Do all fungi matter? Yes, new study argues

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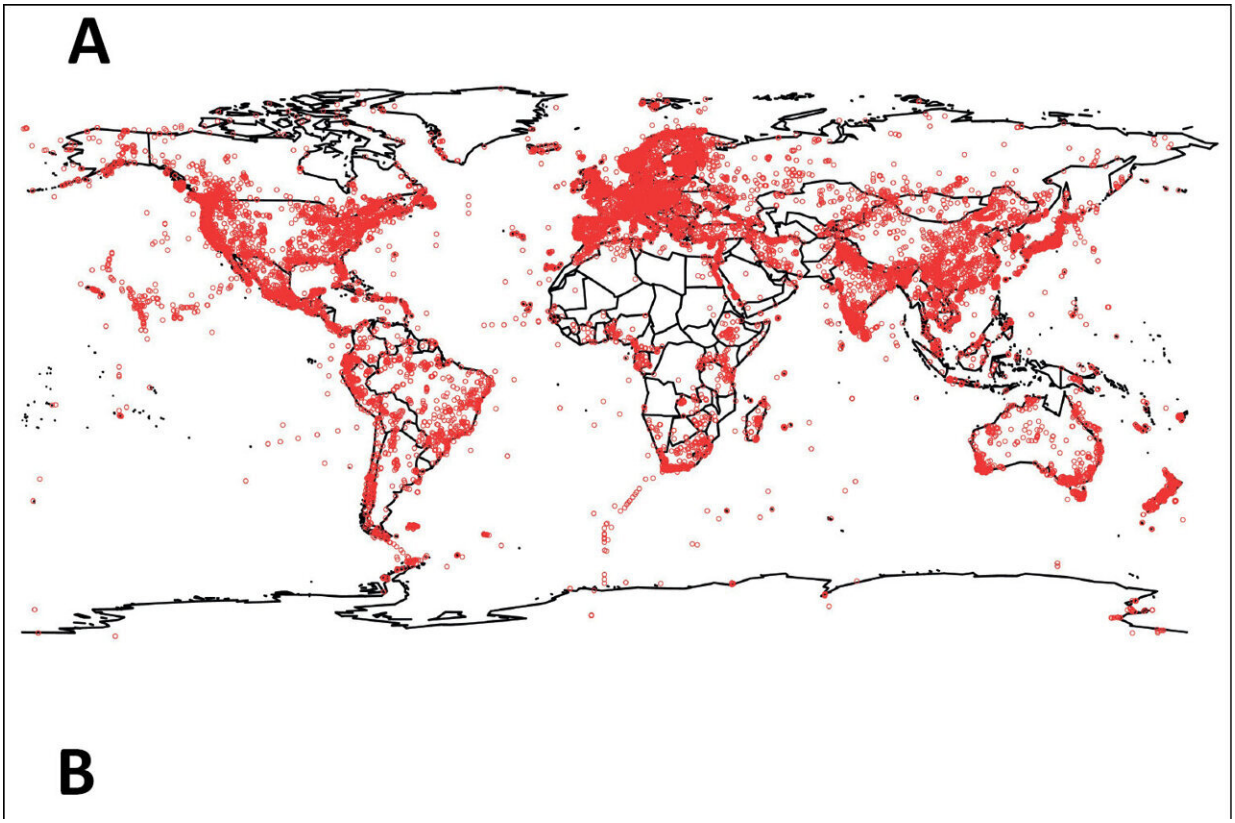

Maps showing the collection localities for the (**A**) Sanger sequences and (**B**) metabarcoding sequences that came with geo-coordinates (36,559 Sanger collection localities and 3,688 metabarcoding collection localities). Credit: *MycoKeys* (2023). DOI: 10.3897/mycokeys.96.102669

Mention fungi, and most people will probably think of the mushrooms they pick in fall, or maybe the yeast they add when baking or making

wine. Others will perhaps recall last week's moldy bread—or cucumbers gone bad in the refrigerator. Indeed, mycologists have studied these fungi as sources of food and fermentation but also decay and disease for centuries.

But while we're used to thinking of fungi as organisms that form physical structures such as fruiting bodies, or yeast-like life forms that we can grow in our kitchens or laboratories, it is gradually becoming clear that fungi don't readily assort into only these two groups. DNA sequencing studies of environmental substrates such as soil are finding massive evidence of large groups of fungi that do not seem to form fruiting bodies and that we seem unable to grow in the lab—but that are there nonetheless.

These groups are often called "dark fungi," in analogy with the concept of "dark matter" in astronomy—something we know is out there, but that we cannot directly observe right now.

A new study in *MycoKeys* contrasts the accumulation of fungal species recovered using traditional mycological approaches with those recovered using environmental DNA sequencing over time. Even when allowing for various kinds of biases, the authors found that species discovery through environmental sequencing vastly outpaces traditional species recovery in a strongly increasing trend over the last five years. The authors conclude that dark fungi form a defining feature of the fungal kingdom.

"And that's where it gets interesting," Henrik Nilsson at the University of Gothenburg, Sweden, and the lead author of the study, says.

"Under the current rules of nomenclature, these fungi cannot be given scientific names—they cannot be described formally. And species and groups that cannot be named formally, well, they tend to fall between the

cracks. They're typically not considered in nature conservation initiatives. They are often left out from efforts to estimate the evolutionary history of fungi, and their ecological roles and associations are largely overlooked when we try to figure out how mass and energy flow in ecosystems. They're essentially treated as if they didn't exist."

Second author Martin Ryberg at the University of Uppsala, Sweden chimes in, "And it's not like we're adding the few missing pieces to an otherwise nearly complete jigsaw puzzle. It seems to be the other way around. We're talking about tens of large groups of fungi—and thousands upon thousands of species, some of which seem to be so common that we have yet to find a soil sample from which they're absent. Indeed, we're talking about what could well prove to be the dominant life style in the fungal kingdom."

The mycological community has been debating whether the rules of fungal nomenclature should be modified to allow formal description of these dark fungi. So far, the matter has not been resolved in the affirmative. "I think our study shows that it's time to stop that debate, like, right away," Nilsson says. "What we should be debating is how we should describe them. What criteria must be fulfilled for a dark fungus to be given a formal scientific name? Clearly, formation of a fruiting body or growth in the laboratory can't be part of those criteria."

Co-author Alice Retter of the University of Vienna, Austria explains, "We figured we'd kickstart the how debate by listing criteria that we think make sense—criteria that would be stringent enough to allow for only particularly well-vetted dark fungi to be described, upholding a high level of scientific rigor and reproducibility in the process. We blended our own observations with suggestions from the mycological community, culled from depositing a preprint of the manuscript at *bioRxiv*."

"We're certainly not claiming that our suggestions form the final word in

the debate. It's more like they're the first. We're thinking that the mycological community will jointly be able to come up with a set of sound guiding principles on the matter—and here comes an initial set of well-meaning observations for nucleation."

The authors advocate gentle modifications to the nomenclatural rules governing the naming of fungi to allow giving formal names to at least the most well-documented species and groups of dark fungi. The suggested modifications would, at present, exclude many rare or otherwise less well-documented dark fungi from formal description.

"But you don't have to have a theory of everything to have a theory of something," senior author Kessy Abarenkov of the Tartu Natural History Museum, Estonia asserts.

"By establishing rules for what's needed to describe dark fungi, and specifying when we'll have to refrain from describing such species at present, mycologists can do what they do best: doggedly gather enough research data to warrant naming of the dark fungi, group by group, and species by species. It's what mycology has excelled at for hundreds of years. It's just the setting that's a bit new."

Sten Anslan, University of Tartu, continues, "Much is at stake, obviously. The current rules governing the naming of fungi have served mycology well for a long time. We don't want to upend or overthrow them. But we fear that if they're not updated in this particular regard, there's a risk that they grow increasingly obsolete over time. Having a book of rules that govern maybe only some few percent of the organisms it was originally conceived to govern—the fungal kingdom—would seem untenable in the long run."

Marisol Sanchez-Garcia of the Swedish Agricultural University concludes, "The nomenclatural aspects of dark fungi will presumably be

discussed at some length at next year's international mycological congress in Maastricht, the Netherlands. We're hopeful that the mycological community will reach meaningful agreement on integration of the dark fungi into the rules of nomenclature. After all, mycologists are used to negotiating and solving non-trivial questions on a day-to-day basis, and this one is hardly any different."

"Being part of tackling a huge, more or less unknown group of organisms where precious little is set in stone and where the rules will have to be adapted over time for the endeavor to stay attuned to recent developments, well, that's what makes being a mycologist so interesting and rewarding in my eyes."

More information: R. Henrik Nilsson et al, How, not if, is the question mycologists should be asking about DNA-based typification, *MycoKeys* (2023). DOI: 10.3897/mycokeys.96.102669

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