Carbon Dioxide in Waitomo Glowworm Cave

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Waitomo Glowworm Cave (WGC) is unique in that it is visited by hundreds of thousands of people each year who visit to see cave wildlife - the glowworms. It is an iconic New Zealand tourist attraction, with many international visitors. "Discover Waitomo" also operates a walking tour and black-water rafting tours through Ruakuri Cave, where visitors also experience the beautiful cave formations and the glowworms. Aranui Cave offers visitors the chance to see some beautiful cave formations and a number of cave weta. The numbers of visitors began to reduce in March 2020 in response to the COVID-19 pandemic and the New Zealand Government announced a nationwide lockdown to begin on 26 March 2020. Discover Waitomo closed all sites and caves for visitation on the evening of 23 March. A small team of fewer than 20 employees continued to work remotely over the lockdown period.

The absence of visitors provided the unanticipated opportunity to study the cave environment when there are no visitors. It is probably more than 100 years since WGC has had such a long period without visitors. The environmental impacts of visitation are a significant component of cave management. Concerns go back to the 1970s, when Les Kermode of the Department of Scientific and Industrial Research pointed out that carbon dioxide (CO^2) exhaled by visitors was potentially leading to speleothem corrosion in WGC (Kermode 1977). Since that time, the cave environment has been monitored, using increasingly sophisticated equipment, much of it under the guidance of Dr Chris de Freitas who led the scientific studies of cave microclimate. From this early start, microclimate data is now available on line and photographic glowworm monitoring allows remote assessment of the glowworm population. The Environmental Advisory Group meets twice a year to examine microclimate and management of the caves. The caves' environmental manager has responsibility for implementing the cave management plan. Currently, sensors detect airflow near the upper entrance, air temperature and humidity both inside and outside the cave, and river level and water temperature in the grotto. Carbon dioxide is monitored at two locations. The data is displayed in real-time in the cave manager's office and each day the likelihood of high levels of CO^2 is assessed, based on anticipated visitor numbers and the temperature profile through the day.

The temperature differential between outside and inside the cave plays an important role in clearing CO^2 because WGC is a chimney-effect cave with air flowing either upward or downward, depending on the differential. On days when the external temperature crosses the cave's internal temperature (around 15°C), the airflow in the cave transitions between up- and down-flow with a stagnant period during the transitions. On days when the external temperature is close to the cave temperature, low airflow can lead to CO^2 build-up. In extreme cases, cave visits can be limited to prevent CO^2 reaching a specified action threshold of 2400 ppm. For context, levels from 250-400 ppm are normal outdoor levels, 400-1000 ppm are typical of indoor settings, and 2000-5000 ppm can start to affect people by producing drowsiness or a sense of stale air.

Another tool available to the cave manager is the status of the upper entrance door. When this automated door is open, air readily flows according to the temperature differential. However, the door is not kept open all of the time because the glowworms in the grotto can be dehydrated by dry air entering the cave. Consequently, cave environmental management aims to strike a balance between allowing airflow to flush visitor-produced CO^2 and limiting airflow to prevent dehydration of the glowworms.

The normal daily operation is to open the door during the day when visitors are in the cave. After tours are finished and the staff have gone home, the door stays open allowing ongoing flushing until the CO^2 in the cathedral chamber reaches 800 ppm. At that point the door automatically closes until the next day when the cycle repeats. The level of 800 ppm, as the threshold for closure of the door, was chosen because CO^2 continues to drop through the night to reach about 600 ppm next morning. The absence of visitors gave us the unprecedented opportunity to observe CO^2 levels with no people adding their exhalations.

As expected, the height of daily peak in CO^2 that usually occurred in mid-afternoon dropped dramatically as visitor numbers dropped through March (Figure 1 on next page).

Once visits stopped entirely on 24 March, the daily range was low. For the next 17 days, a daily pattern was seen in CO^2 levels because the door was opening and closing under the automated procedure, despite there being no visitors. The pattern suggested that the cave is producing above-ambient CO^2 levels even in the absence of visitors and automatic door opening was introducing fresh air at ambient CO^2 levels of around 400 ppm.

On 9 April, the door code was remotely changed to leave the door closed to minimise airflow for the glowworms and to allow us to assess the CO^2 levels. Since then, CO^2 stabilised at around 500-600 ppm.

Interestingly, floods - as measured by water level near the pier in the grotto (Figure 1) - produce a CO^2 spike in the cathedral and other chambers. Note that the CO^2 levels begin to increase before the water level increases, probably due to drip-water from the associated rainfall releasing CO^2 into the cave.

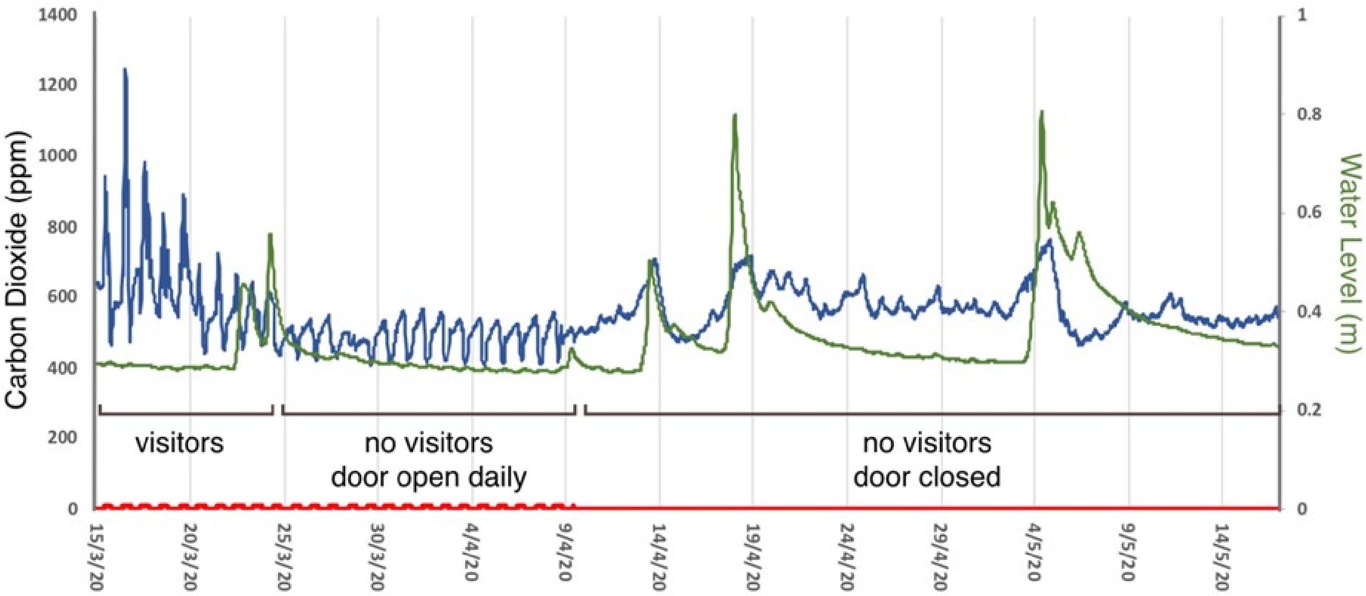

Figure 1. Carbon dioxide levels in Waitomo Glowworm Cave (blue) and water level in the grotto (green).

Periods when the door is open are shown as above baseline (red).

These observations confirm a scientific study (MSc) done by Natalie Miedema at University of Waikato under Dr Chris Hendy's supervision. Natalie analysed monitoring data and determined that floodwaters release CO2 into the cave - probably due to their bringing in water that has flowed through humus and soil and dissolved the CO^2 contained therein. While the contribution of floodwater and drip-water to CO^2 levels is small when compared to that of humans, we are now able to separate the contributions of natural and exhaled sources to the overall cave CO^2 levels.

Kermode, LO (1977), Some aspects of the influence of tourists on the microclimate of Waitomo Cave, Research Report New Zealand Geological Survey. Department of Scientific and Industrial Research.

Miedema, NM (2009), Non-anthropogenic sources of carbon dioxide in the Glowworm Cave, Waitomo, MSc thesis, Earth and Ocean Sciences and Chemistry, The University of Waikato.