Crowdsourcing Fungal Biodiversity: Approaches and standards used by an all-volunteer community science project

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Abstract

Fungal Diversity Survey (FunDiS) is an all-volunteer community science organization that documents the diversity and distribution of macrofungi (visible with the naked eye) across North America. FunDiS addresses a key gap in biodiversity conservation: fungi, one of life's major kingdoms, have been largely neglected in conservation efforts. Fungi are hyperdiverse: it is estimated that only 5% of fungal species have been described (Willis 2018), while support for professional taxonomists has been declining for decades. Therefore, FunDiS engages legions of amateur mycologists to document fungal diversity.

Our participation model has four levels for crowdsourcing fungal biodiversity. It consists of a pyramid of participants and skills, continually drawing more people in at the base (simplest tasks), and encouraging them to move up to the next level.

Level 1. **Field observations**: Community scientists document fungi in the field with georeferenced color photos and post observations on public, databased platforms; FunDiS uses iNaturalist and Mushroom Observer. FunDiS established a curated iNaturalist project called the FunDiS Diversity Database, inspired by FungiMap in Australia. Mushroom enthusiasts add observations, with the incentive that they will be reviewed by a team of expert identifiers. Another team of triagers goes through new observations, rejects those that do not follow FunDiS quality standards, and writes encouraging notes to posters on how to make observations more scientifically valuable. As of August 2021, there were almost 50,000 verifiable observations, of which 30,465 (including 3,204 species) were research grade and uploaded by iNaturalist onto the website of the Global Biodiversity Information Facility (GBIF). Another FunDiS initiative, Rare Fungi Challenges, enlists amateurs to search for rare or threatened fungi.

Level 2. **Sequence**: FunDiS built a program for amateurs to submit tissue for DNA sequencing and provided help interpreting results. Barcoding is especially needed to

identify fungi because mopho-characteristics and images are often insufficient. Participants register projects, post observations to iNaturalist or Mushroom Observer, and apply to FunDiS for sequencing grants or pay out-of-pocket for sequencing. More than 200 local projects have been registered from Alaska to Puerto Rico, and Iceland to Hawaii. Some 7,000 specimens were sequenced by June 2021. Data are deposited in GenBank.

Level 3. **Voucher**: FunDiS supports preserving well-documented, dried specimens in curated fungaria. To date, this participation level has developed slowly because of limitations of personnel and capacity of those institutions.

Level 4. **Super User**: These are advanced observers with extensive field knowledge who have learned DNA technology; can teach others how to analyze DNA results and create phylogenies; and even describe new species. There are perhaps several dozen super users in the North American fungal science community.

Challenges and lessons

Feedback - Feedback to and from participants is critical to the success of community science projects. We have learned that it takes time and personnel to inspire rich interaction with participants in real time and that relying on volunteers with insufficient capacity for coordination, consistency and continuity often disappoints participants. Similarly DNA sequencing is intimidating to most amateurs. We found that guidance was needed for many participants just to correctly document, dry and submit tissue samples for sequencing. An even bigger challenge is making sense of the data that is generated, e.g., knowing if the sequence is of a described species or should be identified as a new species. Deep knowledge is needed for this kind of decision-making. In the past year we were fortunate to have the volunteer services of two professional mycologists and a doctoral student to analyze sequence data.

Linking data - Linking data between field observations, genetic sequences and specimens is a major challenge. Our initial goal was to automate both external and internal data flows, but success has been limited with volunteer programmers. They managed to automate uploading iNaturalist and Mushroom Observer observations to our sequencing facility (Barcode of Life), but most other linkages have been tracked by volunteers on static spreadsheets.

Paid staff - In retrospect, it was optimistic to attempt a project of such ambitious scope using only volunteer management and labor. The vast majority of community science projects are institution-based, with paid staff to manage and funds for outreach (Pocock et al. 2017). To continue at the present scale, we believe a core of paid staff is essential to leverage the large community we have been building.

Keywords

citizen science, mushrooms, FunDiS, iNaturalist, Mushroom Observer, DNA barcoding

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Conflicts of interest

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