available for practical purposes — especially for biomedical applications. Nevertheless, Chen and colleagues' findings represent a key step in the design of efficient molecular machines that can be activated by external mechanical forces. Their results will undoubtedly inspire research towards the design of more-universal mechanosensitive systems that allow controlled release of an even greater diversity of cargo molecules.

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Conservation biology

Climate change predicted to exacerbate bee declines

Nicole E. Miller-Struttmann

What effects will climate change have on insect communities? Analyses of data collected over decades robustly document consequences specific to bee populations, and this evidence might aid future conservation efforts. **See p.337 & p.342**

Although most modern cases of extinction are attributed to habitat loss, invasive species and over-exploitation[1], climate change is rapidly becoming a prominent threat. Research suggests that climate extremes are contributing to declines in bees, butterflies, flies and moths[2] and increasing their extinction risk. However, those results have mainly been correlational rather than providing direct causal evidence, making assessments of conservation status based on them tenuous. Two papers now make key strides in filling that knowledge gap. On page 342, Kazenel *et al.*[3] provide evidence of the direct physiological effects of extreme climate conditions on the long-term population stability of bees, and on page 337, Ghisbain *et al.*[4] predict striking declines in bumblebees, including in many species currently listed in the 'least concern' category of threatened species in the influential listings by the International Union for Conservation of Nature (IUCN).

Documenting species declines in response to changes that occur over decades, such as climate change, requires long-term data sets that are exceedingly rare. The species for which we have those kinds of data tend to be large and charismatic. For the insect world, bumblebees fill that role (Fig. 1a). In response to increasing temperatures, bumblebees have shown contractions in their dispersal ranges, population declines and local extinctions[5–7]. Those declines have been linked to a lack of physiological tolerance of high temperatures as demonstrated through experiments[8] and because of the observed historical climate limits for these species[5]. Together, those studies provide strong support for the role of temperature in driving bumblebee declines.

However, most bee species are ecologically and evolutionarily different from bumblebees. Bees are generally small and solitary, whereas bumblebees are relatively large and social. As such, solitary bees might respond differently to climate change, particularly if their physiological tolerances are more constrained than are those of bumblebees. Kazenel and colleagues address this issue using a 16-year study of 339 bee species, many of which are solitary, in drylands in the southwestern United States. The authors used a robust combination of data for natural variation in climate, and experimental evidence to predict which species would be negatively affected by climate change. They project that of the 243 species that they found were sensitive to drought, 46% will experience population declines with continuing climate change (Fig. 1b).

Previous research in this area has focused mainly on temperature limits that would prevent bee survival[5,9–11] but this metric, although important, does not reflect all the physiological effects of climate change, such as those driven by drought. The species predicted by Kazenel *et al.* to persist despite climate change are tolerant not only of heat but also of dry conditions (desiccation). The authors experimentally determined thermal and desiccation tolerances for a subset of 12 bee species and found that those species that are best able to handle both were more resilient to previous climate change. The 12 species represent 3.5% of those studied by the authors, but they are spread across the evolutionary tree of life (taxonomically diverse) and represent five of the seven bee families found globally.

Although projecting future declines is a crucial step in identifying species' extinction risks, responding with meaningful conservation actions remains challenging. Many governmental protections rely on descriptors of conservation status, such as those established by the IUCN. Such metrics are based on documented population declines. However, as climate change escalates, species that were historically stable might rapidly become threatened, making current conservation-status assignments misleading. Indeed, Ghisbain *et al.* demonstrate that reliance on past declines is insufficient for predicting future effects of climate change on European bumblebees. Using a compilation of historical and contemporary data sets collected between 1901 and 1970, and 2000 and 2014, the authors report (Fig. 1a) that changes in climate, land use and human population size have made parts of Europe less suitable for many bumblebee species. On average, decreases in habitat suitability were relatively low (4.5%), however, local suitability declined by up to 33%. Moreover, those declines are projected to continue or intensify for up to 76% of species.

Similar patterns have been demonstrated previously[5], however, Ghisbain and colleagues go one step further by assessing whether species' current conservation status can predict future habitat suitability (Fig. 1c). Unfortunately, it can't. An estimated 32–76% of species that are currently considered of least concern by the IUCN are predicted to lose at least 30% of their suitable habitat by 2080, a level of decline that would move them to threatened status. Notably, these patterns are consistent regardless of the approach (niche model or climate scenario parameters) used to estimate habitat suitability.

Important unknown factors still hinder our ability to predict species distributions. Foremost among them is dispersal. Current climate 'safe sites' (refugia) for bumblebees, such as regions in eastern Scandinavia, remain intact under several climate scenarios (Fig. 1a), but whether bumblebees can migrate to them remains unclear. Bumblebees occasionally

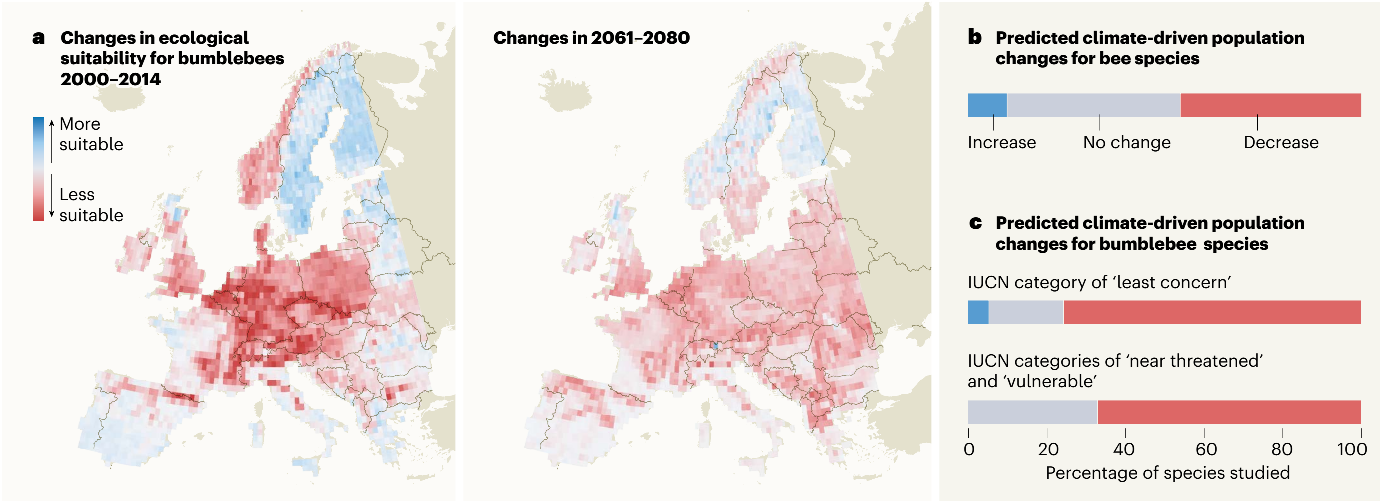

Figure 1 | The effect of climate on insect populations. a, Ghisbain *et al.*[4] assessed the effect of climate on habitat suitability for bumblebee populations in Europe. The data for 2000–2014 indicate that many regions in central Europe are becoming less suitable for bumblebees, with some exhibiting striking reductions in suitability. The geographical range of the inhospitable area is predicted to expand by 2061–2080 under a climate scenario for medium levels of carbon dioxide emissions called socio-economic pathway (SSP) 3, although further changes in suitability in a given population might not be as striking as those of 2000–2014. (Adapted from Fig. 1 of ref. 4.) **b**, Kazenel *et al.*[3] predict the effect on populations of 243 drought-sensitive bee species in the United States of a future climate scenario based on medium levels of greenhouse-gas emissions (representative concentration pathway 4.5). **c**, Ghisbain *et al.* predicted changes for bumblebees in the SSP3 scenario using categories in the classification system of the International Union for the Conservation of Nature (IUCN). The authors examined 37 species in the 'least concern' group and 9 in the 'near threatened' or 'vulnerable' groups.

travel extremely long distances (up to 200 kilometres)[12,13]. However, we currently do not know enough to reliably predict their potential dispersal distances, particularly across varied landscapes. We know even less about the dispersal capabilities of the 98% of bees not analysed in either study, hindering our ability to protect these crucial organisms.

Bees and bumblebees contribute to the production of the world's nutritious, flavourful foods and healthy ecosystems[14–16]. A decline in nearly half of bee species over the next 50 years, as predicted using evidence from these two studies, could be catastrophic to the ecosystem services that these insects provide. Nevertheless, the authors of both papers offer achievable strategies to mitigate losses – landscape redesigns that provide 'stepping stones' to climate refugia, establishing microclimate refugia in areas of stress and adjusting the IUCN status of species at risk of projected climate-induced declines. The response window is, however, closing quickly: widespread local extinctions are projected to occur by 2080.

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Genomics

Mammals repress random DNA that yeast transcribes

Sean R. Eddy

In experiments dubbed the Random Genome Project, researchers have integrated DNA strands with random sequences into yeast and mouse cells to find the default transcriptional state of their genomes. **See p.373**

More of the DNA in the human genome is transcribed into RNAs than scientists can adequately account for. Transcription of around 20,000 known protein-coding genes covers about 40% of the genome, but at least 75% of the genome is transcribed reproducibly at a detectable level[1,2]. A decades-old debate in genomics has failed to resolve how much of the extra RNA transcribed – including thousands of long non-coding RNA sequences – is functional, and how much is 'noise'[3,4]. Central to the disagreement is a lack of clarity about the nature of this transcriptional noise[5]. In 2013, I suggested a 'Random Genome Project' to establish a baseline expectation for the biochemical activity of genomic DNA in the absence of any evolutionary selection for biological functions[6]. Fuelled by rapid advances in synthetic genomics, two studies, one on page 373 (ref. 7) and one in *Nature Structural and Molecular Biology*[8], describe versions of this experiment in yeast (*Saccharomyces*