Recreational impacts on the microclimate of the limestone caves and management in Shoushan National Nature Park of Taiwan

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This study reports a continuous microclimate monitoring carried out in Gorilla Cave、Beifeng Cave、Jingua Cave and Tienyu Cave (Kaohsiung, Taiwan) between June 2018 and August 2019. These limestone caves are located in the Mt. Shoushan, which is mainly composed of limestone and mudstone. This study tried to assess the recreational impacts to the microclimate of the caves by monitoring the CO₂, temperature, humidity and barometric pressure, and provide effective management strategies. A monitoring station was set up at the middle of each cave. We also set up an auto-operated time-lapse camera at the entrance of the caves to record the numbers of tourists and their entering time and the durations in caves. As carbon dioxide in the limestone caves may have negative impact to both speleothems and visitors, our presentation focuses on the variations of CO₂ concentration in the caves.

Daily and seasonal fluctuations of CO₂ concentration were observed. Monitoring data show that the concentration of carbon dioxide in the caves also changes significantly with the wet and dry seasons. The monthly average of the carbon dioxide concentration in the cave has a good correlation with rainfall and temperature, which means that the higher the temperature and humidity, the higher the carbon dioxide concentration in the cave. Besides, the difference between the day-night temperature change outside the cave and the temperature inside the caves also seems to affect whether the carbon dioxide inside the cave is easily dissipated or not. Especially when the temperature outside the cave at night is lower than the temperature inside the cave, the carbon dioxide concentration inside the cave often drops to the environmental background value (around 420 ppm). Therefore, the difference in air density caused by high and low temperature may be an important mechanism driving the gas exchange inside and outside the cave.

Based on the monitoring results, we suggest that (1) The cave is open during the dry seasons from November to April. Although monitoring data indicate that the caves have gradually dried up in October, cave exploration activities have also become active. However, the period from wet to dry in the cave is theoretically the stage of cave rock development. Considering the continuous dripping in the cave at this time, in order to avoid disturbing the development of speleothems, it is recommended to close the caves until most of the caves are dry in November. (2) The caves are open daily from 8 am to 12 am, from 1 pm to 5 pm, with a break of an hour at noon. (3) There are
one batch per hour and 8 batches per day to allow visitors enter the caves, and the stay time is limited to 1 hour. (4) The monitoring results also help us reasonably estimate the number of visitors in each batch, that is, Gorilla Cave is about 15 people, Tienyu Cave is 20 to 30 people, Beifeng Cave is about 20 people and Jingua Cave is 10 to 15 people.