the wave cycle that the signal has completed at any given time). By comparing this phase with that of an oscillator in the receiver, the system can estimate distances with an uncertainty that is smaller than the signal's wavelength, which is around 7.6 cm for the 3.96-GHz wave. One key advantage of the authors' system is that it is compatible with existing 4G and 5G telecommunications networks, which use the same type of multiplexed signal.

The decimetre-scale positioning accuracy reported by Koelemeij and colleagues is certainly impressive, especially because they achieved it using the existing telecommunications infrastructure. Nevertheless, the positioning scheme could be further improved, by adopting certain emerging communications technologies. Combining multiple antennas with millimetre-wavelength signals enables estimation of the angles of signal arrival and departure, as well as the difference in the time it takes the signal to travel between the user and several base stations[6]. With this information, a high level of accuracy can be maintained with fewer base stations and a reduced reliance on synchronization, by making use of natural reflections in the receiver's environment[7]. Knowing these angles makes it possible to estimate the orientation of the receiver as well as its location — a desirable feature of navigation systems[8].

In this respect, Koelemeij and colleagues' system would benefit from using higher-frequency signals than those implemented in their study. High-frequency signals have short wavelengths, which means that more antennas can be packed into the same area than can those that process low-frequency signals. For example, a 140-GHz signal can accommodate 25 times more antennas in the same area than can a 28-GHz wave. Having so many antennas enables measurement of the curvature of the signal's spherical wavefront, which can also provide valuable positional information[9].

One of the next steps for telecommunications networks will be the introduction of materials known as reconfigurable intelligent surfaces, which can be used to coat walls and objects in a receiver's environment. Such materials can be programmed to change the direction in which an incoming signal is reflected, providing a low-cost way of controlling signal propagation with very low power requirements[10].

These developments will all lead to improved location information that is expected to have exciting applications in a future network known as the Tactile Internet, which will provide information through touch, as well as visual and auditory signals. Accurate positional information could lead to 'smart cities', in which homes automatically turn on heating as their occupants get closer, and drones that deliver packages to recipients on the move. Koelemeij and colleagues' scheme brings these cities a step closer to reality.

Hui Chen and **Henk Wymeersch** are in the Department of Electrical Engineering, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden.
e-mails: hui.chen@chalmers.se; henkw@chalmers.se

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Ecology

Neighbours and climate affect species extinction

Ellen I. Damschen

Predicting the risk of extinction from climate change requires an understanding of the interactions between species. An analysis of how changes in rainfall affect competition between plant species offers a way of tackling this challenge. **See p.507**

Anticipating how natural ecosystems will respond to climate change, and determining which species are most at risk of extinction, are crucial aspects of conservation work. On page 507, Van Dyke *et al.*[1] shed light on this timely issue.

Between about 10% and 50% of all species on Earth, including flowering plants, are predicted to be at high risk of extinction as a result of climate change[2]. Such predictions are almost always generated by considering how individual species respond to a changing climate, without taking into account their potential interactions with other species. This gap in our understanding is not due to a lack of recognition of the importance of species interactions, but reflects the enormous challenge of measuring the strength of species interactions in realistic field conditions, let alone considering how a changing climate might alter those interactions. Yet such estimates are clearly needed to provide realistic scenarios for the future that can guide conservation actions.

Van Dyke and colleagues provide a major advance in the prediction of species persistence under climate change by coupling a well-designed field experiment with predictive mathematical models in order to determine how climate change affects the outcome of competitive interactions. They obtained seeds of six plant species with a one-year life cycle from a biologically diverse ecosystem in which water is limited and drought is already causing species loss[3]. Sowing these seeds, the authors created experimental communities consisting of varying numbers of individuals of the same species or pairwise combinations of different species. Each of these one- or two-species communities, which developed from seeds sown to generate different population sizes, were subjected to either the ecosystem's current average precipitation or to a 20% reduction in the average precipitation — a scenario mimicking the decreases in rainfall predicted for the area as a result of future climate change. The effects on individual plant survival in each of these contexts were measured, and the data used in mathematical models to generate predictions for whether one or both species would persist. The authors conclude that modest changes in climate strikingly alter the outcome of competitive interactions between species, whereas those same rainfall changes have little effect on how species fare when grown alone. In most cases, the effect of competition on species persistence and coexistence was entirely different under the climate-change scenario compared with the patterns of persistence and coexistence observed under current conditions (Fig. 1).

Surprisingly, climate change was less likely to affect competition between species pairs that were more similar in terms of their roles or functions in the ecosystem. Foundational theories of ecosystem resilience predict that communities that contain species with very different functions will be more resilient in a

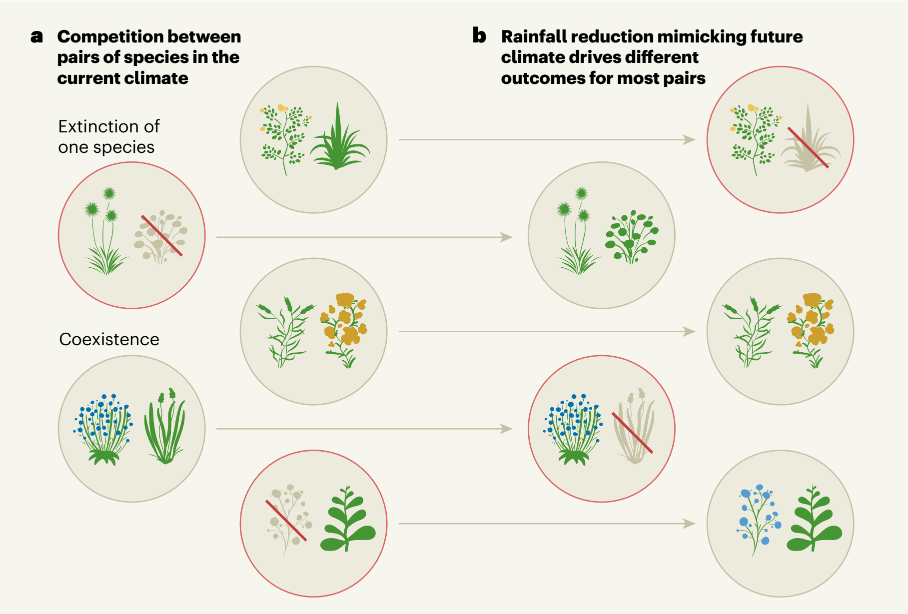

Figure 1 | Altered outcomes when plant species compete as the climate changes. Van Dyke *et al.*[1] carried out a field trial to investigate how a reduction in rainfall affected the persistence of pairs of different plant species. Pairs of species received either rainfall at current levels or a comparatively reduced amount of rainfall to mimic the expected future climate. The authors found that this modest change in the climate altered the outcome of interactions between the pairs of species – whether species coexisted or became extinct – in most cases (10 out of 15 pairs tested). The results offer insights into how climate change can have a major effect on the diversity of a community of plant species.

changing climate than will communities that consist of species with similar functions. However, Van Dyke and colleagues' results reveal that, when species interactions are considered, communities with greater functional diversity might experience more turnover in species composition under climate change as a result of alterations in competitive interactions, compared with the amount of turnover for communities with less functional diversity.

The authors' study convincingly demonstrates that climate can alter the effect of competition between species, providing a fundamentally new understanding of ecological interactions. Furthermore, the results have direct relevance for conservation planning. First, they confirm the crucial need to consider species interactions when attempting to predict the persistence of species in future climates. Second, many conservation plans call for an increase in the functional diversity of species in an ecosystem, under the assumption that a greater variety of functions might buffer the effects of climate change by favouring some species over others, depending on the climate outcome. The authors' results suggest that this approach might instead set up communities to be less resilient, because it would increase the likelihood of changes in the composition of the community's species as a result of altered outcomes of competitive interactions.

Van Dyke and colleagues' findings provide a step forward in terms of linking hard-to-obtain field data and predictive models, yet the conclusions are inherently limited. Although the six species used in the study are representative of the broader community of which they are a part, they are only a small fraction of the species and life histories in their ecosystem, much less those from other ecosystems. Not all ecosystems are controlled by the same processes, and it will be essential to evaluate the effects of climate on competitive outcomes more broadly. It will also be important to establish whether measurable characteristics of species exist that are indeed indicative of the species' responses to climate change and other environmental drivers. Both of these factors will be required for making realistic predictions across whole communities of interacting species and for evaluating the potential for functionally diverse communities to either buffer or exacerbate the impacts of climate change.

The study reveals how climate change can have both direct and indirect effects on the persistence of species and community diversity. It will also serve as a springboard for moving beyond predicting individual species' responses and instead anticipating how the balance of species interactions might be tipped under climate change.

Ellen I. Damschen is in the Department of Integrative Biology, University of Wisconsin–Madison, Madison, Wisconsin 53706, USA.
e-mail: damschen@wisc.edu

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Medical research

Engineered T cells to treat lupus arrive on the scene

George C. Tsokos

In an effort to treat systemic lupus erythematosus, T cells of the immune system were engineered to become cells known as CAR T cells. Their injection into people with the disease resulted in clinical and immunological improvement.

An autoimmune disease called systemic lupus erythematosus (SLE), which mostly affects young women, is associated with various symptoms resulting from inflammation and damage to multiple organs. A multitude of disease-causing processes is involved, driven by factors that might have immunological, genetic, environmental and hormonal contributors. Writing in *Nature Medicine*, Mackensen *et al.*[1] describe a highly promising approach to treating the disease.

The development of SLE involves the full arsenal of the immune system (both its adaptive and innate branches), and leading the way[2] are antibody-producing B cells, which act abnormally to produce diverse, self-targeting antibodies termed autoantibodies. Beyond existing treatments such as corticosteroid drugs and cell-killing agents, the therapeutic tools available for clinical testing usually aim to