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REVIEW PAPER

Mapping the landscape of mycological organizations in europe: where citizen science meets professional mycology

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Abstract
Fungi have been used by humans since prehistoric times. Informal structures or groups for knowledge exchange regarding mushrooms and lichens probably existed for ages. Only recently, mycological activities have been structured in formal organizations. And where until a few centuries ago there were only learned societies and naturalists' clubs, nowadays also mycological societies and citizen scientists have joined the landscape. However, the history of mycological organizations and activities in Europe is difficult to track. Here, we initiated two surveys to characterize the current landscape of mycological organizations focused on fungal diversity across Europe and to collate citizen science activities mapping fungi. The surveys were shared on social media and sent to mycologists in 49 countries in Europe. Responses of the surveys allowed us to present the history, geographical distribution, and structure of mycological organizations in Europe as well as their types of activities, including the publication of journals and magazines, the organization of meetings and educational initiatives, and citizen science projects. In addition to the surveys, local mycologists presented expert knowledge for a more comprehensive overview. Our data show that the mycological landscape in Europe is diverse and heterogeneous. We discuss ways to overcome economic, cultural, and linguistic barriers towards better integration of mycological communities, activities, and data in Europe. Mycological societies focused

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on studying fungal diversity can be leveraged towards common goals that include raising public awareness, data integration, uniting academics and non-academics, and developing common standards for research and communication.

Keywords Amateur mycologists · Citizen science · Fungi · Learned societies · Multi-country collaboration · Mycological societies

Abbreviations

BLAM	Bryologisch–Lichenologische Arbeitsgemeinschaft für Mitteleuropa
BMS	British Mycological Society
CEMM	Confederación Europea de Micología Mediterránea
ECCF	European Council for the Conservation of Fungi
EMA	European Mycological Association
est.	Established
GBIF	Global Biodiversity Information Facility
IAL	International Association of Lichenologists
IMA	International Mycological Association
IMC	International Mycological Congress
IMD	International Mycological Directory
ISFC	International Society for Fungal Conservation
IUCN	International Union for Conservation of Nature
SSC	Species Survival Commission

Introduction

The use of mushrooms and other fungi has a long tradition around the globe. In Europe, mushroom traces have been detected in dental calculus from the Upper Palaeolithic Period, pointing to fungi being used as a food resource already in this period (Power et al. 2015). Several fungal fragments were also discovered with the body of a hunter living around 3300 BCE, named Ötzi, but in this case with a supposed use as tinder (Peintner and Pöder 2000) and for their antibiotic properties (Fowler 2001). Diverse uses of mushrooms by the Aztec people, including ritual and medical purposes, are documented as early as the 16th century (Guzmán 2003). For as long as people have used fungi, there has been a need to exchange information about their recognition and potential applications. In many human societies, especially in rural areas, mushrooms have traditionally been harvested by women, who are often actively involved in disseminating mycological knowledge within their families as well as during workshops and fairs (Garibay-Orijel et al. 2012). People with extensive knowledge of mushrooms have often played important roles in societies around the world, referred to as shamans or healers and regarded as having access to the world of spirits (Winkelman 2019). Informal structures or even groups to exchange knowledge for mushroom hunting and lichen foraging probably existed for ages, even if their history is hard to track.

It is only during the last few centuries that these groups have started to gain a more formal structure. Historically, a distinction between learned societies and naturalists' clubs can be made. Learned societies first began to develop in Europe from the 15th century onwards (Late and Pölönen 2021) and were usually non-profit organizations involving academics in

the advancement of specific research disciplines (Hopkins 2011). The first formal mycological societies in Europe were established in the late 19th century. A lot of information concerning the history, activities, and structure of mycological societies across Europe is found in local literature, e.g., for the Austrian Mycological Society (Krisai-Greilhuber and Moser 1999; Plsek et al. 2023), British Mycological Society (Webster 1997), Danish Mycological Society (Rune 2003, 2004a,b, 2005), Estonian Mycological Society (Pärtel and Suija 2023; Pärtel 2024), Polish Mycological Society (Ławrynowicz and Wrzosek 2012; Wrzosek et al. 2013), Rhine-Neckar Mycological Working Group (Otto 2021), and Société des naturalistes luxembourgeois with its mycological research group (Massard 2015). For some societies, a lot of information can also be found on their websites, e.g., the Finnish Mycological Society (https://www.funga.fi/), German Mycological Society (https://www.dgfm-ev.de/), Greek Mushroom Society (https://www.mycohellas.gr), Macedonian Mycological Society (https://www.macfungi.com/), Polish Mycological Society (http://www.ptmyk.pl/), and Royal Flemish Mycological Society (https://www.kvmv.be/). However, generalizations about mycological societies in Europe are hard to draw given that these papers and websites are often written in the national languages.

While learned societies brought together mostly academics, numerous naturalists' clubs were gatherings of working men and middle-class people keen to fill their newly found leisure hours with interesting pursuits (Alberti 2001). Naturalists' clubs emerged from the early 19th century onwards – and exist to this day. It is commonly thought that there is opposition between non-academics and academics (Miller-Rushing et al. 2012), but until the beginning of the 20th century scientific research was often also conducted by non-professionals who were experts in the field (Vetter 2011). This is not different in mycology, where many important authors of fungal names were amateur mycologists, including Hubert Bourdot (1861–1937) (Gilbert 1939; Gicquel 2023), Giacomo Bresadola (1847–1929), Theodor Holmskjold (1731–1793), Jakob E. Lange (1864–1941), Pier Antonio Micheli (1679–1737) (Watling 1998), and Knud Hauerslev (1905–2000) (Dörfelt and Heklau 1998). Miles Joseph Berkeley (1803–1889), a clergyman by profession, was an amateur mycologist but named over 5,000 species and pioneered the field of plant pathology (Egerton 2012). Also, the father of mycology, Elias Magnus Fries (1794–1878), collaborated with several fungal amateurs who shared specimens, drawings, and experience with him, most famously Hampus Adolf von Post (1822–1911) (Petersen and Knudsen 2015).

Despite non-academics having contributed to research for centuries before, the term "citizen science" was first used only in 1989 (Kerson 1989). Since its first appearance, citizen science has had many definitions and the concept is subject to rapid development (Eitzel et al. 2017; Haklay et al. 2021). We here define it as public engagement in scientific research, in which members of the community actively contribute to science either intellectually or with tools and resources.

In this paper, we (1) present an overview of the history and current status of mycological organizations focused on studying fungal diversity in Europe, (2) discuss the role they have played in fungal research, and (3) examine their activities. Our long-term goal is to create a database to integrate information on mycological organizations in Europe.

Methods

For this study, we adopted the list of European countries ($n=49$) from Eurostat's overview of population indicators (https://ec.europa.eu/eurostat/databrowser/view/demo_gind/). In addition, we applied the following definitions to avoid confusion:

(1) Mycological societies: organizations that are legally registered and have a formal structure, including membership.
(2) Mycological groups: informal gatherings of mycophiles including Facebook groups and iNaturalist projects.
(3) Mycological organizations: umbrella term covering both mycological societies and groups.

We only consider mycological organizations that focus on the diversity of fungi (including lichenized ones). We exclude organizations specialized in medical mycology, veterinary mycology, plant pathology, microbiology, and biodeterioration.

A survey (hereafter termed 'Survey 1') was created with Google Forms to characterize the current landscape of mycological organizations across Europe. The survey asked for the name of the organization in the national language and in English, country, links to homepage and social media, year of establishment, membership information, publication strategies (if any), structure (at the national level versus regional), and activities. Multiple entries by a single person were allowed. The survey was shared on social media and proactively sent to mycologists in the 49 target countries in Europe as defined above. This resulted in the survey being completed by several of them. Others provided information on the mycological landscape in their respective countries by email to the corresponding authors. This means that we had two different sources of information. Representatives of some countries decided to translate Survey 1 in their national language to achieve more efficient dissemination at the country-level and complement their prior knowledge of the mycological landscape locally, when necessary. As a result, the survey was translated to German, Portuguese, and Spanish.

Survey 1 was shared broadly on social media (including within mycological Facebook group/pages) from 29 March 2024 onwards. Responses ($n=73$) were collected onto a Google Spreadsheet and analyzed using basic descriptive statistics. In some cases, we also used data from the European Mycological Association website (http://www.euromould.org/resources/links/socs.html), and asked local mycologists to place the survey results in a local perspective. For the purpose of the paper, only responses provided until 14 July 2024 were analyzed (Additional File 1: Table S1). The survey remains active to this date (see Data availability statement), and our long-term goal is for the responses of this survey to be the main, up-to-date source of information for all European mycological groups and societies.

A second, separate survey (hereafter termed 'Survey 2') was initiated to map citizen science activities focusing on fungal diversity globally. The survey asked for the name of the project in the national language and in English; geographic focus; use of tools, apps and/or platforms; organizational structure *sensu* Haelewaters et al. (2024) (unstructured, structured, derived); web links; and whether or not vouchers were deposited and collecting permits were required. Again, responses were collected onto a Google Spreadsheet and analyzed using basic descriptive statistics. For the purpose of the paper, only responses with a focus on Europe and provided between March and 14 July 2024 were analyzed ($n=32$;

Additional File 2: Table S2). The survey remains active to this date (see Data availability statement), and our long-term goal is to be able to map all current mycological citizen science projects on a global scale.

A selection of the raw data on mycological societies and citizen science projects will be made available open-access on the homepages of FunDive (https://fun-dive.eu/) and the European Mycological Association (http://www.euromould.org).

History and geographic distribution of mycological organizations in Europe

The history of formal mycological societies dates back to the 19th century (Figs. 1 and 2B), when the first formal organizations were created in France (1884), and the United Kingdom (1896), followed by Denmark (1905) and the Netherlands (1908). The second wave of establishment of mycological societies happened after the first and second World Wars, for example in Austria, Belgium, Czechia, Germany, and Finland. Finally, after the classification of the Fungi as a separate kingdom (Whittaker 1959), a rapid growth in the number of mycological societies can be observed (see Fig. 1). To better integrate mycological communities and promote research in mycology, the International Mycological Association (IMA) was established in 1971 during the First Mycological Congress (IMC-1) in Exeter, United Kingdom (Simmons 2010). The European Mycological Association (EMA) is younger and was set up only in 2003 at the XIV Congress of European Mycologists in Katsiveli, Crimea, Ukraine. Interestingly, the European Council for the Conservation of Fungi (ECCF) was already established in 1985 to draw attention to the importance of protecting fungi in light of the declining populations of certain fungal species in Europe (Senn-Irlet 2005).

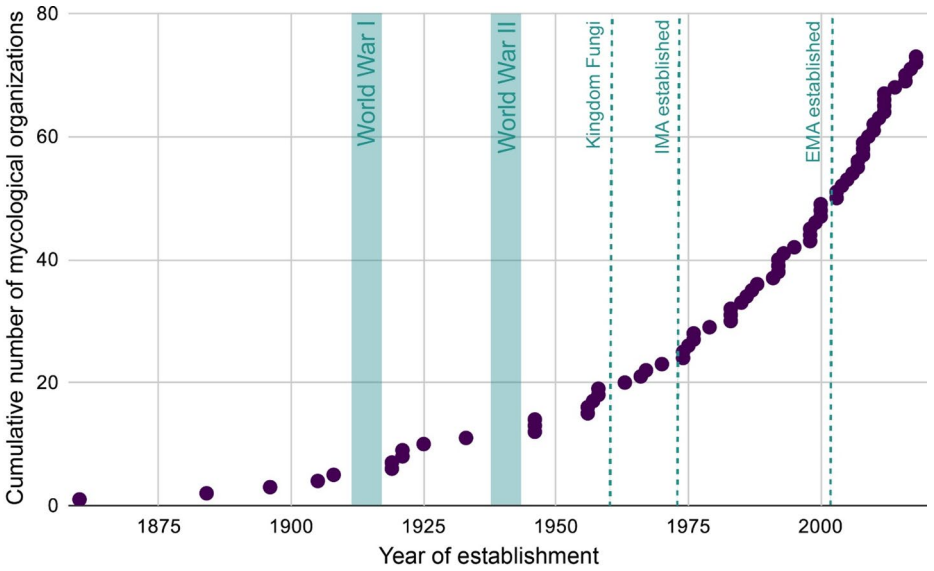

Fig. 1 Cumulative number of mycological organizations in Europe from 1860 to 2018 based on Survey 1. For botanical and naturalists' organizations, the year of establishment of mycological group or section is shown. For reference, a select number of important events are indicated: World Wars I (1914–1918) and II (1939–1945), the formal separation of Kingdom Fungi (1959), the establishment of the International Mycological Association (1971), and the establishment of the European Mycological Association (2003)

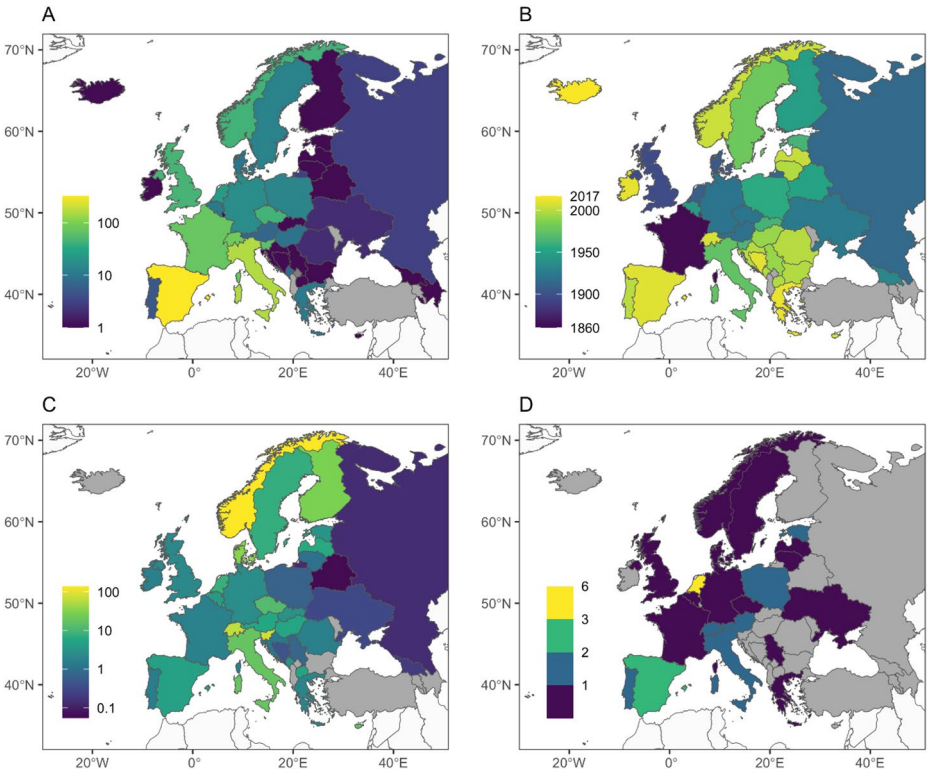

Fig. 2 Maps showing (**A**) log-transformed number of mycological organizations per country (scale reflecting original values), (**B**) the year of establishment of the oldest mycological society in each country, (**C**) log-transformed number of members in mycological societies per country per 100,000 inhabitants ($n=70$; Facebook groups excluded from analysis; scale reflecting original values), (**D**) citizen science projects per country in Europe, including social media initiatives

Societies from southern and eastern Europe have shorter traditions of formal mycological movements. In part, this phenomenon can be explained by a shorter history of statehood in some countries. For example, country-level mycological organizations in the Balkans were established only after the breakup of former Yugoslavia. In some cases, societies currently recognized as country-level were functioning before at a regional level. For example, the mycological section within the Estonian Naturalists' Society was established in 1963 (Pärtel and Suija 2023), although until 1991 in the framework of the Soviet Union.

Europe's rich and complicated history has affected both the motivation of people for mushrooming and the tradition of forming formal organizations, including mycological ones. Of course, one cannot discuss the history of the establishment of mycological organizations without consideration of broader academic infrastructure. At a time when learned societies started to establish in western Europe, e.g., Académie Française (est. 1635) and the Royal Society (est. 1660), the number of universities in eastern Europe was still limited. In addition, the motivation of people to establish mycological organizations and engage in different activities may also have been differentially affected by the political systems

(Bozogáňová and Výrost 2019). Note that more general correlations between biodiversity data and political systems have also been explored (Zizka et al. 2021).

In some regions, mycological activities have traditionally been carried out in specific sections of botanical and naturalists' organizations. For example, this is the case for the mycological group (est. 1981) within the Italian Botanical Society (est. 1888), the mycological research group (est. 1983) of the Société des naturalistes luxembourgeois (est. 1890), and the mycological (est. 1956) and lichenological sections (est. 1983) of the Polish Botanical Society (est. 1922). The Russian Botanical Society (est. 1915) has two sections and one commission dealing with fungi. In Norway, the mycological section/group is part of the *Norges sopp- og nyttevekstforbund* (Norwegian Mushroom and Useful Plants Association) which was established in 1902. In some cases, mycological activities are still carried out in these specific sections, e.g., the mycological group of the Italian Botanical Society is still active, and the Commission for the Study of Macromycetes of the Russian Botanical Society organizes regular workshops every two years in different provinces to promote mycology.

In some other cases, these sections gave birth to independent, dedicated organizations. In Hungary, a separate mycological section was formed in 1962 as a part of the Hungarian Forestry Association (est. 1866), and later this section was established as the individual Hungarian Mycological Society in 1992. In Estonia, the mycological section of the Estonian Naturalists' Society (est. 1853) was created in 1963, and in 2000 the section was renamed the Estonian Mycological Society (Pärtel and Suija 2023). In some countries active sections and independent organizations coexist. In Italy, for example, the independent Società Lichenologica Italiana (Italian Lichen Society) with approximately 250 members was established in 1987. However, a lichenological working group within the Italian Botanical Society is also functioning. Similarly, in Poland, the Polish Mycological Society (est. 2012) coexists with the still active mycological section (est. 1956) of the Polish Botanical Society and in Russia, the National Academy of Mycology (est. 2000) and Saint-Petersburg Mycological Society (est. 2012) coexist with the Russian Botanical Society (est. 1915).

Mycological organizations in Europe are not solely geographically structured. Some have a taxonomic focus. One example is the Journées européennes du Cortinaire (est. 1983), an organization to bring together mycologists studying the genus *Cortinarius* (Basidiomycota, Agaricomycetes, Agaricales, Cortinariaceae). Organizations focusing on lichenized fungi represent another example. All of these were established after World War II, with a quick rise particularly in the heavily industrialized countries in Central Europe in the 1950s and 1960s. The International Association of Lichenologists (IAL) was founded in 1964, seven years before the IMA. While a European organization for lichenologists does not exist, there are two regional multi-country lichenological associations: Bryologisch–Lichenologische Arbeitsgemeinschaft für Mitteleuropa (BLAM) covering German-speaking Central European countries, and the Nordic Lichen Society covering Denmark, Iceland, Scandinavia, and the Baltic region. In some countries, such as Russia, no national-level lichenological organizations exist even though there are dozens of professional lichenologists. Some organizations focus on both lichens and bryophytes, e.g., BLAM, the Swiss Association of Bryology and Lichenology (Bryolich), and the Bryologische en Lichenologische Werkgroep in the Netherlands. The focal substrates, purposes, and methods for collecting and preserving specimens are more similar between bryologists and lichenologists than they are to those of mushroom hunters. And thus, while bryologists and lichen enthusiasts target taxa within

different kingdoms, they occupy the same corner of the naturalists' spectrum. In this paper, we included all those organizations in the analyses.

The number of mycological organizations per country varies from one up to more than a hundred in Italy and Spain (Fig. 2A). The number of mycological organizations per country does not correlate with any of the following parameters: size of the country, population size, tertiary education attainment, gross domestic product per capita, and actual individual consumption per capita, as defined by Eurostat (2024b) (Additional File 3: Table S3). The large number of mycological groups in some regions reflects extensive activity at the local scale that is usually integrated at the national level by one or a few larger organizations. To define the real reasons underlying such a landscape of mycological organizations in Europe, more detailed studies are needed; perhaps at the regional level and including the level of mycological knowledge (rather than the tertiary education level).

Structure of mycological organizations in Europe

Legal framework

Although traditionally mycological societies were registered at regional or national levels, modern mycological groups often lack a legal framework. National law dealing with societies varies from country to country. In some cases, the growing number of administrative obligations has discouraged mycologists from forming legally recognized societies or may lead them to dissolve existing ones. An interesting case is the history of the Mycological Society of Montenegro. The organization was active as a formal, registered society starting from 1998, but it was legally dissolved in 2012. However, members of the society have remained active. The journal *Mycologia Montenegrina* was published by the Mycological Society of Montenegro from 1998 to 2009, and then by the University of Montenegro until 2017. In other words, the society's journal existed for longer than the society itself legally existed. Another case is the Estonian Naturalists' Society (est. 1853, as Die Dorpaten Naturforscher-Gesellschaft) that signed an association agreement with the Estonian Academy of Sciences in 1998 and the University of Tartu.

Although globalization and development of the internet enabled effective and rapid exchange of information without the need for establishing a legal entity, being a formal society opens opportunities, such as applying for external funding, hosting meetings and events under the society's name, and enhancing credibility. In some cases, informal mycological groups with active members can be leveraged to start formal societies or register as specific legal entities later on. In Greece, amateur mycologists formed regional groups in the late 1990s, but it was not until 1999 that the first formal society was established. This event boosted the mycological movement in the larger area. As another example, BLAM was officially established in 1958 and registered as a charitable society ("Verein" in Germany) only in 1995. Therefore, formal mycological societies are not only coordinators of local mycological activities and facilitators of interactions at an international level, but they also enable attracting partnerships and applying for funding that can be further used to better understand fungal diversity on a regional and continental scale.

There are a few countries that do not have any formal or informal mycological organizations. The mycological activities in those countries are coordinated by a limited number of

devoted researchers at specific research institutes. Examples of such cases are Azerbaijan (Aghayeva 2018) and Belarus (Yurchenko 2008).

Membership and personnel

The number of members per organization differs across Europe (Fig. 2C). The highest number of members are found in Italy (Associazione Micologica Bresadola having 9,000 members divided into 131 local groups), Norway (Norwegian Association for Mycology and Foraging having 7,600 members in 42 local societies), Switzerland (Swiss Union of the Mycological Associations having 5,000 members), and Denmark (Danish Mycological Society having 2,000 members). In a few countries the number of members per mycological society is relatively low, but there are many of them, resulting in a high cumulative number of members for those countries. The highest number of members per 100,000 inhabitants is observed in Denmark, Norway, Slovenia, and Switzerland (Fig. 2C). There seems to be a tendency for mycological organizations in Balkans (except Slovenia) and Baltic countries to have relatively few members, from 15 in the Mycological Society MycoBH (Bosnia and Herzegovina), and 30 in the Lithuanian Mycological Society, to 200 in the Greek Mushroom Society.

In today's landscape, social media have become very important for communication and outreach. Some established formal mycological societies are now successfully running social media groups. A prime example is the British Mycological Society (BMS) that has 900 members, and its Facebook group (https://www.facebook.com/groups/18843741618) with 43.3 K members (as of 14 July 2024). In addition, there are many informal, community-driven social media initiatives that we refer to as 'mycological groups' in this paper. Some of them are geographically oriented, whereas others have a taxonomic focus. Examples of mycological groups working efficiently but without being legal entities are *Гриби України* (Fungi of Ukraine, https://www.facebook.com/groups/Hryby.Ukrayiny), *Funga Íslands – sveppir ætir eður ei* (Funga of Iceland – fungi that are edible and those that are not, https://www.facebook.com/groups/158936901179264), *Fungos de Portugal* (https://www.facebook.com/groups/621699714945817), and *Ascomycetes of the world* (https://www.facebook.com/groups/ascomycetes). While these are doing a great job in engaging society in mycological activities, it is difficult to assess the actual number of members who are actively engaged (see BMS example above).

In the past, some mailing lists and forums, like *Mycologia Europaea*, were initiated to bring together academic and non-academic mycologists. Several mycological organizations have also used forums and mailing lists. While several of these are still active today, social media are more commonly used nowadays for communication with and among members.

Only in 8 out of all 73 (ca. 11%) surveyed mycological organizations, at least one person of staff is working in the organization's office (Fig. 3A). The majority (89%) of mycological organizations are run only by volunteers. The vast majority (97%) of surveyed mycological organizations bring together both academics and mycologists without an academic background (Fig. 3B). Although this kind of collaboration was already successfully happening in 19th-century Yorkshire (Alberti 2001), it was not common for a long time. For decades, naturalists' clubs have gathered mostly non-academics, while professional mycologists were members of learned societies. Nowadays, only 2 out of 73 (3%) surveyed mycological organizations are composed exclusively of academics. These are the Ukrainian Botan-

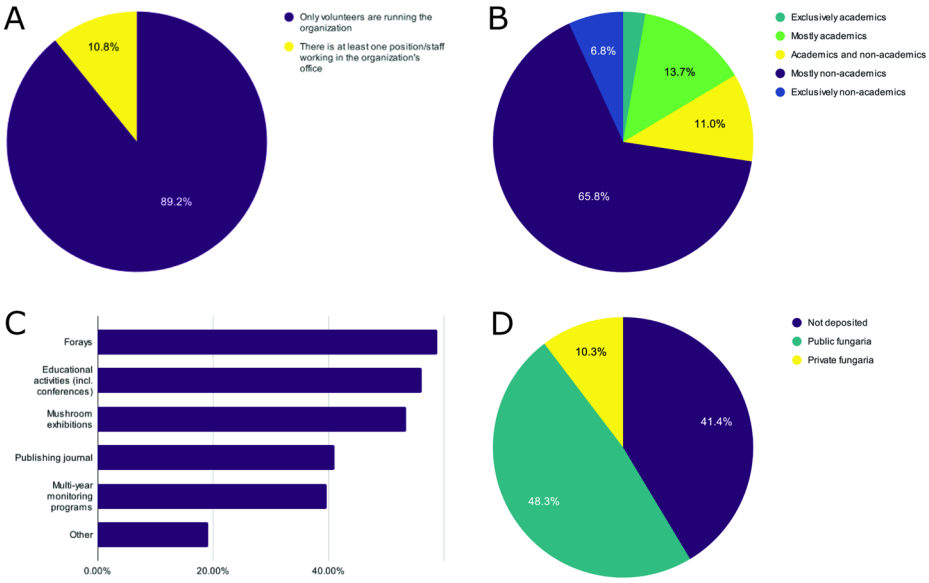

Fig. 3 Characteristics of the (A) workforce structure, (B) membership details, and (C) main types of activities reported by mycological organizations as per Survey 1, and (D) proportion of voucher specimens collected during citizen science activities that are deposited in public and private fungaria as per Survey 2

ical Society and the Irish Fungal Society. Approximately 14% of surveyed mycological organizations are composed of mostly academics, with examples from Czechia, Georgia, Italy, Lithuania, Poland, and Serbia. Around 73% of surveyed mycological organizations declared to be composed exclusively or mostly of non-academics. Note that in Czechia, there are two separate organizations each with a different focus. *Česká vědecká společnost pro mykologii* (Czech Scientific Society for Mycology) brings together mostly academics and is focused on professional mycology and fungal conservation, while *Česká mykologická společnost* (Czech Mycological Society) integrates mostly non-academic mycologists and focuses on educational activities. However, nowadays many mycologists are members of both organizations.

Mycological activities in Europe

Activities organized by surveyed mycological organizations are broad, including forays, mushroom exhibitions, the organization of courses, meetings, symposia, and congresses, multi-year monitoring programs, and publishing magazines and journals (Fig. 3C). Additionally, several citizen science campaigns contribute to the landscape of mycological activities in Europe (Fig. 2D). While activities organized by mycological organizations are summarized from Survey 1, citizen science activities are reported from Survey 2.

Publication of journals and magazines

Only 41% of surveyed mycological organizations publish journals or magazines (Fig. 3C). We complemented those results with information found in the literature and provided by

co-authors, resulting in a list of 62 titles (Table 1) comprising widely diverse types of publications from 46 mycological organizations in 14 different languages. Seventeen (28%) of listed titles are newsletters or online bulletins. Forty-three (73%) are peer-reviewed journals. The term "peer-reviewed" is considered broadly here, with some of the listed journals being reviewed by an internal board or a single dedicated editor. Some of the listed peer-reviewed journals are published in national languages, such as *Magyar Gombász* (in Hungarian) and *Mykologické listy* (in Czech), whereas others are published only in English, like *Acta Mycologica*, *Czech Mycology*, *Folia Cryptogamica Estonica*, and *Italian Journal of Mycology*. Even others are accepting contributions in multiple languages, e.g., *Agarica* (in Danish, English, Norwegian, and Swedish), *Fungi Iberici* (English, Portuguese, and Spanish), *Herzogia* (in English and German), *Mikológiai Közlemények - Clusiana* (Hungarian and English), *Notiziario della Società Lichenologica Italiana* (English, French, and Italian), and *Sterbeeckia* (Dutch and English). Several peer-reviewed journals published by mycological organizations in Europe are well known and broadly cited, despite not having a recognized Impact Factor: *Acta Mycologica*, *Czech Mycology*, and *Folia Cryptogamica Estonica*. Only 11% of the titles in Table 1 are on the list of Journal Citation Reports (Krampl 2019) and have an Impact Factor. Examples of this category are *Herzogia*, *Fungal Biology*, *Fungal Ecology*, *Mycological Progress*, and *The Lichenologist*. This is not a European-specific pattern. Other mycological societies outside of Europe also publish journals with a recognized Impact Factor, for example *Mycologia* from the Mycological Society of America, *Mycoscience* from the Mycological Society of Japan, *Mycobiology* from the Korean Society of Mycology, and *Mycosystema* (formerly as *Acta Mycologica Sinica*) from the Mycological Society of China.

Meetings and educational activities

Forty-four out of 73 surveyed organizations (60%) engage their members by organizing mushroom forays. Two other main common activities are the organization of meetings, conferences, and educational activities (58%), and the organization of mushroom exhibitions (55%). Some of the surveyed organizations, including Associazione Micologica Bresadola and Royal Flemish Mycological Society, reported to maintain a mycological library. Several organizations are organizing "mushroom festivals", "fungus fairs", and "mushroom days" to promote knowledge about mushrooms to the broader audience. Most mycological organizations hold annual symposia to share knowledge and research outcomes. Some organizations also organize regular courses or identification sessions. A few mycological societies are involved in country-level formal training and certification of mushroom inspectors (Peintner et al. 2013), who are liable and responsible for the safety and accuracy of mushrooms sold and consumed. The Hungarian Mycological Society organizes two levels of courses (Kisné Fodor et al. 2024). Similarly, the German Mycological Society is responsible for the certification of mushroom inspectors.

In recent years, several educational activities have also been organized virtually or in hybrid form. In the Netherlands, a 2023 online mycology course developed by the Dutch Mycological Society reached 867 participants, showing a massive interest in fungi among Dutch naturalists. A few hundred attendees are also joining online lectures organized by German-speaking mycological organizations. The Iberian Mycological Society organizes not only lectures but several online courses, for example on molecular identification of

Table 1 List of journals currently published by mycological organizations per country, as per survey 1

Country	Title of journal	Name of organization in national language	Language(s) of the journal	Peer-reviewed?	Does it have Impact Factor?
Austria	*Österreichische Zeitschrift für Pilzkunde*	*Österreichische Mykologische Gesellschaft*	English, French, German	Yes	No
Austria	*Mitteilungen der Österreichischen Mykologischen Gesellschaft*	*Österreichische Mykologische Gesellschaft*	German	No	No
Austria, Germany, Switzerland	*Herzogia*	*Bryologisch-Lichenologische Arbeitsgemeinschaft für Mitteleuropa e.V.*	English, German	Yes	Yes
Austria, Germany, Switzerland	*Herzogiella*	*Bryologisch-Lichenologische Arbeitsgemeinschaft für Mitteleuropa e.V.*	German	No	No
Belgium	*Sterbeeckia*	Royal Flemish Mycological Society	Dutch, English	Yes	No
Belgium	*Sporen*	Royal Flemish Mycological Society	Dutch	Yes[a]	No
Belgium	*Bulletin de l'Association des Mycologues Francophones de Belgique*	*Association des Mycologues Francophones de Belgique*	French	Yes[a]	No
Belgium	*MycoLux*	*Association des Mycologues Francophones de Belgique*	French	Yes[a]	No
Bulgaria	*Mycobiota* (previously *Mycologia Balcanica* 2004–2013)	Bulgarian Mycological Association	English	Yes	No
Cyprus, Greece	*Μυκητολόγος* (*Mycologist*)	Cyprus Mycological Association	Greek	No	No
Czechia	*Czech Mycology*	*Česká vědecká společnost pro mykologii*	English	Yes	No
Czechia	*Mykologické listy*	*Česká vědecká společnost pro mykologii*	Czech	Yes	No
Czechia	*Mykologický sborník*	*Česká mykologická společnost*	Czech	Yes[a]	No
Denmark	*Svampe*	*Foreningen til Svampekundskabens Fremme*	Danish	No	No
Denmark, Estonia, Finland, Iceland, Latvia, Lithuania, Norway, Sweden	*Graphis Scripta*	Nordic Lichen Society	English	Yes	No
Estonia	*Folia Cryptogamica Estonica*	*Eesti mükoloogiaühing*	English	Yes	No

Table 1 (continued)

Country	Title of journal	Name of organization in national language	Language(s) of the journal	Peer-reviewed?	Does it have Impact Factor?
Europe	*IMA Fungus*	International Mycological Association	English	Yes	Yes
Europe	*Journal des Journées européennes du Cortinaire*	*Journées européennes du Cortinaire*	English, French, German, Italian, Spanish	Yes[a]	No
Finland	*Karstenia*	Finnish Mycological Society	English	Yes	Yes
France	*Annales de la SHHNH*	*Société d'Horticulture et d'Histoire Naturelle de l'Hérault*	French	No	No
France	*Bulletin trimestriel de la Société mycologique de France*	*Société mycologique de France*	French	Yes[a]	No
France	*Bulletin semestriel de la Société mycologique du Nord de la France*	*Société mycologique du Nord de la France*	French	Yes[a]	No
France	*Bulletin d'information de l'Association Française de Lichénologie*[b]	*Association Française de Lichénologie*	French	Yes[a]	No
France	*Bulletin mycologique et botanique Dauphiné-Savoie*	*Fédération mycologique et botanique Dauphiné-Savoie*	French	Yes	No
France	*Bulletin semestriel de la Fédération des Associations mycologiques méditerranéennes*	*Fédération des Associations mycologiques méditerranéennes*	French	Yes	No
France	*Bulletin de la Fédération mycologique de l'Est*	*Fédération Mycologique de l'Est*	French	Yes	No
France	*Bulletin de la Fédération des Associations mycologiques de l'Ouest*	*Fédération des Associations Mycologiques de l'Ouest*	French	Yes	No
Hungary	*Mikológiai Közlemények - Clusiana*	*Magyar Mikológiai Társaság*	English, Hungarian	Yes	No
Hungary	*Magyar Gombász*	*Magyar Mikológiai Társaság*	Hungarian	Yes	No
Italy	*Bollettino del Circolo Micologico "G. Carini"*	*Circolo Micologico "G. Carini"*	Italian	No	No
Italy	*Rivista Micologica Romana*	*Associazione Micologica ed Ecologica Romana*	English, French, Italian, Spanish	Yes	No

Table 1 (continued)

Country	Title of journal	Name of organization in national language	Language(s) of the journal	Peer-reviewed?	Does it have Impact Factor?
Italy	*Italian Journal of Mycology*	*Unione Micologica Italiana*	English	Yes	No
Italy	*Micologia Toscana*	*Associazione Gruppi Micologici Toscani*	English, French, Italian	Yes	No
Italy	*Notiziario della Società Lichenologica Italiana*	*Società Lichenologica Italiana*	English, Italian	Yes	No
Italy	*Rivista di Micologia*	*Associazione Micologica Bresadola*	Italian	Yes	No
Luxembourg	*Bulletin de la Société des naturalistes luxembourgeois*	*Société des naturalistes luxembourgeois*	English, French, German	Yes	No
Montenegro	*Mycologia Montenegrina*[b]	Mycological Society of Montenegro	English, French, German, Italian, Serbian	Yes	No
The Netherlands	*Buxbaumiella*	*Bryologische en Lichenologische Werkgroep*	Dutch	No	No
The Netherlands	*Coolia*	Dutch Mycological Society	Dutch	No	No
Norway	*Sopp og nyttevekster*	*Norges sopp- og nyttevekstforbund*	Norwegian	No	No
Norway	*Agarica*	*Norges sopp- og nyttevekstforbund*	Danish, English, Norwegian, Swedish	Yes	No
Norway	*Funga*	*Norges sopp- og nyttevekstforbund*	Norwegian	No	No
Norway, Sweden, The Netherlands	*Lindbergia*	Dutch Bryological and Lichenological Society and Nordic Bryological Society	English	Yes	No
Poland	*Acta Mycologica*	Polish Botanical Society	English	Yes	No
Portugal, Spain	*Fungi Iberici*	Iberian Mycological Society	English, Portuguese, Spanish	Yes	No
Romania	*Moeszia - Erdélyi Gombász*	*László Kálmán Gombászegyesület*	English, Hungarian	Yes	No
Russia	*Планета грибов* (*Planet Fungi*)	Saint Petersburg Mycological Society	English, Russian	No	No
Russia	*Mycology Today*	National Academy of Mycology	Russian	Yes[a]	No
Slovakia	*Catathelasma*	*Slovenská Mykologická Spoločnosť*	English	Yes	No
Slovakia	*Spravodajca Slovenskej mykologickej spoločnosti*	*Slovenská Mykologická Spoločnosť*	Slovak	Yes[a]	No

Table 1 (continued)

Country	Title of journal	Name of organization in national language	Language(s) of the journal	Peer-reviewed?	Does it have Impact Factor?
Spain	*Tiempo de Setas* (digital newsletter)	*Programa Micocyl*	Spanish	No	No
Spain	*Revista Catalana de Micologia*	*Societat Catalana de Micologia*	Catalan, English, Spanish	Yes	No
Spain	*Bolets de Catalunya*	*Societat Catalana de Micologia*	Catalan, Spanish	No	No
Spain	*Boletín*[b]	*Grupo Micológico Caesaraugusta*	Spanish	No	No
Spain	*Boletín micológico de FAMCAL*	*Federación de asociaciones micológicas de Castilla y León*	Spanish (also accepting contributions in other languages)	Yes[a]	No
Sweden	*Svensk Mykologisk Tidskrift*	*Sveriges Mykologiska Förening*	Swedish	No	No
Sweden	*Lavbulletinen*	*Svensk Lichenologisk Förening*	Swedish	No	No
Switzerland	*Meylania*	*Schweizerische Vereinigung für Bryologie und Lichenologie*	German, French, English, Italian	Yes[a]	No
United Kingdom	*Field Mycology*	British Mycological Society	English	Yes[a]	No
United Kingdom	*Fungal Biology*	British Mycological Society	English	Yes	Yes
United Kingdom	*Fungal Biology Reviews*	British Mycological Society	English	Yes	Yes
United Kingdom	*Fungal Ecology*	British Mycological Society	English	Yes	Yes
United Kingdom	*Bulletin of the British Lichen Society*	British Lichen Society	English	No	No
United Kingdom	*The Lichenologist*	British Lichen Society	English	Yes	Yes

[a]The peer review process is done by an internal board of editors or a single dedicated editor. In some cases, authors are requested to have their manuscript reviewed independently before submission

[b]No longer published at this time

fungi. The Austrian and Bavarian Mycological Societies run a YouTube channel for outreach to a broader audience, with 880 subscribers as of 3 December 2024 (https://www.youtube.com/@youtubekanalderomgundbmg6044).

Finally, several mycological organizations collect data on fungal occurrences. In many European countries, there are biodiversity data-integrating infrastructures at the national level, where mycological data are incorporated. Examples are the National Database of Flora and Fauna (https://www.ndff.nl/) in the Netherlands, the Finnish Biodiversity Information Facility (https://laji.fi/en), and the Biodiversity Atlas Austria (https://biodiversityatlas.at/). Some mycological societies developed their own tools to coordinate the collation of fungal data. For example, the Danish Mycological Society is involved in development of

the Danish Fungal Atlas (Danmarks svampeatlas; https://svampe.databasen.org/), the Finnish Mycological Society established the Finnish Fungal Atlas (https://sieniatlas.fi), and the German Mycological Society is using the Pilzgucker.de portal (https://www.pilzgucker.de). Other societies use different biodiversity data-recording platforms, such as Observation.org (https://observation.org), common in Benelux countries, and iNaturalist (https://www.inaturalist.org/).

Some organizations mostly use Facebook groups not only to communicate with their members but also to gather information on fungal occurrences. An interesting example of this is the Czech Facebook group *Mykologická Poradna* (https://www.facebook.com/groups/makromycetes/). This group is primarily designed to help a broad group of mushroom hunters with fungal identification. However, as many posts contain information on rare species, moderators are engaging members to share metadata of their records, and finally the data obtained from this Facebook group were used to prepare several scientific papers (e.g., Holec et al. 2022; Tejklová and Zíbarová 2023). Similarly, fungal records posted on the Facebook group *Гриби України* (Fungi of Ukraine, https://www.facebook.com/groups/Hryby.Ukrayiny) contribute to country-level databasing and publications (e.g., Prylutskyi et al. 2023).

Fungal conservation

Finally, several mycological organizations are also engaged in fungal conservation. Some of them, for example the *Société Mycologique du Nord de la France* (Mycological Society of northern France) and *Česká vědecká společnost pro mykologii*, are even funded by local authorities to act as data providers, database managers, and coordinators of work on fungal inventories and regional Red Lists (Zíbarová et al. 2024). In Hungary, a specific Facebook group, *Védett és vörös listára javasolt gombák* (Fungi recommended for protection and red listing, https://www.facebook.com/groups/523171891599301) collates data on protected and rare fungi. International efforts towards better conservation of fungi are coordinated by the European Council for the Conservation of Fungi (ECCF). Founded in 1985 at the 9th Congress of European Mycologists, it brings together mycologists from nearly every country in Europe (Perini et al. 2008). The ECCF is recognized by the IMA as the fungal conservation representative body for Europe and currently serves as the European hub of the IUCN SSC Fungal Conservation Committee (https://www.iucn-fungi.org/).

Citizen science projects

The ongoing globalization and rapid development of online tools have encouraged the development of projects including citizen scientists in the collation of fungal biodiversity data (Haelewaters et al. 2024). Through Survey 2, we identified 34 projects focused on 21 countries in Europe (Additional File 2: Table S2). The largest number of citizen science projects was reported from the Netherlands (6 projects), followed by Spain (3 projects) (Fig. 2D). Five projects focused on regional scales, while three projects covered multi-country activities. The "Phragmoproject" gathered records of jelly fungi in Belgium and the Netherlands (Schoutteten and Enzlin 2018). Mycoblitz Europe is a European-wide project that aims to map and barcode fungal species across Europe. It uses iNaturalist's "Umbrella Projects" tool as a platform (https://www.inaturalist.org/projects/european-mycoblitz).

Despite being one of the largest initiatives in Europe with 416 observers having contributed 35,029 observations (as of 14 August 2024), it is run by a single person.

The vast majority of citizen science projects reported in Survey 2 rely on the collection of fungal occurrence data. Only two of them are derived in structure (*sensu* Haelewaters et al. 2024), and asked volunteers or children to collect soil samples from residential gardens for the isolation of *Aspergillus fumigatus*, revealing potential health risks of exposure (Shelton et al. 2022), and the discovery and description of new species (Groenewald et al. 2018). Most projects are low-budget initiatives informally gathering (photo) observations; 59% of them deposit specimens in public fungaria (from the responses it was clear that some of the surveyed projects only deposit a small number of collected specimens). If fungal monitoring through the collection of specimens is a goal, then citizen science initiatives should strive to deposit specimens in fungaria, in accordance with best practices for fungal taxonomy (Aime et al. 2021).

It is important to note that the fungal citizen science activities presented in this section are a minority of all ongoing citizen science projects in Europe. Because both surveys were advertised concurrently, we likely surveyed only those citizen science projects that were aware of the importance of high-quality fungal data acquisition. This paper is only a starting point; we hope that more citizen science activities will be added to Survey 2 in a way that it will facilitate integration of fungal data records.

Towards better collaboration of mycological organizations in Europe

While Europe is a relatively small continent, it has a rich history, with 24 official languages (EEC Council 2013) and as many as 200 other languages spoken across the continent. In addition, high economic disparities can be observed across Europe, with minimum wages per month varying from €360 to €2,571 among countries (Eurostat 2024a). With more data in hand on mycological organizations on the European continent, these economic, cultural, and linguistic barriers should be explored to better address existing limitations in international collaboration of mycological groups. A limited understanding of multiple languages has already been identified as a barrier impeding collaboration between researchers from different countries (e.g., Haelewaters et al. 2021; Nuñez and Amano 2021). Therefore, we want to discuss possible ways to overcome these issues.

Integrating data

Several European initiatives aiming at the integration of data on fungal occurrences across the continent have been developed, leading to >26 million fungal occurrence records in the GBIF (Global Biodiversity Information Facility 2024). Although this is an impressive number, it probably is still far from complete and not nearly enough for accurate conservation assessments. Data integration towards a common European Red List of fungi has been ongoing for five decades, with several publications focused on fungal distribution data (Lange 1974; Dahlberg and Croneborg 2003; Fraiture and Otto 2015). The conference "Fungal Conservation in a Changing Europe: the Challenges Ahead" was jointly organized by ECCF and the International Society for Fungal Conservation (ISFC) in 2017. Also, Cybertruffle Foundation developed *Cyberliber* (http://www.cybertruffle.org.uk/cyberliber/), an open digital library of old mycological literature, and *Cybertruffle Robigalia* (http://ww

w.cybertruffle.org.uk/robigalia/eng), a database integrating data on fungal distributions with broader taxonomic scope. Even if it is limited in geographic coverage and it has not been updated for several years, *Robigalia* still is a valuable source of information. Recently, the Joint Network for wild Fungi (https://www.impel.eu/en/projects/joint-network-for-wild-fungi-jonef) was initialized to engage country-level monitoring agencies to integrate fungal distribution data. It is dedicated mainly to legislation issues dealing with fungal conservation, fungal monitoring, and the inclusion of fungi into Annexes I and V of the Habitats Directive (Council Directive 92/43/EEC of 21 May 1992).

Fungal occurrence data from different mycological organizations and citizen science projects remain dispersed. Infrastructural tools that can integrate these data and mobilize them to GBIF are urgently needed. The PlutoF biodiversity data management platform (https://plutof.ut.ee/) is one such tool that is currently being intensively tested in mycol ogy. Several projects across Europe use PlutoF to upload citizen science-sourced fungal specimens and observations (e.g., Mielke et al. 2025). The platform integrates specimen data with associated metadata and DNA barcodes, which can be also incorporated into the UNITE Species Hypotheses database (Kõljalg et al. 2020).

Integrating communities

Over the past few decades, there have been numerous initiatives to integrate mycologists globally and across the Europe continent more specifically. In 1971, the first edition of the *International Mycological Directory* (IMD) was published, aiming to provide lists of mycological societies by continent, fungaria, and living collections of fungi (Ainsworth 1971). Two more editions were published (Hall and Hawksworth 1990; Hall and Minter 1994). In 2008, the IMD became an online resource hosted by Cybertruffle (Minter 2008). Similar lists of mycological resources, including societies by continent, are hosted by the European Mycological Association (http://www.euromould.org/resources/index.html). The list of mycological societies was last updated in September 2019. Although these resources are important and useful, they merely serve as a starting point to develop more current and dynamic tools. This is crucial in a mycological landscape that is evolving quickly and less formal than in previous decades, shaped by the development of social media and citizen science tools and projects. Citizen scientists passionate about mycology often bring professional skills and expertise that are rare in academia, as well as valuable networks, thereby driving the dynamic growth of activities related to fungal diversity and conservation.

Currently, there are two pan-European mycological organizations to bring together mycologists across the continent: the European Mycological Association (EMA) and the European Council for the Conservation of Fungi (ECCF), which functions under the umbrella of EMA. While the ECCF is focused on promoting the conservation of fungi, EMA has a broader scope. It embraces all aspects of mycology and welcomes both academic and non-academic members, building on the tradition of Congresses of European Mycologists, organized since 1956. These congresses are organized every four years and still represent the most important meetings of pan-European mycological communities. EMA has also organized workshops and forays jointly with country-level societies. Although these initiatives have not continued to date, we hope that this paper can be an inspiration for the revitalization of these activities.

On the other hand, several regional meetings and symposia are organized jointly at the regional level. Joint, multi-organization mushroom forays are organized in the Nordic region (including Estonia, Iceland, and Scotland), Baltic countries (Estonia, Latvia, Lithuania), Austria and Germany, Belgium and the Netherlands (Cristella working group), Czechia and Slovakia, and on the Iberian Peninsula. The Confederación Europea de Micología Mediterránea (CEMM) organizes the annual European Mediterranean Mycology Days, which are held in different countries. Some of these regional activities have a very long tradition. For example, the Symposium of Baltic Mycologists (Estonia, Latvia, Lithuania) has been organized triannually since 1959. A unique multi-country collaboration is the Commission for Dutch names of Fungi, which governs the application of vernacular names of fungi in the Dutch language area, i.e., the Netherlands and the Flemish Region of Belgium. This commission is composed of representatives from both the Dutch Mycological Society and the Royal Flemish Mycological Society. In several cases, these regional collaborations may have been facilitated through common cultural history and linguistic background.

One of the ways to mitigate linguistic and cultural barriers is to organize activities bringing together mycologists and students from different cultural and linguistic backgrounds to actively engage with each other towards common goals. For example, a joint summer school program is organized by mycologists from Czechia, Denmark, Germany, and Poland. This program has already run for three years thus far, with more than 20 instructors, providing training to 125 students (mostly at the master-level) and increasing networking among future mycologists from eight countries in Europe. During summer schools, original data may be produced and result in scientific papers (e.g., Holec et al. 2023).

While the current landscape of mycological activities in Europe is complex and heterogeneous, we observe an increase in both the number of formal mycological societies (as descendants of learned societies) and citizen scientists interested in mycology (descendants of naturalists' clubs). Mycological societies could be leveraged to facilitate activities around common goals which include: (1) raising public awareness of fungi, (2) fungal data integration, (3) bringing together mycologists, mycophiles, and students from different backgrounds, and (4) the development of common standards for mycological research and communication. Ample opportunities exist to achieve these goals, ranging from joint multi-country forays, summer schools, training workshops, and symposia. We encourage mycological groups and societies to collaborate on joint actions and proposals and to act as facilitators of the integration of mycological activities across Europe.

Epilogue

Most great learning happens in groups. Collaboration is the stuff of growth.

— Sir Ken Robinson (UK).

This paper aimed to present the heterogeneity and multiplicity of mycological organizations focused on fungal diversity across Europe. As far as possible, we wanted to draw the general landscape avoiding any judgmental opinions. If certain organizations are not represented here, it was not on purpose. Because we are fully aware that not all fungal activities in Europe are included, both surveys mentioned in this paper will remain active for the foreseeable future. This paper already brought together many European mycologists, mycophiles, and mycological organizations, and we hope that in this way we can facilitate further collaboration.

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Data availability All data used for this paper are included in the Supplementary information. The Google Form "Characterizing mycological societies in Europe", referred to as Survey 1 in this paper, can be accessed through this link: https://forms.gle/fM5pVcNBF8f6NuB2A. The Google Form "Mapping mycological citiz

en science projects globally", referred to as Survey 2, can be accessed through this link: https://forms.gle/hFH77Pdi8j3Hm15D8.

Declarations

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