

**Cultivating a Climate of Cave Conservation Awareness:
A synthesis of current speleothem sampling methods and best practice recommendations**

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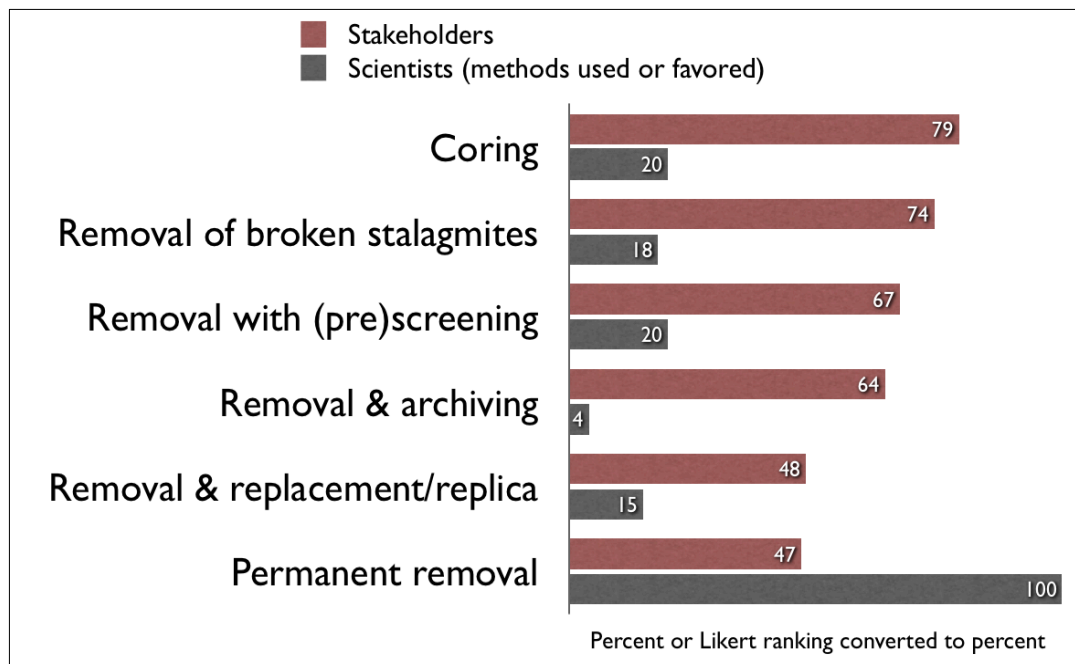
Summary

Speleothems, or cave formations such as stalagmites, are very useful archives of past climate change. They form over hundreds of thousands of years and can be dated absolutely using uranium incorporated into the speleothem structure. Rainfall has a particular oxygen isotope composition that is conserved as that rainfall drips through the soil and rock above the cave, enters the cave, and deposits calcium carbonate in the form of a speleothem. Sampling of the isotope chemistry must be along the growth axis, generally requiring removal from the cave. Speleothems are slow-growing, non-renewable resources on human timescales. Many different stakeholders value caves for reasons such as biologic, ecologic, mineral and hydrological resources, tourism, recreation, education, science, exploration, and existence reasons (Truebe et al. 2011). Development of sustainable sampling methods, balancing conservation and science, ought to be a priority of the paleoclimate community. Thus, the objectives of this study were to:

1. Develop a list of currently used speleothem sampling methods
2. Increase transparency of speleothem selection and sampling methodology for scientists and other stakeholders
3. Provide a forum (initially through online survey) for other cave stakeholders such as managers, owners, and recreational cavers to give feedback on currently used methods
4. Develop a set of “best practice” recommendations for sampling. These guidelines are more an approach than a list of ways to sample, as sampling method will depend highly on location and discussions between scientists and stakeholders.

Surveys were completed in 2013 (scientists) and 2014 (stakeholders). Forty-five scientists from nineteen countries (of 79 initially contacted) filled out the scientist survey that was emailed to them. More than 100 stakeholders, including managers, cavers, other cave scientists, and cave owners, answered the second survey. The main finding is that scientists and stakeholders value different methods to sample speleothems (see Figure 1); much work remains to align stakeholder and scientist priorities in sampling speleothems for paleoclimate research. However, many scientists expressed a strong understanding of cave conservation and desire to do better when sampling, and stakeholders expressed a desire to feel more comfortable raising issues of conservation with scientists. There is a very large chance that the “best practice” method doesn’t yet exist, and only through maintaining and encouraging open communication between scientists and stakeholders can we hope to develop that method in the future. Thus, my next steps with this project include developing a workshop where stakeholders and scientists can speak directly about sampling concerns and methods, ideally at the American Geophysical Union Fall Meeting and/or the National Cave and Karst Management Symposium. I will also be publishing the full results and recommendations in a journal that is accessible to scientists and stakeholders alike.

Figure 1. Comparison of methods used and favored by scientists and methods approved of by stakeholders, according to surveys performed for this study.



Project Design, Methods, and Target Audiences

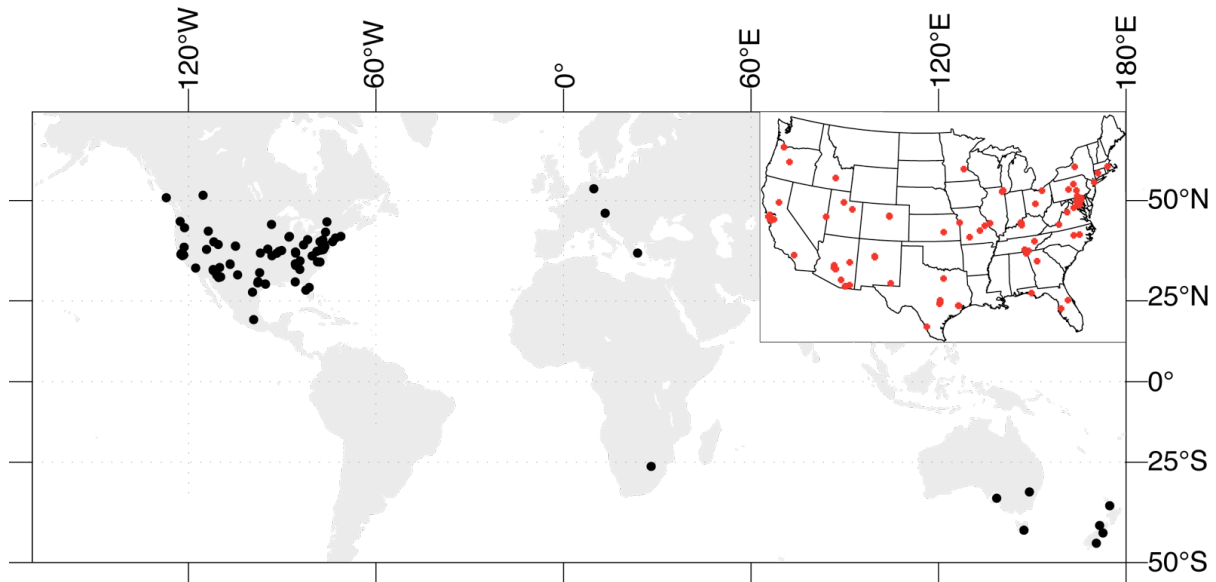
I designed the project to answer the question “what is the best method to sample speleothems for paleoclimate research?” However, I began to realize that question was challenging, because like many cases of resource management, there is rarely a one-size-fits-all solution. Instead, I began to develop a sense of “what is the best practice approach to sampling speleothems to ensure all stakeholders have a voice in the process?” recognizing, of course, that stakeholders include future generations who would not currently have a voice in the sampling process. Scientists and stakeholders understand the value of science in caves and how it can often be at odds with conservation, and indeed, the law: “significant caves on Federal lands are an invaluable and irreplaceable part of the Nation’s natural heritage” (Federal Cave Resources Protection Act, 1988). However, no forum currently exists, except on a 1:1 basis, to engage on these dilemmas. Thus, to initiate the conversation, I designed two surveys, one geared toward paleoclimate scientists and another geared toward “other cave stakeholders”, which includes cave managers, cave owners, recreational cavers, and other types of scientists that study caves or what lives in caves. The surveys were all electronic.

The response from paleoclimate scientists was substantial. The paleoclimate scientist surveys were sent to 79 active speleothem paleoclimatology labs, based on publications on speleothems in the last 10 years. Fifty-six scientists responded, with 41 filling out the survey (>50% response rate). Respondents came from 19 different countries worldwide! For the purposes of this project summary, I will only analyse the responses to one question, namely: *What is your ideal sampling method? Are you using this method? Why or why not?* (Complete results will be available in the eventual publication.) The responses to this question are shown

in Figure 1. Primarily, scientists use (1) permanent removal of speleothems from the cave (100%), with others including (2) removal with pre-screening for age dates or dripwater chemistry (20%), (3) coring of stalagmites (20%), (4) removal of broken stalagmites (18%), and (5) removal and replacement or replica (18%). More than 1/3 of responding scientists were distressed by the current methods they used, commenting, for instance, “I am not happy with the brutal methods I usually use, but I have few options” given constraints on time and funding. It is important to note that the respondents to the paleoclimate scientist survey were likely somewhat self-selected as conservation-minded already, but there is clearly substantial room for discussion with other cave stakeholders about methods in the future.

I designed the second survey in Qualtrics, using the outputs from the first survey, to ensure as complete a list of methods as possible. The second survey was sent through a variety of email and social media channels to the National Speleological Society (NSS; the major cave-related organization in the United States), as well as the speleological societies of any other countries that had functional email addresses online. There were around 100 complete replies to the survey, though an additional 166 respondents completed a handful of questions (no questions were required). The completion rate was almost 42%. Respondents in the stakeholder group came from across the United States and from eight other countries (see Figure 2).

Figure 2. Map of cave stakeholder responses (approximate location obtained through Qualtrics logon information).



Respondents were 69.8% male, with an average age of 49, which is fairly (anecdotally) typical of the caving community, in the United States at least. Respondents were employed in cave management agencies such as the United States Forest Service, the United States Fish and Wildlife Service, the Bureau of Land Management, the National Park Service, and various state and county parks. Respondents who identified their interaction with caves specified that they were recreational cavers, project cavers (who focus on mapping, exploration, etc.), cave rescue specialists, and cave managers. The average number of cave trips per year per respondent was

21 trips, and the average number of different caves visited per year was 12. These “cave demographic” questions were necessary to understand who actually filled out the survey. My target audience was represented fairly well in the respondents to the survey.

Stakeholder responses were elicited about the methods used to sample speleothems for paleoclimate research. The top five methods favored by stakeholders were: (1) coring (79%); (2) removal of broken stalagmites (74%); (3) removal with (pre)screening (67%), (4) removal and archiving (64%); (5) removal and replacement/replica (48%), only shortly ahead of the sixth method, permanent removal (47%) (see Figure 1 for a comparison with methods used and favored by paleoclimate scientists). Although not all respondents to the survey know a lot about the methods that scientists used, comments in the short answer/open-ended sections of survey indicated a substantial engagement and interest in the material:

“Speleothem and sediments are excellent records of the past. For practical purposes they are non-renewable. If possible, they should not be removed and if they are then residual fragments should be placed back in the cave environs and not left to desiccate[sic]. Project cavers that know the cave or who can scout the cave should be consulted as to best locations, and to assist in collection. Of course, proper personnel and environs protection should be practice[d]...Over the years, collection practices have changed and improved. I am sure that improvements will continue so we need to strive to do minimal damage... while we continue to learn.”

Additional results from both surveys will be available as a part of the other outputs of this study (forthcoming).

Outputs during Fellowship and Follow-up

I am producing a number of outputs, matched to each audience for the work.

- (1) I will be submitting a paper to the peer-reviewed *Journal of Cave and Karst Studies*. This is a publication in which occasional paleoclimate science articles appear. This publication is also available to NSS members, and by request, so this output will hopefully be available to all target audiences. I have preliminary support from the journal editor for publishing the results in this particular journal.
- (2) I will also be writing a small feature article for the *NSS News*, for those members of my target audience who don’t download the JCKS.
- (3) I will give oral presentations at the National Cave and Karst Management Symposium (I presented the results of the first half of the survey at NCKMS 2013), and the American Geophysical Union meeting.
- (4) I have also developed a 2-page “decision/action framework” (appended to the back of this report). Although it is in progress, this framework has most of the steps mentioned by respondents to both surveys, and might prove a useful reference tool for scientists new to working with stakeholders, and for cave managers and other cave stakeholders to recognize they can have a voice in the sampling process as well.

Finally, I am also planning on facilitating or co-facilitating a workshop at the American Geophysical Union (AGU) and/or the National Cave and Karst Management Symposium. I suspect it will be more likely to get scientist to attend a workshop if it is at AGU, so I’m primarily focusing on that venue, and I’m currently seeking sources of funds to bring other cave stakeholders to that conference and little to no cost to themselves or their agencies.

A few words on my experience with use-inspired research

I undertook this study because of a set of personal experiences, as a child learning about cave conservation and as an adult in conversation with other speleothem scientists, frustrated about the methods currently in use to sample speleothems. I admit, the magnitude of response to my surveys suggested these few personal experiences attempting to reconcile conservation with paleoclimate research in caves may be more the norm than we, as a scientist community, express regularly. I went into this study with a number of expectations that were completely upended:

- (1) I didn't expect nearly 50 paleoclimate scientists from 19 countries to take even 10 minutes from their day to answer questions about how they sample speleothems and what considerations go into selecting samples for their studies. But, in fact, many wrote very long replies and were very engaged with the content and expressed interest in seeing the results.
- (2) I didn't expect more than a handful of people to take the longer "stakeholder" survey, and yet I had more than 100 complete responses to all questions.

Respondents to both surveys were incredibly engaged, often following up with me via email conversation about the eventual publication and to add anecdotes that were remembered at a later time. I did encounter some obstacles along the way, including scientists who ignored the survey and used my email reaching out as an opportunity to vent frustration about sampling rules enforced by land management agencies or my inability to search the literature—because all the data on speleothem sampling is, of course, already published (it's not; I checked!). I also experienced stakeholder responses that ranged from excitement that someone was actually researching this topic to outrage that no one had yet studied it to frustration that my survey wasn't asking the right questions. I mention these anecdotes because I really didn't expect I would have to develop a thick skin in this type of work—some of the personal emails and responses were quite vehement! However, on the whole, I was pleasantly surprised and enthused by the magnitude and tenor of responses to both the scientist and stakeholder surveys. I am excited to continue the discussion at workshops and conferences for scientists and stakeholders (hopefully with both in the same room at some point in the near future!).

Works Cited

Truebe, SA, JE Cole, M Lee, and HR Barnett. 2011. "Reconciling Speleothem Sampling for Paleoclimate Research with Cave Conservation." Proceedings of the National Cave and Karst Management Symposium (October 2011): 149-153.

Contact information

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For Scientists

A transition to conservation-aware sampling can occur at all stages of research design, implementation, and follow-up. These recommendations were made by respondents to the cave conservation and speleothem paleoclimate science surveys reported on in Truebe et al., (in prep).

| | Design | Implementation | Follow-up |
|-------------|--|---|--|
| Funding | <ol style="list-style-type: none"> 1. Request funding for pre-screening and monitoring 2. Request funding for interpretive educational products, or an honorarium for cave owners/ managers involved in the project. | | <ol style="list-style-type: none"> 1. Consider returning value to the cave through providing time or resources for trail maintenance, restoration, interpretive signage, or other benefit collaboratively decided on with the cave manager/owner. |
| Fieldwork | <ol style="list-style-type: none"> 1. Discuss which caves and locations in caves would be least invasive with cave managers and other cave stakeholders 2. Cultivate relationships with local agencies and caving clubs; perhaps set up agreements with local construction and mining companies to locate sites that might work for research, but are slated for destruction 3. Scout sites with managers for broken material and/or to plan sampling 4. Photodocument entire sampling process (including planning) 5. Discuss and decide on sampling strategies and pros/cons with cave managers | <ol style="list-style-type: none"> 1. Monitor for a few months or years to find the best site (include cavers in deciding sample sites) 2. Take small samples for radiocarbon or uranium series dates 3. Use broken material 4. If coring or drilling in any way, drape the speleothem to prevent powder or drill water from contaminating the cave aesthetically 5. Photodocument 6. Include cavers and cave managers while sampling | <ol style="list-style-type: none"> 1. Return samples to the cave if unsuitable. 2. Patch top of speleothem if cored (can also be done same time core is taken) 3. Deposit samples and data about where they came from (including photos) in a communal archive for use by future researchers 4. Replace 1/2 (polished) back into the cave, if appropriate for educational purposes |
| Labwork | <ol style="list-style-type: none"> 1. How will the speleothem will be processed? Consider sawing the sample with thin-kerf saws to allow for potential reconstruction and replacement in the cave. 2. Consider scanning the speleothem with MRI or CT | | <ol style="list-style-type: none"> 1. Consider developing a replica of the speleothem for replacement in the cave (using cave-appropriate materials) |
| Publication | <ol style="list-style-type: none"> 1. How will cave conservation be addressed in the final report/ paper? | <ol style="list-style-type: none"> 1. Discuss speleothem selection process 2. Discuss sampling methods with specifics in paper or supplementary material | <ol style="list-style-type: none"> 1. Acknowledge cave managers and consider adding them as co-authors if appropriate. 2. Send copies of all studies/data to cave managers 3. Write for local caving club newsletters, a blog, or the <i>NSS News</i> (if in U.S.), etc. |

Additional recommendations mentioned by respondents to the two surveys. These recommendations for speleothem paleoclimate sampling practices are based on two surveys of cave paleoclimate scientists and other cave stakeholders including managers (from most US land-managing agencies), owners, recreational cavers, and other cave researchers.

1. For managers

- 1.1. Science does not necessarily take precedence over conservation every time; speak up with methods or studies that feel “uncomfortable”
- 1.2. Work with scientists to reach a mutually-agreeable sampling method for each case
- 1.3. Work with scientists to consider ways to return value to the cave, such as time or resources for trail maintenance, restoration, interpretive signage, educational products, etc.
- 1.4. Attend sampling trips, photo document, and be available for questions about sampling and restoration (if possible)

2. Funding agencies

- 2.1. Allow time and funding for pre-screening and monitoring
- 2.2. Allow funding for return visits to remote sites (to support trips for monitoring and pre-screening)
- 2.3. Avoid funding studies that lead to wholesale removal of many speleothems
- 2.4. Provide opportunities for scientists to design and implement a speleothem archive

3. Speleothem paleoclimate scientist community

- 3.1. Support publication of high-quality non-traditional speleothem studies (e.g., cores)
- 3.2. Support publication of papers with details about sampling methods and speleothem selection
- 3.3. Contribute to the communal speleothem archive

4. Entire cave stakeholder community

- 4.1. Endeavor to create and cultivate a climate of cave conservation awareness through maintaining open channels of communication
- 4.2. Work together to identify sites where “salvage paleoclimatology” would be appropriate (such as locations with active road-building, quarrying, or mining)
- 4.3. Build an archive where speleothem and other cave samples could be stored and available for other researchers (of paleoclimate, geology, speleology, hydrology, or any other discipline). The archive could be digital if contributors agree to a sample-sharing system where samples are stored in the original researcher’s lab but are available to other researchers