BIODIVERSITY

Interacting global change drivers

Climate change impacts on species do not occur in isolation. Now research on drought-sensitive British butterflies uses citizen science to attribute the drivers of population changes and shows landscape management to be a key part of the solution.

Josef Settele and Martin Wiemers

Biodiversity is affected by a plethora of global change factors, which makes attributing observed changes to particular drivers and pressures, and accounting for their interactions, a challenging task[1]. Unfortunately "tools to understand and manage these interactions remain limited"[2]. In this issue of *Nature Climate Change*, Oliver *et al.*[3] present one way to disentangle interacting environmental effects — in this case, climate change and habitat fragmentation — on drought-sensitive butterfly populations. They analyse the responses of 28 butterfly species to an extreme drought event in 1995 using long-term monitoring data from the UK Butterfly Monitoring Scheme. This data was linked with satellite-derived land-cover maps to characterize how the area and configuration of surrounding semi-natural habitats (SNH) modifies species responses to drought. They selected six species that exhibit reduced growth rates during times of aridity. All six exhibited major population collapses after the 1995 drought. The authors used the return time of aridity events as a way to communicate the core results — for example, an aridity return time of effectively one year under the RCP8.5 scenario in 2100.

The green-veined white (*Pieris napi*) is widespread and abundant throughout Europe and one of six butterfly species that showed a major population collapse in the UK following the 1995 drought.

Oliver *et al.*[3] use five SNH scenarios (that is, five landscapes) and calculate the probability that drought-sensitive butterfly populations can persist when exposed to covariation in climate and habitat. This is a very creative way to make progress in the attribution of observed and/or simulated biological changes to climate and/or land use.

They find, unexpectedly (or as the authors put it: "contrary to recent current thinking") that it is more important to target habitat creation to reduce fragmentation than solely to maximize the SNH area. Unfortunately, the authors also suggest that micro-evolutionary rescue over the next four decades is unlikely. The consequent conclusion that these butterflies are imperilled by climate change and that landscape management — in combination with major emission reductions (for example, in line with the RCP2.6 scenario) — offers the best solution to prevent extinctions is an important take-home message. If we consider landscape management as a means to prevent extinctions, or at least delay them, the time bought through adequate management might leave sufficient opportunities for rescues through the combination of micro-evolutionary processes, dispersal and mitigation of climate change impacts[4]. The need to account for changes in local habitat when exploring the impacts of recent climate change has also been highlighted in a recent study that also emphasized the importance of habitat management to support species under variable local climates[5].

These results show us which avenues we have to take to prevent species loss; that we have to act for immediate effects (that is, through appropriate land management to reduce fragmentation) as well as to combat longer-term problems (that is, to reduce climate change). It is also a call to overcome the temptation to concentrate on only one driver while ignoring the others, despite the fact that we have (and the authors had) to deal with uncertainties across three dimensions: emissions scenarios, climate change models (translation of CO_2 into temperature and rainfall), and species responses (in this case to drought events, that is, impacts of aridity on species and how this is modified by land use). To reduce the uncertainty in species responses, the authors used stringent criteria for inclusion of sites and species. This led to a much reduced data set that makes generalizations of the findings difficult. Furthermore, the lack of recovery in four of the six selected species might have been due to factors unrelated to the drought event (for example, an early recovery could have been superimposed on an unrelated trend in the opposite direction). Just the same, these results have high potential relevance for other drought sensitive taxa and it is frightening how great a shift in land use and CO_2 emissions may be required to aid drought-sensitive species.

The large-scale analysis performed by Oliver *et al.*[3] reinforces the opportunities created by the production of large-scale and long-term datasets, which can frequently only be created with the help of the general public through citizen science approaches. As for birds, monitoring schemes and distribution analyses for butterflies are well established and increasingly deliver data that are used in the study of climate change impacts. For example, one of the most highly cited papers in *Nature Climate Change* dealing with terrestrial biodiversity is entirely based on citizen science data from species distribution and monitoring-based trends of birds and butterflies[6]. Furthermore, "if we are to achieve genuinely informed and effective engagement on climate change issues"[7], having citizens involved as direct contributors to research is surely helpful. For natural scientists, collaborating with the public should be encouraged[8] and is often a step out of their comfort zones that may well contribute to changing our intellectual climate[7]. ❐

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CLIMATE TARGETS

Values and uncertainty

Policymakers know that the risks associated with climate change mean they need to cut greenhouse-gas emissions. But uncertainty surrounding the likelihood of different scenarios makes choosing specific policies difficult.

Robert J. Lempert

Climate change presents a risk management challenge. But covering oneself against this risk is significantly more complex than buying insurance for your car or house. In those cases, accurate actuarial tables exist that define the risk, and one can compare the known costs of premiums with known replacement costs. In contrast, managing climate risks involves judging poorly understood outcomes and likelihoods while engaging people with many different views regarding, for instance, how much to value the present versus the future. Writing in *Nature Climate Change*, Laurent Drouet and colleagues[1] offer an intriguing new take on this challenge, which combines several interesting innovations.

First, they conduct a meta-analysis, extracting a wide range of estimates of future climate change, impacts and mitigation costs from the data generated by the three working groups of the IPCC Fifth Assessment Report[2–4], and extrapolate outcomes over a wide range of futures.

Second, they include deep uncertainty by projecting impacts and future climate using different types of model and considering separately bottom-up versus top-down estimates of mitigation costs.

Third, they consider alternative ethical stances towards risk by using three different decision criteria: expected utility, which weighs all outcomes according to their estimated likelihood; a 'maxmin' criteria that focuses entirely on the worst-case outcomes; and a maxmin expected utility, which considers outcomes from only the worst-case models, but weighs these outcomes by their estimated likelihood.

Fourth, they use an exploratory analysis[5,6], the purpose of which is not to generate a normative policy recommendation, but rather to examine the implications of a wide range of futures and values. In particular, Drouet and colleagues seek to identify self-consistent sets of values, expectations and policies that can inform processes of deliberation and social choice.

Using this analytic machinery, they ask at what level global cumulative carbon budgets should be set, according to each of the alternative decision criteria. They find that with low cumulative emissions targets, uncertainty regarding the cost of mitigation has the biggest impact on the overall cost. With high targets, uncertainty regarding climate impacts has the biggest effect on the costs.

As uncertainty regarding future impacts is larger, the worst-case criterion gives a low cumulative emissions target (one consistent with the internationally agreed goal of keeping warming below 2 °C). The expected utility criterion pays more attention to the best estimates for impacts and mitigation costs, so gives a higher target for any but the lowest discount rate, where the long-term damages begin to dominate the balance of benefits and costs. Interestingly, uncertainty about the climate system weighs least heavily.

Commentators often claim that climate science implies a need for the 2 °C target, but Drouet and colleagues make it clear that our choice depends most strongly on our expectations about the behaviour of future biological and socio-economic systems — that is, the impacts of climate change and the cost of mitigation — and our values, such as preferences towards the future and how much attention we pay to worst cases.

How might the answer have turned out differently if additional futures or criteria were included in the study? Drouet *et al.* extrapolate well beyond the historical data. We have no direct evidence regarding the impacts of a world beyond 4 °C of warming, or one in which a large economy runs