CellPress

Feature

Butterflies take a well-studied tumble

Massive amounts of observation data recorded by amateurs are available for butterflies, allowing scientists to study their population dynamics and response to environmental threats. They report serious declines in many rarer species leading to an overall loss in biodiversity. As these declines reflect the impacts of land use change, climate change and pesticide use, they also provide an alarm system to warn of imminent dangers to other, less visible parts of our natural environment. **Michael Gross** reports.

This summer, the legendary wildlife presenter David Attenborough urged UK nature lovers once more to go out and record what kinds of butterflies they see. The seventh instalment of the Big Butterfly Count, organised by the charity Butterfly Conservation, which Attenborough chairs, ran from July 15 to August 7 (http://www.bigbutterflycount.org/). Detailed results are yet to be released, but the website already logs more than 38,000 counts. According to the instructions provided, a count involves a 15-minute period spent either walking or stationary in any kind of habitat, such as gardens or parks, and ticking off sightings on a chart provided with photos of 20 species that are common in the British Isles. In 2015, around 52,000 volunteers reported sightings of 585,000 individual butterflies and moths. The gatekeeper or hedge brown butterfly (*Pyronia tithonus*) leads the field with more than 100,000 observations, ahead of the large white (*Pieris brassicae*) and the meadow brown (*Maniola jurtina*) butterflies.

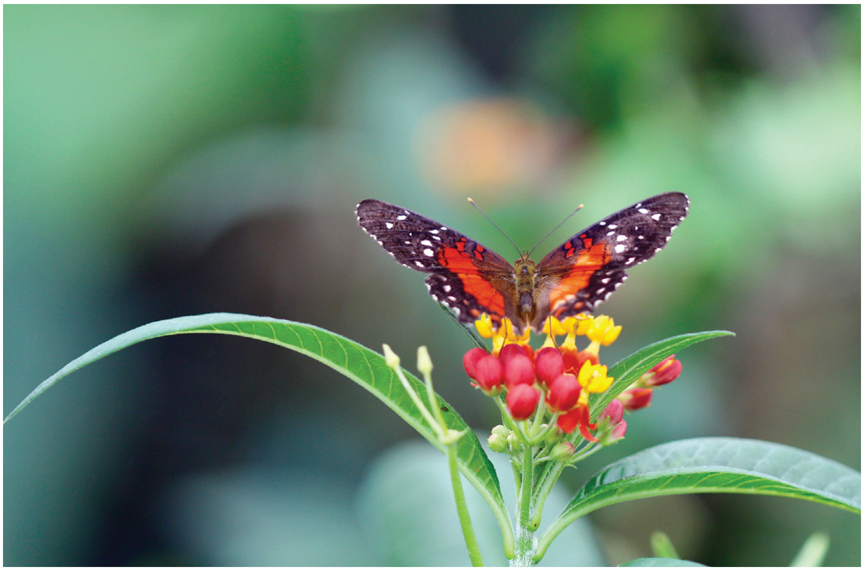
Today's amateurs reporting their sightings with laptops and smartphones are continuing and adding to the work of earlier generations with cameras and note pads, and indeed of Victorian naturalists who liked to catch the insects and keep them in their colourful collections. Artists have also been drawn to the colourful wing patterns since the time of Maria Sibylla Merian (Curr. Biol. (2016) *26*, R343–R346), long before photography made it easier to capture their beauty. The ease of observation and the continuing enthusiasm of many amateur naturalists have produced a unique body of data that allows researchers to study the population dynamics of many species across large parts of Europe, and in some cases over centuries. They find dramatic declines in biodiversity, reflecting the man-made changes in the environment.

Changing times

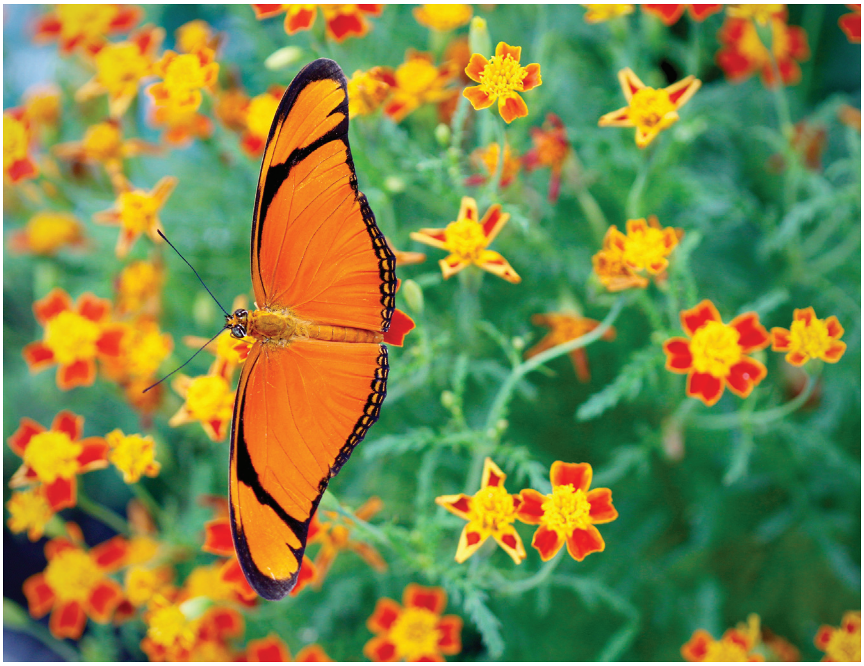
Historic butterfly collections allow researchers to use genome analysis and work out how species adapted to changing conditions, or in some cases failed to adapt. The group of Toby Fountain at the University of Helsinki, Finland, recently used this approach to analyse how a regional population of the Glanville fritillary butterfly in south-west Finland became extinct in the 1970s. The researchers analysed museum specimens of this extinct population dating from 1880 to 1968, while also studying a surviving introduced meta-population from the Åland region for comparison (Proc. Natl. Acad. Sci. USA (2016) *113*, 2678–2683).

As their established habitats became fragmented and in some places disappeared, the populations had to disperse and adapt to new environments. Genotyping of more than 200 SNPs revealed that the insects evolved rapidly in response to these challenges, but ultimately they failed to keep up with the pace of the environmental change. For the surviving populations in the Åland region, by contrast, the habitat patches remain sufficiently close to allow exchange and maintain a healthy meta-population. Thus, the findings underline the dangers of habitat fragmentation for biodiversity.

Using a multitude of historic observation reports and recent analyses, Jan Christian Habel and colleagues at the Technical University Munich, Germany, travelled back even further in time. The team used records dating back to before the onset of the Industrial Revolution and the intensification of agriculture to study population changes in Lepidoptera (butterflies and moths) as well as their host plants in grasslands near the city of Regensburg, Bavaria. While the loss of biodiversity in the 20th century is already well documented, this study shows that the trend extends further back into history, through to the late 18th and early 19th century (Conserv. Biol. (2016) DOI: http://dx.doi.org/10.1111/cobi.12656).



Biodiversity focus: Butterflies can be highly visible indicators of biodiversity and thus of ecosystem health. This one is a scarlet peacock (*Anartia amathea*), which is common across South America and the Caribbean. (Photo: Natasha de Vere.)



Colour coding: The unique and aesthetically appealing wing patterns of many species of Lepidoptera have helped to inspire many amateur observations and recordings, leading to a unique body of population data. This image shows the Julia butterfly (*Dryas iulia*), which is found across the Americas from Brazil to Texas and Florida. (Photo: Natasha de Vere.)

For their study area, the authors observe only modest impacts of climate change, such as range shifts. Most of the population shifts they record can be linked to the changes of nutrient availability and thus to the increasing use of fertilisers. Most butterfly species tend to require plant species that live in nutrient-poor environments. With the general increase in nutrient availability from widespread fertiliser use, these plants were gradually replaced by other species, and butterfly habitats were destroyed or fragmented.

In terms of the responses to these changes among the Lepidoptera species, Habel and colleagues found that those species more narrowly specialised on a certain kind of habitat were the worst affected and often became extinct in the area. Considering the complex life cycle of the Lepidoptera, it is often the larval stage, the caterpillar, that has the most stringent requirements and lacks the mobility range to find a more suitable habitat.

This trend led to a dramatic loss of overall species diversity. A mixture of many different habitat specialists gave way to a more uniform community dominated by a few habitat generalists.

While this decline in biodiversity is best studied in Europe, it appears likely that the intensification of agriculture on other continents is having a very similar effect there, and that these effects will also extend to many other, less conspicuous species.

Protective measures

Where the requirements of a diverse community are known, conservation work can strive to maintain favourable conditions at least in protected areas. But even then, errors in management can lead to a loss of biodiversity, as the group of Peter Mayhew at the University of York, England, found when they studied the rare moth species, dark bordered beauty (*Epione vespertaria*) at the last known site in England where it still occurs, a protected 570 hectare lowland heath area known as Strensall Common, about ten kilometres north of York (PLoS One (2016) *11*, e0157423).

The researchers found that adult numbers collapsed dramatically in recent years, losing an average of one-third from each year to the next between 2007 and 2014, with a simultaneous contraction in range. These losses can be linked to the concurrent reduction in the availability of the preferred host plant. This population feeds on the creeping willow *(Salix repens)*, while all three populations known in Scotland feed on aspen *(Populus tremula)*.

While the general site management with sheep grazing and occasional cutting of shrubs and trees appears suitable for maintaining the Lepidoptera habitat, the researchers found that subtle, unintended changes to the way the sheep were managed led to increased grazing pressure on the willows, which likely contributed to the moth declines. Therefore, measures to boost the willow patches and protect them from grazing sheep have already been put in place, and further observations and protective measures will be carried out to help the survival of this last population in England, which would have gone extinct had it not been under systematic observation.

The usual suspects

Climate change is bound to affect the fate of insect populations in some way, but it is hard to predict which ones will be affected in which ways. To test hypotheses suggesting that UK butterflies might generally benefit from climate change, Georgina Palmer from the University of York and colleagues have systematically evaluated the changes in abundance and distribution of 155 British butterfly species since the 1970s using large datasets based on volunteer observations.

The results show that some species, such as the treble brown spot moth (*Idaea trigeminata*) and the speckled wood butterfly (*Pararge aegeria*), have indeed benefited from climate change, while others like the grizzled skipper butterfly (*Pyrgus malvae*), the September thorn moth (*Ennomos erosaria*) and the mouse moth (*Amphipyra tragopoginis*) have suffered.

This complex pattern of responses can be easily rationalised, as each species has its own requirements and preferences in terms of climatic conditions. Palmer estimates that two-thirds of the changes in abundance that were recorded can be explained by such species-specific preferences.

The publication of this work in *Science Advances* has recently been retracted due to methodological inaccuracies that don't affect this general conclusion.

As co-author Chris Thomas from the University of York summarised in a press statement: "It turns out that these 155 different species of butterflies and moths have almost 155 different 'opinions' on how much the climate has changed, and whether it has got better or worse. Climate change is causing massive alterations to our wildlife."

Pesticides used in agriculture are also among the factors that may harm butterflies — in some cases even intentionally, when their caterpillars are considered pests. Neonicotinoids, systemic pesticides once introduced to limit the toxic effect to the insects that attack the actual crop plant they protect, have in recent years caused widespread concern due to their persistence in the environment, which is believed to harm non-target species like bees even at concentrations below the acute toxicity threshold. Knock-on effects are even noticeable in vertebrates depending on insect prey, including birds (Curr. Biol. (2014) *24*, R717–R720).

In a recent study, Andre Gilburn from the University of Stirling, UK, and colleagues used volunteer observations made between 1984 and 2012 to find statistically significant correlations between butterfly population trends and environmental factors, including temperatures and neonicotinoid use. Out of the 17 species investigated, the researchers identified 15 that appeared to decline in line with the use of these systemic pesticides (Peer J. (2015) *3*, e1402, http://dx.doi.org/10.7717/peerj.1402). The authors also note that butterfly declines are dominant in England, where the use of neonicotinoids is widespread, whereas populations have remained stable in Scotland where these are much less widely used.

Habitat lost: A study of Lepidoptera and their habitat in grasslands near Regensburg, Germany, covering more than two centuries, shows that biodiversity loss accompanied the intensification of agriculture and the increase in fertiliser use. The image shows semi-dry grasslands at Fellinger Berg, one of the sites studied. (Photo: Johanning/Wikimedia Commons.)

Lessons to learn

Moths and butterflies may not be as immediately useful to human needs as bees, but they do of course have important parts to play in ecosystems as prey and occasionally as pollinators. More importantly, they can act as indicators of biodiversity and general ecosystem health due to their high degree of visibility and easy identification.

Centuries of amateur enthusiasm for observing, recording and collecting butterflies has yielded a body of population data that researchers interested in other parts of the natural environment, such as soil invertebrates (Curr. Biol. (2016) *26*, R387–R390), could only dream of. Systematic use of this treasure trove of ecological data across time and space, in combination with information on climate, pesticide use, and other disturbances, can help improve our understanding of how the biosphere is affected by these changes.

Subtle methodological adjustments could make such investigations even more fruitful. Lars B. Pettersson from Lund University, Sweden, and colleagues have recently shown that a grid-based monitoring approach could improve the reliability of volunteer butterfly-recording schemes. Understandably, volunteers choosing their own observation path tend to prefer environments where they expect to see many butterflies, such as semi-natural grasslands. This bias risks neglecting other butterfly habitats, including coniferous forests, bogs, and clear-cuts (Nat. Conserv. (2016) *14*, 41–62, http://dx.doi.org/10.3897/natureconservation.14.7497).

Pettersson and colleagues therefore suggest that volunteer programmes could introduce a systematic grid of suggested monitoring routes, which would provide a more complete and representative picture of butterfly populations. Such grid-based schemes could complement traditional ones with freely chosen routes, to provide better overall assessments of biodiversity trends, Pettersson says.

Currently, the largest body of observation data is available for Europe, where a rapid decline in insect biodiversity has accompanied industrialisation and intensification of agriculture over the past two centuries. It would be interesting to extend the analysis to the emerging economies where similar developments are now happening at a much faster speed, and where biodiversity is bound to suffer as a consequence. Most importantly, the understanding of ecosystem function gained from leisurely observing butterflies on a summer day could help to inform measures to save at least some remnants of our planet's rapidly dwindling biodiversity.

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