment interactions.

Ecosystem modelling can approach the same problem from a different direction. It is now possible to create computer-simulated ecosystems that change and develop in response to fire, disease, temperature, rainfall, drought, soil fertility and other variables. Eventually it should be possible to model past human activities into these simulations, informed by historical and archaeological data. Fossil records can be used to verify the simulations so that they can be used as robust tools for predicting future environmental changes. Of course, such simulations will only be as good as the ecology that underpins them, so we must also strive to increase our knowledge of the individual species and their complex interactions with other species and environmental factors.

What does this all mean for Tertiary-relict plants?

It means we should be careful about pointing the finger at ourselves when it comes to explaining their present-day rarity. Drought seems to be an important factor for some species (Hampe & Arroyo, 2002; Pulido *et al.*, 2008), but the long-term effects of a Mediterranean climate on plant distributions have only recently begun to be explored (Rodríguez-Sánchez & Arroyo, 2008). The ecological strategy of Tertiary-relict plants is certain to be critical in predicting their adaptability to environmental change

(Svenning, 2003). 'Opportunistic' and 'thermophilous' species may fare better than those with a 'conservative stenoecious' strategy (*sensu* Denk *et al.*, 2001).

Indeed, as Calleja and colleagues (2008?) suggest, we need a new and comprehensive framework for understanding Tertiary-relict plants. Integrating some measure of past human activity into this framework should ensure that our future impact on these ancients will be positive rather than negative.

Simon E. Connor

Centro de Investigação Marinha e Ambiental, Universidade do Algarve, 8005-139
Faro, Portugal

E-mail: sconnor@ualg.pt

References

- Calleja, J.A., Benito Garzon, M. & Sainz Ollero, H. (2008?) A Quaternary perspective on the conservation prospects of the Tertiary relict tree *Prunus lusitanica* L. *Journal of Biogeography*,
- De Nascimento, L., Willis, K.J., Fernández-Palacios, J.M., Criado, C. & Whittaker, R. (2008?) The long-term ecology of the lost forests of La Laguna, Tenerife (Canary Islands). *Journal of Biogeography*,
- Denk, T., Frotzler, N. & Davitashvili, N. (2001) Vegetational patterns and distribution of relict taxa in humid temperate forests and wetlands of Georgia (Transcaucasia). *Biological Journal of the Linnean Society*, **72**, 287-332.
- Hampe, A. & Arroyo, J. (2002) Recruitment and regeneration in populations of an endangered South Iberian Tertiary relict tree. *Biological Conservation*, **107**, 263-271.
- Head, L. (2008) Is the concept of human impacts past its use-by date? *The Holocene*, **18**, 373-377.
- Mai, D.H. (1989) Development and regional differentiation of the European vegetation during the Tertiary. *Plant Systematics and Evolution*, **162**, 79-91.
- Pulido, F., Valladares, F., Calleja, J.A., Moreno, G. & González-Bornay, G. (2008) Tertiary relict trees in a Mediterranean climate: abiotic constraints on the persistence of *Prunus lusitanica* on the eroding edge of its range. *Journal of Biogeography*, **35**, 1425-1435.
- Roberts, N. (1998) *The Holocene: an environmental history*. Blackwell, Oxford.
- Rodríguez-Sánchez, F. & Arroyo, J. (2008) Reconstructing the demise of Tethyan plants: climate-driven range dynamics of *Laurus* since the Pliocene. *Global Ecology and Biogeography*, **17**, 685-695.
- Svenning, J.-C. (2003) Deterministic Plio-Pleistocene extinctions in the European cool-temperate tree flora. *Ecology Letters*, **6**, 646-653.

Editor: Robert Whittaker