The impact of fire on karst: experimental fires on two contrasting caves in New South Wales

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Abstract

Bushfires are a natural part of the Australian landscape and are essential for the propagation and survival of some flora and fauna. Fires can dramatically change the surface environment by modifying hydrology, removing vegetation, and altering soil structure and geochemistry. Karst processes such as limestone dissolution and speleothem formation are sensitive to environmental changes. Despite this, there has been limited research into the impact of fire on the belowground karst environment. We conducted experimental fires over two contrasting cave sites in New South Wales and monitored the impact on cave drip water. The post-fire drip water response varied between the two caves and we hypothesise this was due to differences in cave depth and the temperature of the fire. This research can be used to inform fire management policies on karst environments.

Introduction

Bushfires were an unfamiliar phenomenon to me when I first arrived in Australia, having lived for most of my life in south west England. However, over the last six years I have learnt that while having the potential to be natural disasters and causing death and destruction, bushfires are also essential for the landscape to thrive and for the propagation of certain flora species.

Despite bushfires being an important geomorphological agent that shapes the landscape, there has been little research published on the impact of fire on karst environments and the speleothems and caves below ground. This research area is important from a management perspective as it raises the question: should we burn on karst? It is also interesting from a scientific perspective as speleothems are well-established paleoclimate proxy climate records and could also be potential paleofire records.

Our research team wanted to address this knowledge gap by conducting experiments in two caves in NSW. We monitored the cave drip water geochemistry and hydrology for a year to establish the baseline cave conditions. A controlled fire on the surface above the cave was ignited, and then we continued the monitoring for a further eight months post-fire (Coleborn et al., 2018).

So, what did this monitoring look like? We visited the caves on a bi-monthly basis, left bottles out overnight to collect drip water at various points in the cave and then analysed the drip water for a range of characteristics including stable water isotopes, trace metals and major anions and cations. We also monitored the drip hydrology using Stalagmate™ drip loggers. Stalagmates are small sealed boxes that contain a battery, memory and a pressure sensor (for more about this piece of equipment see Baker et al., 2010). As a drip falls from the cave roof onto the surface of the Stalagmate, the pressure sensor is activated and records the drip. Using these loggers over a long period of time enables us to see how the cave responds to recharge and how water travels through the ground before it reaches the cave.

We worked in two caves in New South Wales: South Glory Cave and Wildman's Cave. South Glory cave is located at Yarrangobilly Caves in the Kosciuszko National Park and is covered by vegetation sub-alpine open snow gum. Wildman's Cave is located at the Wombeyan Karst Conservation Reserve with open woodland and shrubby understorey vegetation. Both caves are situated in Silurian limestone however, South Glory is much deeper (~40m bgl) and longer (~242m) than Wildman's cave which is 6m bgl and ~42m long. We also ignited a third fire on karst at Borenore Karst Conservation Reserve which did not include caves.

A hazard reduction fire was ignited above South Glory Cave in April 2015. The main fire lasted around two hours with some hotspots burning up to 48 hours after ignition. The fire was quite patchy; in some areas there was flaming combustion of the understorey, whereas more open, grassy areas were left relatively unburnt. In contrast, the 'experimental' fire at Wildman's Cave covered a smaller area (~10 x ~10m) but was more intense with soil surface temperatures recorded up to 700°C and there was some evidence of calcining of limestone outcropping.

Controlled fire ignited on 24th April 2015 above South Glory Cave, Yarrangobilly Caves.

Experimental fire in May 2016 above Wildman's Cave, Wombeyan Karst Conservation Reserve. Photo credit: Andy Baker

The results showed a contrasting response to fire between the two caves. At South Glory Cave, we saw a significant increase in some metal concentrations (B, Fe, Si, Na and Pb) ~3 months after the fire. The concentration of boron increased by three orders of magnitude. We attributed this response to the influx of ash from the surface into the cave drip water below. We also saw a change in the isotopic signature of the water at six sites, which we concluded was due to the partial evaporation of soil water.

At Wildman's Cave the concentration of bedrock derived elements (calcium, magnesium and strontium) decreased rapidly after the fire. We hypothesise this was due to decreased limestone dissolution time and potentially decreased soil CO_2 from sterilisation of the soil by extreme heat from the fire. The stable water isotopic signature of drip water after the fire resembled the incoming rainfall. We concluded that this was due to the complete removal of the soil water by evaporation and the direct routing of rainfall through increased preferential flow paths to the cave drip sites. This was supported by the change in the drip discharge pattern; the cave responded more quickly and was more responsive to smaller rainfall events.

Conclusion

In summary, the cave experiments were contrasting in terms of cave depth and fire intensity and had different responses. South Glory Cave is relatively deep and had a low intensity fire whereas Wildman's Cave is relatively shallow and had a much more intense fire. The stable water isotopic signature after the fire indicated partial evaporation of soil water at South Glory whereas at Wildman's suggested complete removal of the soil water store by the fire. There was an ash derived signal in the drip water at South Glory whereas at Wildman's there was a hydrological response. The hydrological response was not visible at South Glory due to mixing and greater depth and there was no ash elemental response at Wildman's most probably due to high temperatures and volatilisation of elements.

This research had implications for karst management in New South Wales as it showed the effect of prescribed fires on the cave environment are typically less than that of wildfire. The formation of surface ash provides a previously unrecognised source of soluble nutrients to the karst that may be transported to the cave. And finally, a policy of fire exclusion for the management of karst areas will result in the degradation of their associated terrestrial ecosystems.

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