SCIENCE FOR ENVIRONMENT POLICY

Trees at the edge: species respond differently to climate changes at hot and cold range edges

6th July 2021
Issue 564

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Source:
Kunstler, G., Guyennon, A., Ratcliffe, S., Ruger, N., Ruiz-Benito, P., Childs, D. Z., Dahlgren, J., Lehtonen, A., Thuiller, W., Wirth, C., Zavala, M. A. and Salguero-Gomez, R. (2020) Demographic performance of European tree species at their hot and cold climatic edges. *Journal of Ecology,* 109: 1041–1054.

Contact:
Georges Kunstler,
georges.kunstler@inrae.fr

As our climate changes, concern is rising over how plant species will adapt in terms of their geographical distribution (or range). Research has identified conflicting patterns in species performance, especially at the outer edges of their ranges, casting doubt on our ability to accurately predict the impacts of climate change. A study assesses 27 European tree species to identify how populations' performance can change at their range edges, and how this response differs between the 'hot and dry versus the 'cold and wet' edges[1] of each species.

Understanding how plant populations respond at their 'range edges' — the outer boundaries at which a species is found— is crucial for forecasting the impacts of climate change. One long-standing theory in this area is the 'abundant-centre' hypothesis, which posits that a species' abundance is highest at the centre of its range and declines towards the edges. In addition, the theory assumes that this decline in abundance results from a decline in population performance. However, research provides weak support for this theory — possibly because most studies explore geographically peripheral populations without considering local climatic or environmental constraints, say the researchers of a new study. They emphasise the importance of considering the biophysical constraints present at range edges, and of analysing edge demographic performance in relation to climate rather than geography.

Using forest inventory data from over 90 000 plots across Europe, the researchers modelled trees' response to climatic change for 27 species, with data covering more than 1 million adult trees from Mediterranean, temperate and boreal biomes. The time between data points ranged from 4 to 16 years. They evaluated how species responses translated into the life trajectory metrics of lifespan and passage time (the time taken for a tree to grow to a large size) — metrics that scale up to reflect general population dynamics.

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Trees at the edge: species respond differently to climate changes at hot and cold range edges (continued)

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To cite this article/service:
"Science for Environment Policy":
European Commission DG Environment News Alert Service, edited by SCU, The University of the West of England, Bristol.

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They then compared species performance at 'hot and dry' or 'wet and cold' climatic edges to those at the ranges' climatic centre, and assessed whether any variations were tied to species' biotic interactions (such as competition), stress tolerance, or functional traits (those that impact an organism's fitness by affecting growth, reproduction or survival).

The findings provide limited support for the 'abundant-centre' hypothesis that demographic performance is lower at climatic edges than at the centre of a species' range; instead showing that decline in demographic performance is strikingly different at 'cold and wet' and 'hot and dry' edges.

Overall, the metrics of tree growth and passage time were constrained at cold and wet edges while survival and lifespan were constrained at hot and dry edges, with large variations between species. Constraints were more pronounced for species in areas with extreme conditions, i.e. the hot edges of hot-distributed species and cold edges of cold-distributed ones.

Of the functional traits explored — wood density, leaf traits and size, and xylem (vascular tissue in plants which conducts water and dissolved nutrients upwards from the root) vulnerability to embolism (blockage, often induced by drought) — only leaf nitrogen content showed a notable link to edge response, with high nitrogen content curtailing survival and lifespan at hot edges and curtailing growth at cold edges. For most species studied, the response seen for both growth and survival metrics differed depending on tree size.

The results suggest that the view that the tree performance is equally constrained at the edges of all species is over simplistic. Instead, the researchers posit that the performance at the edge depends on the edge and species characteristics. The researchers thus caution against the assumption that climate change will affect European tree species only at their range edges. They recommend that the traits and climatic position of the species need to be considered when modelling the impacts of climate change on key European tree species, and caution that negative impact might also occur in the core of the species range.

As European forests are crucial providers of ecosystem services, sheltering biodiversity and carbon and supporting livelihoods across the EU, determining how tree range will change (both now and in the future under projected climate changes) is critical to support initiatives such as the EU Forest and Biodiversity Strategies. These strategies prioritise effective afforestation, forest preservation and restoration, and aim to plant 3 billion additional trees by 2030[2].

1. The hot and dry edge (or cold and wet edge) correspond the most extreme hot or cold conditions experienced by a species in the national forest inventory data and is defined as the 5% quantile (95%) of the temperature experienced by the species.

2. EU Biodiversity Strategy for 2030.