GLOBAL CHANGE ECOLOGY

Complex causes of insect declines

Insects across the globe are facing multiple anthropogenic pressures. A study combining several data streams and advanced modelling helps to unravel the main factors underlying declines in monarch butterfly populations.

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Monarch butterflies perform one of the most spectacular events in the insect world — migrating thousands of kilometres across North America, over multiple generations, between their wintering and summer breeding grounds each year. This phenomenon was only fully described in the 1970s, but it is already in danger of being lost. Numbers of monarch butterflies have plummeted over the past decades[1–3]. Declines have been reported at both overwintering and breeding grounds, for both the west and east coast populations. The monarch is one of the most studied and recognizable insect species, but the causes of its decline are controversial. Writing in *Nature Ecology & Evolution*, Zylstra et al.[4] show how integrated modelling can help to quantify the relative importance of the main factors at play.

The monarch may be exceptional in terms of its migration, but it is less so in terms of its population trend. Many butterfly species are declining in North America and also in Europe[5–7]. These declining trends also mirror those of many other insect groups[8] but the trends are highly variable across time periods and taxa[9]. In the case of monarchs, multiple causes have been speculated to play a role in the decline. One is the loss of milkweed host plants on which the larvae specialize (Fig. 1). Milkweed has declined due to changes in agricultural practices, especially the use of herbicides such as glyphosate that eradicate 'weeds' competing with crops[10]. Another potential cause is increased mortality during migration or overwintering due to, for instance, changes in nectar availability along the migration route or habitat at overwintering sites[11,12]. A third factor is the direct and indirect effects of climate change — including on monarch development and survival or the availability and quality of milkweed host plants[13]. Testing these hypotheses, however, has been persistently challenging owing to the complex life cycle of the species, which is spread out across multiple countries and seasons.

Zylstra et al. met this challenge by bringing together data from multiple butterfly monitoring programmes to track the monarch throughout its annual cycle. The authors used data from five monitoring schemes across large parts of the summer breeding grounds of the eastern monarch population — in Ontario, Canada and the Midwestern USA. They also included data from the species' wintering grounds in central Mexico, specifically within the Monarch Butterfly Biosphere Reserve where the monarch forms dense colonies during hibernation. Using a full annual-cycle model, Zylstra et al. simultaneously tested the effects of climate, land cover and herbicide use on both summer and winter population size.

Fig. 1 | An adult monarch butterfly on a milkweed plant. Credit: Janet MacFarlane

Their findings revealed that annual population sizes of monarch butterflies were best explained by climate conditions during spring and summer. There was a negative association between herbicide use and population size, but this effect was much weaker than the climatic effects. Associations between winter and summer population sizes suggested that changes in migration and overwintering mortality were unimportant.

Overall, the results support climate being a key driver of monarch population size. Moreover, by studying the population dynamics over a broad geographic extent, the authors showed that the climate effects varied regionally — with less-positive effects of warmer summer temperatures in the warmest regions. From this, the authors speculated that these regions may become inhospitable for monarchs as temperatures continue to rise.

A limitation of the study, recognized by the authors, is that it is unclear whether climate is driving long-term trends of the monarch population or is rather more responsible for year-to-year fluctuations. This wasn't separated by their model. As Zylstra et al. pointed out, the steepest decline of monarch populations occurred before 2004, during the period of widespread expansion of herbicide use, but there were less butterfly data available before 2004 for the analysis. Indeed, other studies have concluded that halting and reversing the loss of milkweed plants should be the priority for conservation[13,14]. As with most species, no single factor is probably responsible for the decline of the monarch[15]. Moreover, the relative importance of different pressures may have changed over time. Habitat loss, especially associated with agricultural intensification, and climate change have both been commonly highlighted as leading causes of declines for butterfly species elsewhere[5,16].

One of the greatest challenges for ecologists is overcoming the lack of large-scale monitoring data for insects. While some taxa, such as birds, are relatively well monitored by large-scale and standardized programmes, most insect taxa are sampled only locally, at best[17]. Hence, evidence for insect declines so far mostly comes from data collected at a relatively small number of sites[18,19]. Zylstra et al. show how different data sets can be brought together to examine insect population dynamics at larger scales. This is especially important for migratory species since different monitoring programmes target species at different points in their life cycle. But even beyond migrants, combining multiple sources of data and information can expand the spatial and temporal scale of a study, helping to understand whether declining trends are widespread over a species' range. Greater scale can also help identify causes of declines by encompassing larger gradients in the intensity of pressures and increasing the statistical power to detect their impacts.

Recent advances in integrated modelling offer new ways to combine the information within different data sets to study species' population and distribution dynamics[20–23]. Zylstra et al. provide an example for an iconic insect species but these types of models have so far only been rarely applied to insects[24]. As the statistical tools develop, data integration may help to overcome some of the problems associated with the sparsity of the data available for insects and allow better understanding of the extent and drivers of insect declines. Moreover, data integration could help identify the most effective approaches to tackle insect declines and provide a more robust evidence base for conservation actions[25]. ❐

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Competing interests

The author declares no competing interests.