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Changing Seasonality

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It is late November here in Scotland and it has been unseasonably warm. I keep forgetting and dress as if it is a winter like any other. In my down jacket, waiting at the bus stop, I find I'm ridiculously overdressed. But it's not only me who is confused. As a major newspaper pointed out just the day before (1), after an unprecedented heatwave this summer and above average temperatures every month so far this year (2), the UK is now experiencing a 'second spring', with many plants sending out new shoots or even flowering. In my own garden, the irises I put in last winter had flowered as expected in May. But sometime around October they started coming up again and their pots are now full of green shoots, although no flowers as yet. For many this can create a deep sense of unease, with the seasons seemingly out of synch. While we know local weather can always be unpredictable, the seasons by contrast can seem reliable, even a bit dull, appearing in culture and literature as "the tired formula of a repeating seasonal cycle, a there-and-back walk up and down the hill" (3, page 451). But as literary scholar Sarah Dimick has suggested (4), this once reliable seasonal form is becoming disordered as climate breakdown challenges the taken-for-granted round, changing not just weather patterns, but the seasonal indicators that we glean from the behaviour of the plants and animals around us.

In the case of my irises, once I started looking into it, I realised I needed to be careful about reading them as a new disorder of the seasons. In fact, this behaviour can be completely normal, even encouraged. Having a second flowering in a year is called reblooming, repeat flowering, or 'remontancy' (i.e., coming up again). And it is not that uncommon amongst certain flowers. Indeed, breeders of irises have sought to cultivate this trait deliberately (5). Around here, I've seen the arrival of snowdrops startle and concern people as being "too early". But as one close observer told me, when she checks her records, this too can be perfectly within their usual behaviour. Working out whether a behaviour is untimely, or within the expected seasonal range, is part of the job of phenologists, those people who study yearly lifecycle timing within ecosystems. Since the late 1990s their work has become widely influential, as, despite the traps laid by irises and snowdrops, climate change is indeed shifting when plants and animals move through their life stages. According to the UK government's Spring Index, for example, spring has advanced more than 8 days on average since the early 20th century (6). And, as we will see, this change in seasonal timing is having wide ranging

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effects across ecosystems. That is, while we look to many plants and animals for our sense of seasonality, the cues they themselves look to – whether this be light, temperature, water levels or wildfires – are proving just as unsettling and confusing for them.

One of the most dramatic concerns that phenologists have had about changes in seasonal timing has been about the potential rise in 'trophic mismatches'. These can occur when a creature becomes dangerously out of synch with its food source. One example was reported in 2014, where breeding puffin pairs on the island of Røst in Norway had dropped from 1.5 million to between 350,000 and 400,000 over the past 35 years (7). A contributing factor appears to be a mismatch between the timing of puffin breeding, and the spawning times of the herring that they feed on. The suggestion is that this mismatch arises because puffins and herrings appear to be telling the time in different ways, according to different cues. As Lief Nøttestad suggested in the report, puffins are guided by the changing length of daylight, responding particularly as the days lengthen in the spring. Because our rotation around the sun is (fairly) constant, this means that the puffins are also fairly regular in their nesting each year. The spawning time of herring, however, is guided by the temperature of the ocean, and this can occur from February to April with earlier spawning when the seas are warmer. Nøttestad explains,

> *When the herring spawns early in the spring, as we've observed in recent years, the larvae drift northwards before the puffin's nesting season has fully started. The result is a mismatch between the puffin and its food.* (quoted in (7))

Thus, while the relatively steady temperatures of the Holocene have supported sufficient overlaps of puffins and herring, climate change may prove these timing strategies no longer workable.

It can be easy to assume that being in synch is a good thing. However, other examples of shifting seasonal cues show what happens when species that were previously out of synch start occurring together. Recent observations of two Australian parrots, Little Lorikeets and Eastern Rosellas – both beautifully coloured birds that build their nests in tree hollows – have reported new conflicts between them over nesting sites. Birdwatchers have apparently not seen them in competition before, but in 2021 James Fitzsimons reports seeing these parrots squabbling over a nest site in Melbourne during May (southern autumn). The Lorikeets were thought to be unusually nesting at this time due to cues given by unseasonal eucalypt flowering (8, page 108). While this is a one-off example, and more research is needed, we can see how mixed-up seasonal cues can cascade across an ecosystem. In this case, shifts in temperatures and/or rainfall may have led to early flowering by the eucalypts (9), which in turn changed the timing of the Little Lorikeet, leading to new conflicts with the Rosella. Seasonal timing is indeed a community affair!

Other processes interfering with seasonal timing include our ways of managing landscapes, which can interfere with the ways that other beings tell what part of the year they are in. This may not be so apparent in the Northern Hemisphere, particularly in temperate regions, where it is difficult for land managers to directly change dominant seasonal cues, such as the length of day or the ambient temperature. However, in the Southern Hemisphere, as well as in tropical regions, a greater variety of cues are used, with more plants responding to rainfall and/or wildfires for germination. Over evolutionary time, these cues have proved to be better markers of conducive environments for young plants. However, these markers are also more likely to be transformed by extensive land management schemes, such as those used frequently in Australia.

A first example is the alteration to river flows. In the Murray-Darling Basin, dams, weirs, and reservoirs are some of the tools used to maintain high water flows in summer for agricultural purposes (10). Research by Lyndsey Vivian and her colleagues (11) has shown that this practice is particularly problematic for native riverside grass species. These grasses experience the high water levels as 'unseasonal', having evolved with low levels in summer. In addition, unseasonal summer flooding increases methane emissions (a significant greenhouse gas) from wetlands when they are used as reservoirs. Researchers have urged land managers to be more aware of the consequences of disrupting wetland and forest landscapes along the Murray-Darling (12), partly because this also disrupts what we might call their 'timescapes'. So while the case of the herrings and the puffins showed us how mismatches can occur between individual species, here the conflicts in timing involve whole ecosystems. Land managers must find ways of negotiating between the forested wetland temporalities, which have evolved over millennia, and temporalities of downstream agricultural landscapes, which often rely on introduced species such as rice and cotton that tell time in quite different ways.

A second example are fire tolerant plants, or pyrophytes, which use wildfires as a key indicator for when to germinate. In Australia, a range of plants may sprout following the end-of-dry-season wildfires, leaving new seedlings to benefit from the cleared landscape, the ash fertiliser, and the coming wet season. However, climate change is causing more intense wildfires, as well as unseasonal fires in what has generally been the 'wet season'. New seedlings emerging at the start of a prolonged dry period are finding it tougher to hold on until the right conditions for their growth return (13). In terms of land management, seemingly unsolvable conflicts in timing arise once again. This is because the rise of controlled burning regimes, as part of reducing the levels of dry vegetation that fuel large fires, are becoming much riskier during the traditional end-of-dry-season period. Hotter and drier summers are reducing opportunities to initiate safe burns, particularly since autumn rains are also decreasing (13, 14). Thus, while ecologists are encouraging land managers to implement burns at times that are seasonally appropriate for native vegetation, climate change is putting the times of plants, wildfires and safe landscapes significantly out of joint.

Finally, one of the more surprising examples of how climate change is affecting seasonal cues are the mismatches occurring *within* individual species. Scientists are finding cases where the timing of male and female flowers might themselves be following different cues and so diverging from one another. Dioecious plants, for example, have male and female flowers on separate plants. To produce viable seed, not only must male and female plants be in the same area, but their flowering times must also overlap (14). Changes in these plants, due to climate heating, is seen as putting them at particular risk of what is called 'phenological isolation'. In 2020, cases in India were found where male Eastern cottonwood (*Populus deltoides*), a key industrial forestry variety, flowered unseasonally in the northern autumn, making them wildly out of synch with the female flowering trees that produced catkins in the spring. The suggestion is that male plants might respond differently to cues of higher temperature or dryer conditions isolating them in time from their female counterparts. Elsewhere, studies have suggested that timing of a plant's own flower and leaf development might be getting out of synch, or even that 'below-ground growing seasons' – or the timing of root growth – might not be lining up with the parts of the plant growing aboveground.

Far from being a dull *fait accompli* then, our knowledge and experience of the seasons derives, not just from the weather, but from the cues that we receive from the plants and animals around us. Their complex methods for working out when to initiate various life stages do not rely on fixed internal rules, but adapt and respond to their changing environments. This is why the usual seasonal variations that inevitably occur can be taken in most creatures' stride. The worry is that with climate change and large-scale landscape change, both caused by human activity, cues that once worked reliably enough now risk leading more-than-human communities wildly astray. However, there is also the view that timing things right has often arisen from taking a chance and seeing what happens. As horticulturist Alys Fowler commented, when reflecting on the UK's 'second spring,' "Many plants are opportunists – if the temperature is right and the day length OK . . . they will have a go. I guess there is some evolutionary advantage to that" (quoted in (1)). Perhaps my irises, then, with their willingness to have a second shot, could represent something very powerful. Not that everything is going wrong, but instead reminding us that seasonal time is part of a continual experiment, a time that can never really be taken for granted.

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