Timing is everything

Adjustments in the timing of seasonal events can seem like a relatively subtle impact of climate change, but one with potentially large ramifications for the health of ecosystems and the services they provide.

We scarcely need to mention that the 2018 boreal summer has been, historically speaking, exceptionally warm. Yet compared with recent years — nearly all among the warmest on record — it does not seem so unusual. Changes in both average climate conditions (presses) and climate variability and extreme weather (pulses) can have serious ecological repercussions, as outlined in a recent Perspective by Harris and colleagues¹. Such changes also affect agro-ecosystems, and a report from the Food and Agriculture Organization of the UN (FAO) finds that a recent increase in global hunger is driven in part by climate variability and extremes², a worrying trend indeed. One form of biological response that modulates climate impacts is phenology — changes in the timing of seasonal events. As this odd season draw to a close, it seems fitting to reflect on what we know about this aspect of living in a changing climate.

Phenological changes such as earlier spring leaf unfolding, altered migration timing and changes in flowering onset and duration represent a major mode of ecological response to climate change. These changes may seem small and sometimes even difficult to notice, but the cumulative and interacting effects on ecosystem health and functioning can be very significant indeed.

At a fundamental level, earlier spring green up and delayed onset of autumn dormancy lead to longer growing seasons and there are now many documented examples of this response, particularly in northern high-latitude ecosystems³. An extended growing season is important not only because of its direct impact on the ecosystems in question but also because of the potential for increased carbon uptake, which could reduce atmospheric CO₂ and so moderate the degree of warming to some extent — a negative climate feedback.

Phenological adjustments can also modulate climate feedbacks related to surface reflectance, surface roughness, and fluxes of water and energy⁴.

The extent to which climate trends will continue to rearrange ecological calendars depends on a suit of variables including photoperiod, soil characteristics, species migration, recruitment, establishment, competition and community dynamics. Several recent studies suggest that photoperiod may not be as large a constraint on these phenological changes^{5,6} as initially anticipated, but this also highlights the potential for increases in seasonal vulnerability, for example to spring frost⁷.

Animals are also susceptible to environmental changes altering the timing of their significant life events, not least because of their dependence on vegetation. Long-distance migrants, hibernating species and tight mutualistic associations seem especially vulnerable. Recent work has also identified body size as influencing the strength of phenological response⁸, suggesting that associations between species that differ markedly in body size, such as hosts and parasites and predators and prey, may be more susceptible to being desynchronized. The opening up of asynchronies between interacting species — phenological mismatches — are of particular concern, as they can alter the availability of resources and consequently species fitness. Some examples include plants and their herbivores, bird hatching and caterpillar prey abundance and plant–insect pollinator associations.

Highly managed agricultural systems are not immune to these phenological adjustments either, with wine grapes being famously sensitive⁹. Extreme heat has also been shown to affect staple crop yields by shortening growing seasons¹⁰.

Phenological changes are already altering the character of many ecosystems, although

there are examples of systems showing little sensitivity so far, such as seabird breeding¹¹. The diversity of response is a mixed blessing, however, as it increases the chance of phenological mismatch.

What starts out as a series of small, individual adjustments can quickly cascade into complex and significant changes that impact ecosystem structure, biodiversity and biogeochemistry. Phenological research has made great inroads into revealing the ways in which these changes alter ecosystems, but we have still hardly begun to plumb the depths needed to understand how these interacting effects will play out over the coming decades. What seems relatively clear is that, when combined with the host of other human effects on the landscape, phenological changes are likely to be a source of additional ecological stress. There is much work to do in determining the carbon cycle implications of phenological changes, as well as the conservation measures that will be most effective in buffering ecosystems from these changes. As with most climate impacts, the most effective defence is clearly to minimize the degree of climate change, but failing that we need to know much more to effectively manage this unfolding global experiment. □

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