ACKMA Cave Climate Project – An Update

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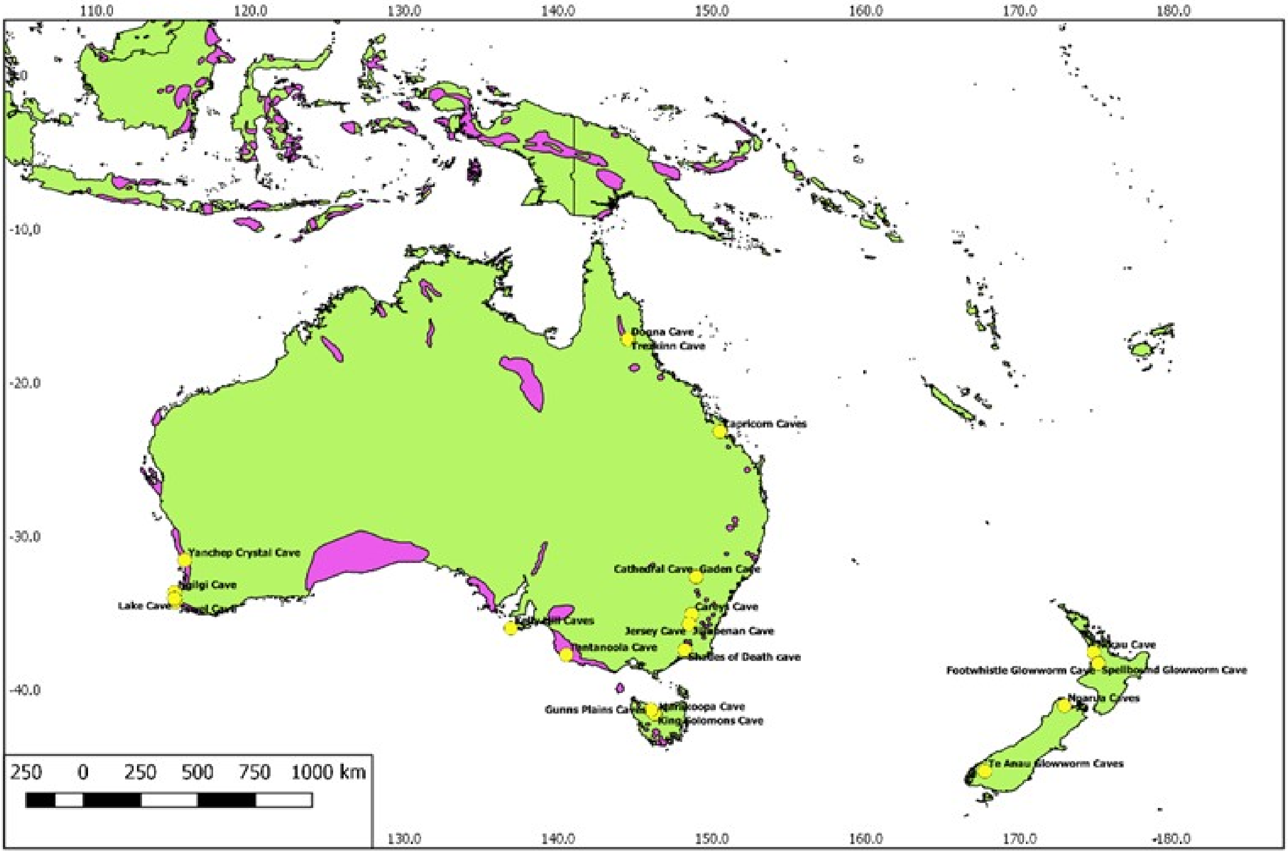
Introduction

Since our last article on this project, published in the ACKMA Journal 119 in June, there has been significant progress with a large number of show cave sites set up and recording data. Most individual sites have been downloading data every month and sending them through to Andy Baker, who has produced graphs and some preliminary interpretations. A number of sites have successfully recorded cave climate data with no visitors, which provides a very useful baseline from which to understand the natural fluctuations in temperature and humidity. Several sites have now re-opened to visitors under COVID-19 restrictions, so we are starting to see evidence of the minor fluctuations due to people being in the cave.



Distribution of participating show cave sites in Australia and New Zealand. The Cango Caves site in South Africa has also been supplying data from existing monitoring but has not yet received data loggers due to air freight restrictions.

Currently involved in the project are:

Australian sites

New South Wales: Careys Cave, Wee Jasper, Wellington, Yarrangobilly

Queensland: Capricorn Caverns, Chillagoe

South Australia: Kelly Hill, Tantanoola

Tasmania: Gunns Plains, Mole Creek

Victoria: Buchan, Shades of Death Cave

Western Australia: Calgardup Cave, Jewel Cave, Ngilgi and Lake Caves, Margaret River, Yanchep

New Zealand sites

Footwhistle, NgaRua, Nikau, Spellbound and Te Anau caves.

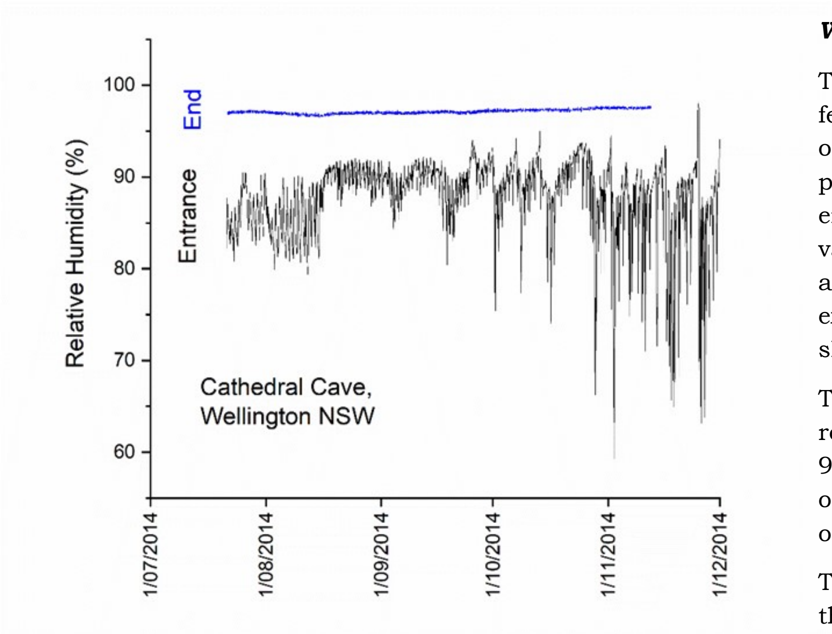
South African site

Cango Caves.

Caves and cave relative humidity

First, some science. The humidity in a cave primarily depends on the water vapour content of the air, and the cave air temperature. The same amount of water vapour in cool air will have higher humidity than in warm air.

Data loggers provided in the ACKMA baseline cave climate monitoring initiative record temperature and relative humidity, and also calculate the dew point. We previously wrote about how cave air temperatures might vary through the year. What do we expect to see for relative humidity in caves? Something like the following examples.

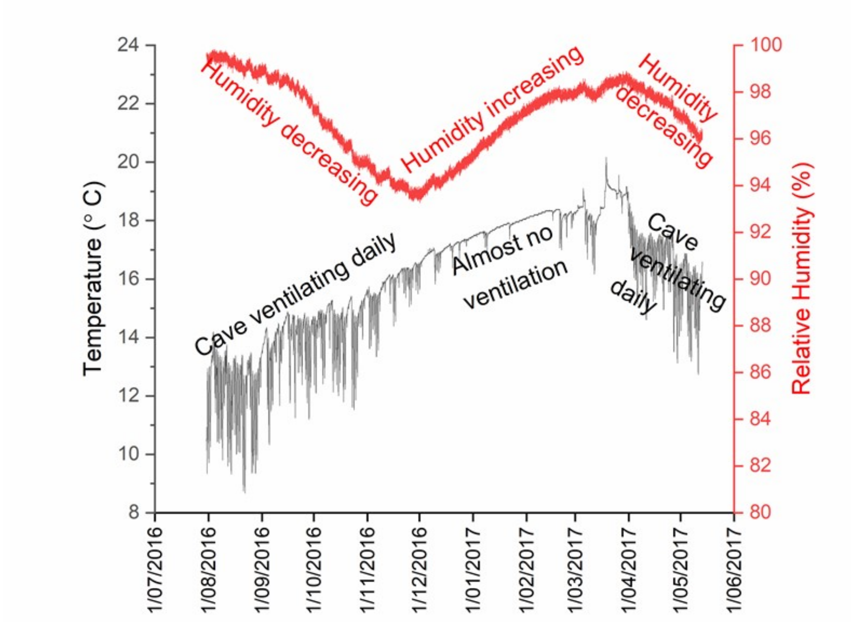


Wellington, NSW

The data, from Cathedral Cave, shows the differences between the cave entrance and the end of the cave. It is some old data from a research project. The relative humidity near the tourist entrance is the black line. The relative humidity varies between 60 and 95%. Warm and buoyant air leaves the cave every night, drawing in external air with lower relative humidity, as shown by the daily wiggles in the black line.

The blue line is at the end of the cave. Here, relative humidity is constant and high - over 95%. There is groundwater present at the end of the cave, providing a near continuous source of water vapour.

The high and constant relative humidity tells us that this part of the cave does not ventilate very much and condensation on the walls is likely.



Daylight Cave, Sebastopol, NSW

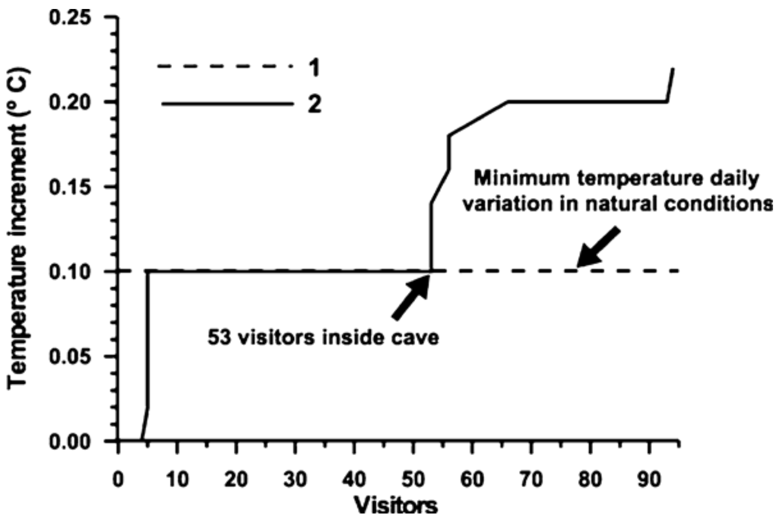
The second example is from the Kempsey Speleological Society Cave Studies Team. It is an example of how cave temperature and humidity are related. In this cave, you can see from the temperature data (black line) that the cave ventilates in winter (lots of daily wiggles as relatively warm and buoyant air leaves the cave at night), but not in summer. In winter and spring, the daily ventilation of air leaving the cave must be replaced by air drawn in from the outside and this external air has a lower relative humidity than the cave air. The relative humidity slowly decreases. Once that ventilation stops, the humidity increases slowly through summer. And in autumn, with daily air exchange occurring again, the humidity starts to decrease.

What can relative humidity data tell us?

- It can explain when and where condensation might occur on the cave walls and surfaces.
- It can explain when and where mists might form in the cave atmosphere.
- A constant relative humidity and temperature can suggest limited ventilation and could help identify parts of a cave that might also experience high concentrations of gases such as carbon dioxide.
- Unexpected variations in relative humidity could indicate the presence of an unknown entrance, or how air is moving between entrances.
- Unexpectedly high relative humidity can indicate the presence of a nearby water body.

- Caves with streams or dripping water and which also have a low relative humidity can behave like natural evaporative coolers, with the cave water cooling as it evaporates.
- The main effect of any reduction in humidity is drying and flaking of flowstone surfaces. So, any major and protracted change in humidity can have very harmful effects. This has been seen in caves on several continents where cave ventilation has been altered, for example by opening new entrances or changing door opening protocols.

As we saw in the previous article in this series, large numbers of visitors in a cave can significantly raise the air temperature. A single person releases heat energy at 80–120 Watts, about the same as a single incandescent light bulb. Thus a party of 50 or 60 people on a cave tour can locally raise temperatures by 1–2°C. The passage of tourists through Altamira Cave, Spain, raised air temperature by 2°C, CO_2 concentration from 400 to 1200 ppm and decreased relative humidity from 90% to 75% (De Freitas and Littlejohn 1987). This degree of change in humidity, if allowed to persist, would lead to deterioration of speleothem surfaces. According to Cigna (1993), management needs to ensure that these fluctuations lie within the range of natural variation for the cave, and that they return to normal levels within a short period of time. Calaforra et al. (2003) provide a good example of determining visitor thresholds in such cases.



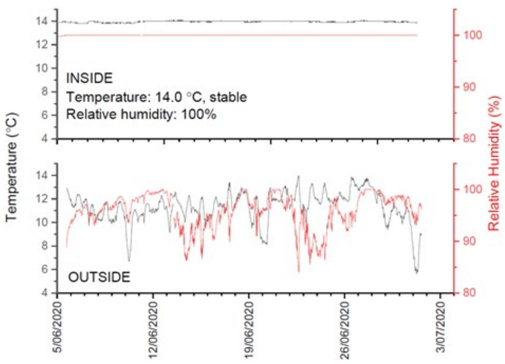
Number of visitors producing an increase in temperature of more than 0.1°C in the Cueva del Agua de Iznalloz, Spain (Calaforra et al. 2003). Key: 1 maximum mean daily variation of temperature under natural conditions; 2 mean variation caused by visitors

Finally, something on how hard it is to make precise and accurate relative humidity measurements. Almost all measurement methods, including loggers, fail to work well in the very high humidity of many cave environments. Once condensation has occurred on the logger, they will just continuously read 100% relative humidity. Putting the loggers in a dry part of the cave will help, but if the humidity is high, it will not be enough to defeat condensation.

The loggers provided in the ACKMA baseline cave climate monitoring initiative have a specified accuracy of ±3.5% for humidity between 60-80% and ±5.0% for humidity over 80%. Our calibration of all the loggers suggested they are precise to ±0.5%. That is, repeated measures are very close to each other, while calibration against more expensive instruments has shown them to be quite accurate. We expect them to provide useful data for relatively dry caves found on the Australian mainland, but they will probably struggle to overcome condensation in wetter caves found elsewhere.

How do you reliably record relative humidity in caves? You need a weather station grade device, such as the Vaisala HMP155, which is used in the examples given here. It has a probe heater option which removes condensation. The probe, datalogger and battery could cost several thousand dollars.

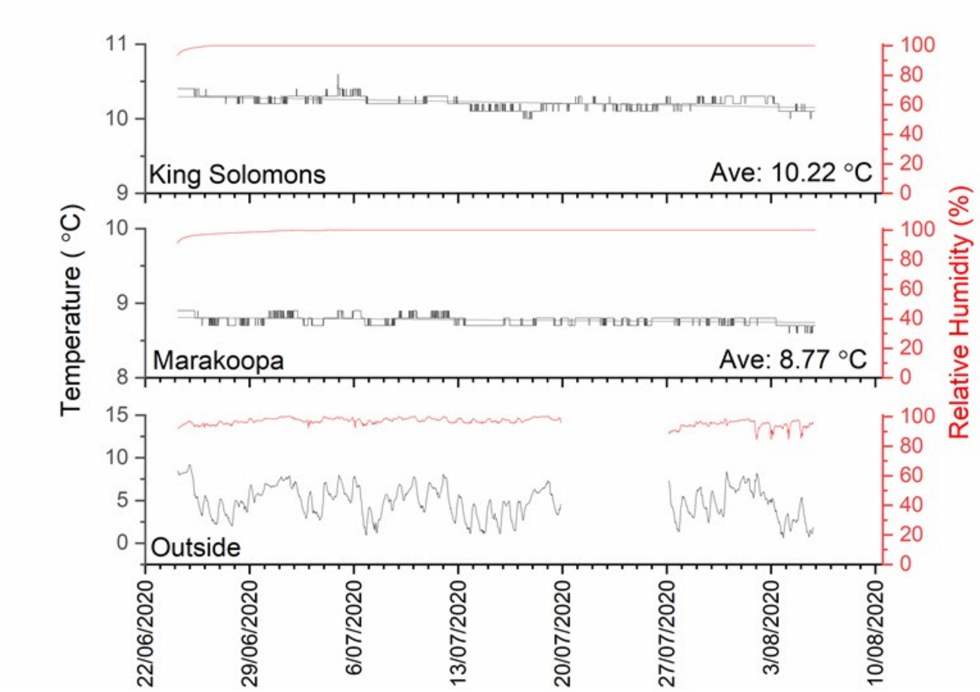
Some preliminary results



Nikau Cave, New Zealand

This is a very stable cave climate regime, with minimal daily fluctuations and no discernible trend over the period of observation. In contrast, the outside datalogger shows substantial daily fluctuations and drops in temperature with some severe low pressure cells coming through from the Tasman.

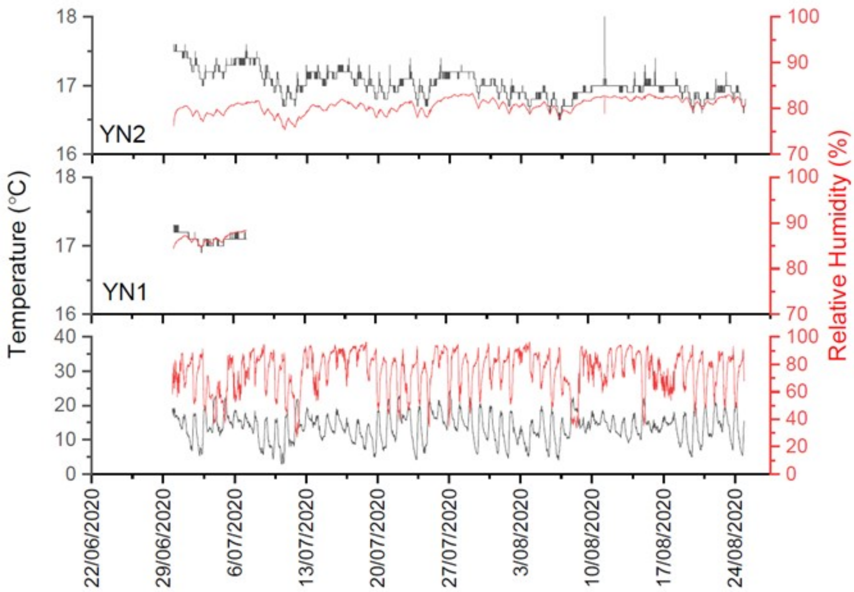
Mole Creek, Tasmania



This dataset shows the cooling effects of the cave stream on temperature in Marakoopa and effects of entrance size. King Solomons is starting to show a decline in temperature at the start of winter in this poorly ventilated cave. This shows the importance of cooling at the surface and conduction of this cooling through the bedrock. This results in the winter minimum cave temperature would be expected to be later than the external air temperature. Another month or two of data from all the participating caves will help show this effect.

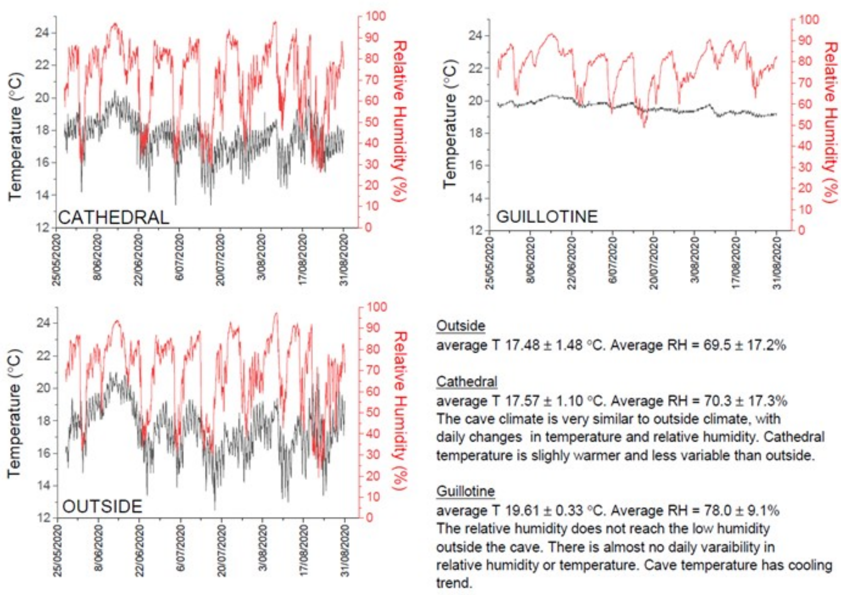
Relative humidity is constantly high in both caves. The outside datalogger shows daily fluctuations, most marked in temperature, and passage of some winter cold fronts.

Yanchep, Western Australia

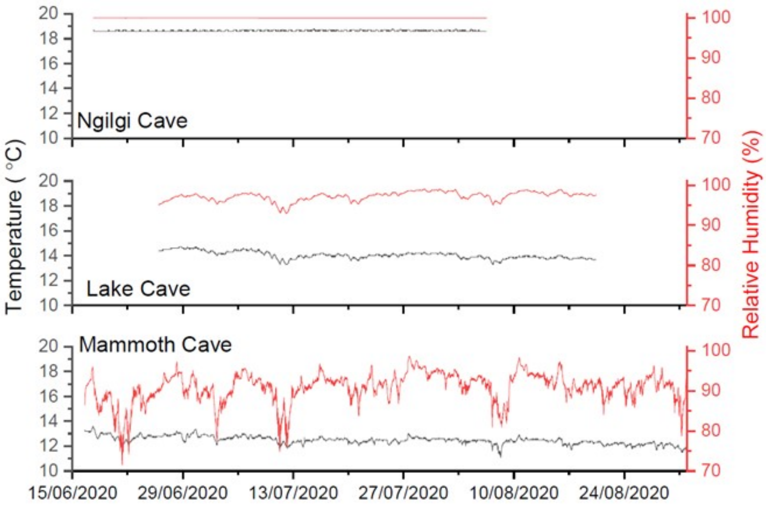


Data from YN2 (Yonderup Cave) shows that this cave has some diurnal fluctuations in both temperature and humidity. The spikes in temperature maybe an effect of visitors entering the cave. The winter cooling trend is also visible at this cave. The outside datalogger shows significant daily variation and the passage of cold fronts due to Southern Annular Mode fluctuations.

Capricorn Caverns, Queensland



These datasets show the effects of cave geometry and multiple entrances. The outside datalogger shows typical winter subtropical weather with cool, drier westerlies blowing from stationary high pressure cells. This is reflected in the Cathedral chamber logger with numerous daylight holes, giving a highly correlated record of temperature and humidity. In contrast, the Guillotine chamber is past a constriction which limits air flow, resulting in reduced temperature fluctuations over the same period. The winter cooling trend is apparent in this chamber. However, humidity shows greater fluctuations which may be due to cooler drier air coming in from another entrance.



Margaret River, WA

In south-west Western Australia, we have several caves participating. Of these three caves, Ngilgi is very poorly ventilated so stability in both temperature and humidity is to be expected. Lake Cave is possibly influenced by air flow from fissures in the large collapse doline, although the actual cave entrance is quite small and would restrict airflow. Mammoth is a multi-entrance cave so variable humidity is to be expected. Again, these caves show the decline in temperature to the cave climate winter minimum temperature, due in the next month or two. Also of interest is the very different average cave temperature for three caves within a few tens of km from each other.

Further reading:

Delving deep into caves can teach us about climate past and present by Gabriel Rau and colleagues: https://theconversation.com/delving-deep-into-caves-can-teach-us-about-climate-past-and-present-50122

Calaforra JM, Fernandez-Cortez A, Sanchez-Martos F et al (2003) Environmental control for determining human impact and permanent visitor capacity in a potential show cave before tourist use. *Environmental Conservation* 30:160–167. Copy available from the authors at:

https://www.researchgate.net/publication/231875886_Environmental_control_for_determining_human_impact_and_permanent_visitor_capacity_in_a_potential_show_cave_before_tourist_use

Cigna AA (1993) Environmental management of tourist caves. *Environmental Geology* 21:173–180. Copy available from the authors at:

https://www.researchgate.net/publication/227018875_Environmental_management_of_tourist_caves

De Freitas CR, Littlejohn RN (1987) Cave climate: assessment of heat and moisture exchange. *Journal of Climatology* 7:553–69

Rau, G., Cuthbert, M.O., Andersen, M.S. et al. (2015) Controls on cave drip water temperature and implications for speleothem-based paleoclimate reconstructions. *Quaternary Science Reviews*, 127, 19-36. Copy available from the authors at www.bakerlabgroup.org

Credit: Part of this text is based on that previously published by Andy Baker as 'Caves and climate' in the 60th Anniversary Edition of the Kempsey Speleological Society TROG Vol 54 No. 5 (Nov 2018).

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