Worrying about weird winters

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Winter is a key determinant of biological processes in temperate, alpine, and polar environments. Winters are changing, yet we currently lack the knowledge to adequately predict the impacts of climate change on winter biology, or to link winter conditions to the growing-season performance of most organisms.

The news media loves weather stories. During the unusually warm North American winter of 2011/12 and the unusually cold winter of 2013/2014, I regularly fielded phone calls from journalists wanting a quick sound bite about the impacts of this weird winter on plants and animals. The sound bite was hard to provide, precisely because we don’t know. At the same time, as a winter-focused biologist working on climate change (the latter usually evokes notions of high temperature stress), I have regularly found myself beginning papers with sentences such as “Winter is important [insert reference here].” Unfortunately, although there are many taxon- or ecosystem-focused studies about winter, a reference that addresses the overall importance of winter just didn’t exist. I invited my colleagues Caroline Williams and Hugh Henry to the table, and we set to work. First, we wanted to get to grips with how important winter really is in ecology; and second, to understand how winter climate change will affect organisms and ecosystems.

Winter is important.1 Winter mortality can drive phenology, population processes, disease prevalence, nutrient cycling and even life history evolution. For example, winter conditions are probably the selective force behind the long migrations of birds and other temperate animals. Although low temperatures are an integral part of winter’s direct influence, winter also drives energy use by endotherms (which must maintain their body temperatures in the cold), and ectotherms (which may rely on winter cold to conserve energy). Similarly, frozen water is both physically disruptive (water expands when it freezes, and can encase plants and animals) and biologically unavailable, leading to dehydration stress during winter. The abiotic conditions that organisms experience in the winter are determined by a complex interaction between air temperatures and the variability about those temperatures, as well as by the buffering effect of snow cover. Together, these abiotic conditions drive biological processes, with consequences for life history, survival and fitness.

Winter is changing.1 It is intuitive to think about climate change in terms of increased temperatures. However, because winter conditions are also driven by variability and the timing and extent of snow cover, there are a range of possible consequences of winter climate change (Fig. 1). For example, warmer winters may lead to increased survival of pest insects – but if those insects are dependent on protection by snow cover, then a decrease in precipitation or increased snow melt may actually expose them to more extreme low temperatures. Similarly, although warmer winters may reduce cold damage to exposed buds on trees, many species require cold to break dormancy (a process called vernalisation), and insufficient chilling overwinter may lead to delayed development in the spring.2 Unfortunately, these specificities of winter climate change are not well-captured in current climate models. This proved unsatisfying for the journalists I spoke to, because an answer of “well, it could go either way” is enticing in reference to a football match, but fails to provide the certainty society demands of scientists.

How can we get closer to providing this certainty, and predicting the impact of changing winters? Following from a previous, summer-focused, framework,3 we first identified the main links between abiotic drivers, biological processes, and their impacts, and used this to pinpoint the stresses associated with winter climate change. We then identified organisinal traits that led to exposure to the stress (e.g., not feeding during the winter), and the traits that made organisms sensitive to the stress (such as having a limited ability to replenish energy stores at the end of winter). This provides a winter-based framework for identifying – a priori, given enough natural history information – the vulnerability of a given species. For example, wolverines (Gulo gulo) require deep snow to build their dens for winter breeding, and reduced snow cover reduces breeding success.4 Thus, wolverines are exposed to winter climate change because of reductions in the snow cover they require, and sensitive to it because they breed only during the winter. However, for most species, the information required to determine vulnerability simply is not available, and we found specific biases in the existing literature; for example, there have been many studies on the winter population biology of arctic mammals, but few on temperate insects, whereas the impacts of freezing are well-understood in crop plants and temperate insects, but poorly-explored in other terrestrial ectotherms. Finally, few studies actually link processes between seasons: there exists a
disjunction between the ecosystems and species that biologists use to explore summer growth and performance, and the favored species for those studying overwintering. We call for extending each of these isolated groups of studies across seasons to better understand how climate change in the different seasons interacts to drive biological processes.

Is there a role for physiologists in understanding winter climate change? The role of physiology in understanding climate impacts—and even predicting them (the Oxygen and Capacity Limitation Theory of Thermal Tolerance has been particularly successful for aquatic animals⁵) is well-established with respect to changes in extreme high temperatures.⁶ However, as we have shown, climate change is not just about heat waves. The stressors associated with winter are highly physiological, which means that physiologists are ideally suited to help answer them. In particular, we see key roles for physiologists in developing finer predictions of energy use, responses to variability, and phenological responses to winter-relevant temperatures. The identification and exploration of threshold responses to temperature (and shifts in temperature) could allow the identification of state changes and tipping points. Finally, when we understand these processes in our ‘models’ (in the Krogh sense), physiologists are also in a position to pass off accessible tools for determining physiological vulnerability to winter to ecologists. Ultimately, this will allow identification of vulnerability and sensitivity of individual species via physiologically-robust measures that can be incorporated into ecological studies of the biological impacts of climate change.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

References

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