Macrofungi from the East Brook Valley of Delaware County New York, USA

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ABSTRACT — This study surveys the area of East Brook Farm, Walton, NY, for its macrofungi biodiversity in seven site locations over a five week period from July – August 2021. Macrofungi specimens were collected, photographed, described, and dehydrated for preservation in herbarium archives stored at Binghamton University. A total of 41 species were collected and described. Species descriptions, location details, and phylogenetic information are provided in this survey. The importance of citizen science and collaborative surveying is also discussed.

KEYWORDS —biodiversity, collaborative, citizen science, survey

Introduction

Macrofungi are generally described as fungi with macroscopic spore-producing bodies (Villeneuve et al. 1991; Schmit et al. 1999; Fazenda et al. 2008; Al-Thani 2010; Thiers and Halling 2018; Kinge et al. 2020). For the purpose of this study, the term macrofungi is defined to include all macroscopic non-lichenized species in Ascomycota and Basidiomycota, as well as members of the genus *Hypomyces* (Hypocreaceae, Ascomycota) with visible stromata.

Macrofungi are integral to the ecosystems they inhabit. Saprobic fungi decompose organic matter, facilitating soil aggregation and nutrient distribution (Lehmann and Rillig 2015). Parasitic fungi consume living matter and play crucial roles in maintaining biodiversity of the ecosystems they inhabit (Hudson et al. 2006). Mycorrhizal fungi facilitate communication and nutrient sharing among plants (Barto et al. 2012; Gorzelak et al. 2015; Simard 2018, Babikova et al. 2013). These fungi assist in the cycling of nitrogen, phosphorus, and carbon, and protect soil systems from nutrient loss (Veresoglou et al. 2012; Cavagnaro et al. 2012; Field and Pressel 2018; Parihar et al. 2019). Some species of ectomycorrhizal fungi also contribute to the resilience and regeneration of forests in response to disturbances such as drought (Pickles and Simard 2017), logging (Policelli et al. 2020), pests (Babikova et al. 2013), and heavy metal pollution (Krupa and Kozdrój 2007).

Globally, many species of macrofungi are facing habitat loss and unfavorable growing conditions due to human interventions such as logging of old growth forests, development, and climate change (Dahlberg et al. 2010; Grilli et al. 2017; Allen and Lendemer 2015), however the impacts of these human interventions on specific populations are generally unknown. Simultaneously, scientists have only officially recognized 120,000 species out of an estimated 1.5 to 3.8 million fungal species (Hawksworth and Lücking 2017). Therefore, it is likely that fungal species are going extinct before they are ever described (Irga et al. 2020; Lees and Pimm 2015).

Our research site is in the East Brook Valley, located in Delaware County, New York at the headwaters of the Delaware River watershed. It serves as a useful microcosm for the temperate deciduous forest biome of the Northeastern United States due to its wide variety of temperate forest and pasture habitats. Survey sites included hemlock, pine, birch, and maple dominant forests, with varying levels of current and past human and non-human disturbance. Some sites had been logged repeatedly, including some within the last 50 years. Other sites featured sufficiently steep slopes to discourage logging and had been disturbed only by water erosion and winds. While definitions of old growth forests are contested within ecological literature (Wirth et al. 2009), for the purposes of this study, we define old growth as an area that has not been subject to major human interventions or stand-replacing disturbances within the last 300 years. While some sites that we studied were sufficiently undisturbed to qualify as old growth, others were influenced strongly by anthropogenic forces. One site was a small wooded strip between the upper bank of the East Brook River and a county highway, affected both by periodic flooding and human activity such as traffic and litter. Our sites featured elevations between 400 m and 665 m, and were variously marked by water features such as seeps, springs, streams, and rivers. The myriad forest types and disturbance levels seen across our research sites provide a variety of ecological niches for fungi to inhabit.

This survey documents macrofungal biodiversity at a specific historical moment. Climate change has increased temperature, humidity, storm severity, and drought intensity throughout the Northeastern United States, and is predicted to continue to do so (National Academy of Sciences 2018). These changes have likely caused and will continue to cause ecosystem adaptations that will alter species community composition and may reduce fungal biodiversity (Pickles et al. 2012). Through the course of our research, we saw some of the predicted effects of climate change at our site. In 2021, Walton NY, the township encompassing our study site, experienced its wettest July on record. National Weather Data show 218% more precipitation than the mean, and 142% more precipitation than the next wettest July in 2018 (National Oceanic and Atmospheric Administration 2021). Changes to precipitation may alter fruiting patterns and ultimately fungal composition within forests.

Studies like ours write natural history, a subject which holds particular importance in moments of significant environmental change. Biodiversity surveys contribute to a body of environmental knowledge that can both measure the success of and bolster conservation efforts (Balmford and Gaston 1999; Halme and Kotiaho 2012; Irga et al. 2020).

Paucity of data is often cited to justify the absence of fungal conservation efforts. The United States Fish and Wildlife Service does not protect any non-lichenized fungal species under the Endangered Species Act (H.R.6133 1982). Globally only 31 countries have official fungal red lists, while another 10 have unofficial redlists; the United States has neither (Antonelli et al. 2020). The International Union for Conservation of Nature has assessed only 550 species of fungi for conservation status, as compared to 58,343 species of plants (IUCN 2022).

Given a dearth of dedicated mycology programs and limited funding (Irga et al. 2020), projects like The Fungal Diversity Survey (Sheehan 2020), the Lost and Found Fungi Project of the Royal Botanical Gardens of London (Antonelli et al. 2020) and Danish Fungal Atlas (Heilmann-Clausen et al. 2019) have used citizen science for data collection. The mycoflora project has distributed DNA barcoding materials to local mycology clubs, to support the production of a North American mycoflora database from citizen scientist contributions (northamericanmycoflora.org). A citizen scientist is defined as a volunteer who collects and/or processes data as part of a scientific inquiry (Silvertown 2009). The dearth of professional mycologists and funding for mycological research leaves a significant need for citizen scientists to assist with field surveys (Irga et al. 2020). Citizen science can raise public awareness of fungal conservation in addition to collecting useful empirical data for scientific research (Thaler et al. 2020, Irga et al. 2020).

This study is the product of a citizen science project in collaboration with Glomus Commune at East Brook Community Farm. One author of this paper is a PhD candidate at Binghamton University, six are undergraduate students, and another author has no institutional affiliation. Our classical sampling methods (Schmit and Lodge 2005) required no specialized knowledge or training, and our research required no specialized or costly equipment. We identified fungi by macroscopic features alone. While these methods limited the scope of our study, they are also accessible to the public and therefore easily replicable among other citizen scientists. Additionally, our open-ended sampling methods created a study that was deeply enmeshed in the environment of our study sites and allowed us to observe more species over a greater area than more constrained studies could while simultaneously using fewer resources.

Studies like ours are needed to document biodiversity in an era of mass extinction and limited funding for mycological research (Irga et al. 2020). Citizen science projects like ours contribute meaningfully to the body of mycological knowledge while simultaneously raising awareness of and interest in fungal conservation.

Materials and Methods

This survey took place over the course of five weeks, between July 13th − August 13th 2021, a period of time where the weather was seasonable enough to camp, in seven field sites in the East Brook Valley area. Samples were collected, documented, photographed, described, and preserved in herbarium collections stored at Binghamton University and online at The Open Repository @Binghamton (The ORB). Our seven field sites, along with the East Brook Valley as a whole, were geographically defined by the patterned flow of water through the landscape.

Brief notations on each survey site with longitudes and latitudes

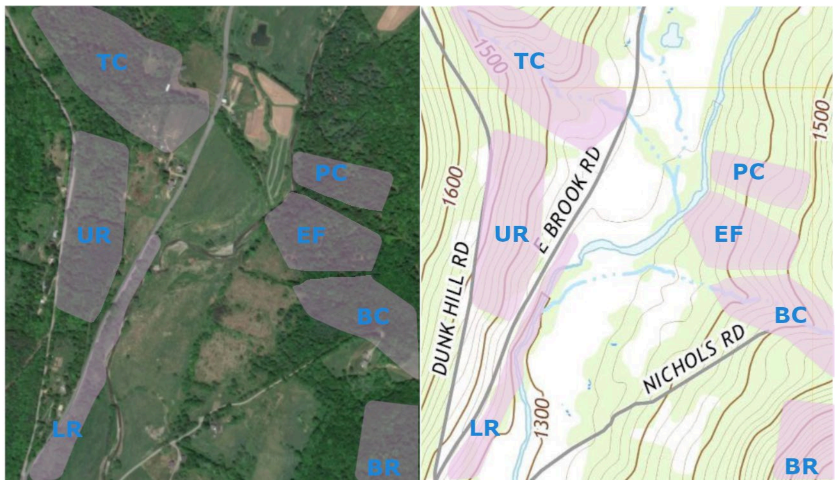

FIG 1. A map of sites studied, satellite image, left, and topographic map, right. Sites are numbered and listed below 1) TC - *Tsuga* Creek 2) UR - Upper Ridgeline 3) EF - *Ericaceae* Forest 4) LR - Lower Ridgeline 5) PC - *Pinus* Creek 6) BC - *Betula* Creek 7) BR - *Betula* Ridge

1) TC - *TSUGA* CREEK — 42.200219, −75.093243

The center of this study area is a stream draining many seeps and springs from Dunk Hill. The stream is nestled between steep ridges of bare silty clay loam soil, studded with dangling hemlock roots and *Kindbergia* spp. covered rocks and occasional *Athyrium*, *Oxalis*, and other small understory plants. The area is shaded by large, old hemlock (*Tsuga canadensis*) with occasional *Acer* spp., *Betula* spp., *Pinus resinosa*, *Fagus grandifolia*, and *Ostrya virginiana*. Some sections of the slopes are old growth due to the impracticality of logging on such steep terrain. On the flat tops of each slope are thick deposits of humus, composed mostly of *Tsuga* and *Pinus* debris.

2) UR - UPPER RIDGELINE — 42.197655, −75.094108

This study area is located on the ridge of Dunk Hill west of Dunk Hill Road. It's primarily characterized by the many seeps from the side of the hill, with muddy silty loam, and *Impatiens* spp. plants growing between the *Polytrichium*, *Climacium*, and *Dicranum* covered rocks. The northern half of the site is dominated by hardwoods such as *Acer* spp., *Crataegus monogyna*, *Betula* spp., *Prunus serotina*, *Malus domestica, Fagus grandifolia*, and *Fraxinus* spp. Glacial erratic boulders and *Rubus* brambles cover much of the ground, along with *Alliaria petiolata*, *Sanguinaria canadensis*, and *Geranium maculatum*. The southern portion is dominated by *Pinus resinosa* and *Pinus strobus*, and the forest floor is coated only with pine duff and fallen branches.

3) EF - *ERICACEAE* FOREST — 42.196969, −75.087752

This study site starts at the western ridge of the East Brook, following colonial stone walls uphill toward Betula Creek. Dominant shrubs include: *Gaultheria procumbens*, *Monotropa uniflora*, and *Vaccinium angustifolium*. On one side of the wall bisecting the area, the dominant trees are *Tsuga canadensis* and *Pinus* spp., while on the other side of the wall deciduous trees and ground cover understory plants abound.

4) LR - LOWER RIDGELINE — 42.195321, −75.093228

This site is a small strip between County Road 22 and the west side of the East Brook. Most of the area is hardwood dominant, featuring mostly *Malus domestica*, *Acer* spp., *Quercus rubra*, and *Ostrya virginiana*, though there is a small patch of *Tsuga canadensis* near a gravel pull-off on the road where passersby often dump trash and deer carcasses. Much of the hillside is quite steep, and the flatter banks next to the brook are covered with various grasses, *Solidago* spp*., Dennstaedtia punctilobula, Osmundastrum cinnamomeum, Onoclea sensibilis*, and other wetland plants. Significant swaths of the bank have been completely overtaken by *Reynoutria japonica.*

5) PC - *PINUS* CREEK — 42.198657, −75.086747

This study site is located east of the East Brook and north of *Ericaceae* Forest. The vast majority of the trees are *Tsuga canadensis* and *Pinus* spp., featuring very few scattered hardwoods. The ground is mostly covered in duff over loam, with occasional rocky seeps covered in *Kindbergia* spp. and *Hypnum* spp. The bank of the East Brook is steeply graded and features old growth *Tsuga* spp*.*

6) BC - *BETULA* CREEK — 42.194740, −75.084761

This site centers on a creek that drains from the western slope of Pine Hill into the East Brook. All the trees buffering the creek are hardwoods, including *Acer* spp., *Betula* spp., *Quercus rubra*, and many other tree species. South of the creek near Nichols Rd, there's a small patch of *Pinus* spp. including one very large and old *Pinus strobus* that has several trunks. Despite steep hillsides near the creek, there are a few large stumps south of the creek, suggesting that the area was logged at one point. Slopes are coated with hardwood leaf litter featuring few rocks. There are significantly more understory plants on the north side of the creek including *Arisaema triphyllum*, *Trillium* spp., *Cypripedium* spp., *Fragaria vesca,* and *Geranium maculatum.*

7) BR - *BETULA* RIDGE — 42.195160, −75.078761

A significant swath of this study site is dominated by *Betula alleghaniensis* and *Betula lenta*, and these trees are spread throughout the hill. Many different species of hardwood abound including *Acer* spp., *Fraxinus* spp., *Carya* spp., *Fagus grandifolia*, *Quercus rubra*, and *Populus* spp. There are many large glacial erratic boulders across the hillside, frequently holding small soil deposits and *Betula* spp. trees atop them. Bare rock faces are home to many foliose and crustose lichens and few bryophytes. The understory plants are diverse, and most notably dominated in sections by *Laportea canadensis*. This section of Pine Hill was notably lacking in seeps or other water features.

Survey Methods

We used classical methods (Schmit and Lodge 2005) to sample fruiting bodies for our research. Our sampling method was opportunistic, and allowed us to both gather and identify the maximum number of specimens in the short duration of our study.

Our research team surveyed, photographed, and collected mushrooms from seven different areas of the East Brook Valley. Field sites were defined based on natural geographic regions shaped by the waterways that feed the East Brook. Our team surveyed sites for an average of two hours at a time on regular excursions throughout the five-week duration of the research project, totaling approximately sixty hours. Sites were repeatedly sampled under different weather conditions to better observe the diversity of the region and the ephemeral macrofungi it holds. Mushroom specimens were observed and photographed before and after being collected. Identification took place in the field when possible.

Samples were preserved by dehydration at 110−115°F and dehydrated for up to twenty-four hours in an Excalibur dehydrator. Specimens were then organized and preserved in the project herbarium with their corresponding identification number. Our logged data of locations, photographs, and descriptions were then uploaded to the citizen science social network iNaturalist:

https://www.inaturalist.org/projects/macrofungi-of-the-east-brook-valley

Results

We found 31 genera of mushrooms and identified the following 41 species described below. Photographs and archival information for dried herbarium specimens can be found at:

https://orb.binghamton.edu/macrofungi_eastbrookvalley/index.html

Amanita frostiana (Peck) Sacc. (1877)

FIG 2. *Amanita frostiana* (Peck) Sacc. (1877)

MYCOBANK 212832

COLLECTION: TC - Tsuga Creek #02.01.02.2021

ECOLOGY: Mycorrhizal. Our specimens were found growing in hemlock and pine duff; in hardwood and coniferous forests.

DESCRIPTION: Cap begins as hemispheric and becomes more convex and eventually flat as mushroom ages; cap color ranging from bright yellow to bright orange with white, yellow, or orange warts. Gills free, white to cream-colored, close to crowded. Stipe pale to bright yellow with white to pale yellow volva at base and a white to bright yellow universal veil.

COMMENTS: The distribution of this species is widespread and potentially global. Sanmee et. al. (2008) reports that a specimen of *A. frostiana* was found in Thailand in 1962, but argues that that specimen was in fact the morphologically similar *A. rubrovolvata*. Further research is required to determine the phylogenetic relationship between the two species and their respective distributions. We are fairly certain that our specimens are *A. frostiana,* but it is possible that some or all of our specimens are in fact the morphologically similar *A. flavoconia. A. frostiana* possesses a whiter stipe and a lined cap margin as well as a more persistent volva. Spores of *A. frostiana* produce a negative amyloid reaction when exposed to Melzer's reagent (Leonard 2006).

Amanita muscaria* var. *guessowii (Veselý 1933)

FIG 3.* Amanita muscaria *var.* guessowii *Veselý (1933)

MYCOBANK 486234

COLLECTION: PC - Pinus Creek #02.01.04.2021

ECOLOGY: Mycorrhizal. Our specimens were found growing near dead pine trees among other species of *Amanita* mushrooms.

DESCRIPTION: The color of this mushroom differentiates it from other varieties of *A. muscaria*. It can be golden-yellow to orange in color and measures anywhere from 4−19 cm depending on how mature the specimen is. Early on, the cap is bulbous and later becomes convex as the mushroom matures. Cream-colored warts ornament the cap of the mushroom. A cream-colored veil is present on a stem that grows upwards of 12 inches in height and up to 1.5 inches in width. It has free, white gills that produce white spores.

COMMENTS: The species *A. muscaria* is a complex given that there are multiple variations that are found in different locations and temporal regions across the northern hemisphere (Michelot and Melendez-Howell 2003). The mushroom contains active ingredients muscimol and ibotenic acid, which cause psychedelic effects, and it has been used ritually across many cultures (Michelot and Melendez-Howell 2003).

Amanita rubescens* var. *alba (Coker 1917**)**

FIG 4. *Amanita rubescens* var. *alba* Coker (1917)

MYCOBANK 172158

COLLECTION: EF - Ericaceae Forest #02.01.05.2021

ECOLOGY: This species grows in mycorrhizal relation with various hardwoods and conifers, especially oaks. These specimens were found in association with *Tsuga canadensis*. Distributed throughout the northeast United States.

DESCRIPTION: Stem between 5−15 cm tall and 1−2 cm wide. Cap convex, flattening with age, and slightly sticky. Cap is white to cream colored with flushes of pink or red with age. Warts on cap vary from whitish-yellow to greyish-brown with a rough texture. This species has white, free gills that discolor red with age and are close or crowded. Volva is white with grey discoloration at the base of the stem. The partial veil is thin and flaky. Remnants of its universal veil can be seen by the warts atop the cap.

COMMENTS: Taxonomy in this genus can be problematic, especially with white varieties such as *Amanita rubescens,* because multiple species are morphologically similar and hard to distinguish (Ali 2018). The European version of *Amanita rubescens* var*. alba, Amanita rubescens f. alba,* was found for the first time in Greece in 2004 and is considered rare, while the North American variety found in this study is common (Gonou-Zagou 2011). Molecular research is necessary in order to understand whether or not these sub-species are morphologically indistinguishable, or just similar. While it is not possible to be fully confident in our identification of this fungus at the subspecies level without microscopy, our taxonomic understanding of this group remains at a higher resolution than most specimens observed.

Artomyces pyxidatus (Pers.) Jülich (1982)

FIG 5. *Artomyces pyxidatus* (Pers.) Jülich (1982)

MYCOBANK 110490

COLLECTION: EF - Ericaceae Forest #04.02.01.2021

ECOLOGY: Found in the Eastern United States, China, and Europe (Lickey et al. 2002). Saprobic, found on decaying hardwood in small clusters.

DESCRIPTION: Fruiting bodies up to 10 cm wide and 15 cm high with white crown-like tips at the top that have 4−8 points. Each cluster has dozens of white branches that are compounded stemming upward. Produces white colored spores.

COMMENTS: Analysis demonstrated that mycelia of *A. pyxidatus* occupying a single substrate could reach a measured size of 1.9 meters square (Tieken 2002).

Boletus subvelutipes (Peck) Bulletin of the New York State Museum (1827)

FIG 6. *Boletus subvelutipes* (Peck) Bulletin of the New York State Museum (1827)

MYCOBANK 170238

COLLECTION: TC - Tsuga Creek #05.04.01.2021

ECOLOGY: Widely distributed. Mycorrhizal with oak, found growing alone, scattered, or gregariously.

DESCRIPTION: Cap 5−9 cm wide; convex, dull orange in color, with a yellow margin, tacky when fresh. Pore surface yellow, bruising blue and ages to a blackish color. Stem 3.5−7 cm long, 1.5−2 cm thick, reticulate near cap.

COMMENTS: This species produces variegatic acid, which causes it to bruise blue, and was shown to have enzymatic deodorization properties (Negishi et al. 2000). In a study from Yunnan, China, fruiting bodies demonstrated significant bioaccumulation of heavy metals such as copper, iron, manganese, zinc, and lead, at significantly higher levels than the other species studied, *Amanita augusta* and *Macrolepiota procera* (Lalotra et al. 2016).

Boletinellus merulioides (Schwein) Murrill (1909)

FIG 7. *Boletinellus merulioides (Schwein.) Murrill (1909)*

MYCOBANK 100148

COLLECTION: EF - Ericaceae Forest #05.60.01.2022

ECOLOGY: Contested ecology, associated with *Fraxinus*. Grows gregariously. Widely distributed in Eastern North America.

DESCRIPTION: Cap 5−20 cm wide with irregular wavy margins, ochre to reddish-brown, tacky when wet and leathery when dry. Pores yellow, irregularly shaped with cross-veins, staining slowly blue then reddening over time. Stem 2−4 cm, off-center, same color as cap.

COMMENTS: *Boletinellus merulioides* is known for forming plentiful sclerotia in the Eastern region of North America (Cotter and Miller 1985). When germinated, the sclerotia collected in the forest formed mycelial colonies that had the same characteristics as colonies formed from sporocarps (Cotter and Miller 1985). This fungus was historically presumed to be ectomycorrhizal, however its primary host tree, *Fraxinus americana*, forms vesicular-arbuscular mycorrhizal connections, which was assumed to preclude ectomycorrhizal relationships (Nuhn 2016). Research has suggested a mutualistic relationship with the aphid *Prociphilus fraxinifolii* (Brundrett and Kendrick 1987); recent isotopic field analysis confirmed ectomycorrhizal relationships between *B. merulioides* and *F. americana*, but could not rule out honeydew from *P. fraxinifolii* as a potential carbon source (Nuhn 2016).

Bondarzewia berkeleyi (Fr.) Bondartsev & Singer 1941

FIG 8. *Bondarzewia berkeleyi* (Fr.) Bondartsev & Singer (1941)

MYCOBANK 293765

COLLECTION: BC - Betula Creek #06.05.01.2021

ECOLOGY: Parasitic and saprobic; usually growing on the base of hardwoods, both alive and dead. Widely distributed. *Bondarzewia berkeleyi* causes butt rot in the heartwood of the host tree which will eventually cause the wood to hollow out.

DESCRIPTION: The fruiting body of this polypore varies from 25−80 cm across and is composed of one to five individual fronds that narrow at the base. Each frond is irregular or kidney shaped, slightly convex, or flat. Flesh texture is dry, velvety, and often radially wrinkled, having zones of different colors or textures, usually off-white to tan, which does not bruise when damaged. White to off white pores run down the psudostipe. The spore print is white and turns yellow to red with KOH.

COMMENTS: Recently, *Bondarzewia berkeleyi* was found to contain a partitivirus and a mymonavirus, a novel discovery and the first to be described in this genus (Vainio and Sutela 2020). Additional research on this species is needed to understand the viruses it hosts. While this species and *Merulius eurocephalus* have morphological similarities, they are not the same species, as was once thought (Kumar and Harsh 2014).

Butyriboletus brunneus (Peck) D. Arora & J. L. Frank (2014)

FIG 9. *Butyriboletus brunneus* (Peck) D. Arora & J. L. Frank (2014)

MYCOBANK 803325

COLLECTION: PC - Pinus Creek #05.06.01.2021

ECOLOGY: Mycorrhizal with hardwoods, although found where conifers are present. Widely found in eastern North America, most often scattered or solitary, sometimes gregarious.

DESCRIPTION: Cap smooth to velvety, convex, red-brown in color, cap flesh stains blue. Pore surface bright yellow and sponge-like with very small pores, stains blue when first affected, then turns brown. Stipe finely reticulate, light yellow, becoming scarlet red towards the base; when exposed to KOH cap turns bright red and inner flesh turns reddish-brown. Taste not distinctive, slightly sour.

COMMENTS: The genus *Butyriboletus* was established in 2014 (Arora and Frank 2014); the species was formerly known as *Boletus speciosus* var. *brunneus*. Morphologically similar to *Butyriboletus peckii,* which is characterized by smaller reticulation on the stipe as well as a yellow coloration that turns red higher up the stipe.

Calocera cornea (Batsch) Fr. (1827)

FIG 10. *Calocera cornea* (Batsch) Fr. (1827)

MYCOBANK 237408

COLLECTION: EF - Ericaceae Forest #10.07.01.2021

ECOLOGY: Saprobic; growing on dead or decaying hardwood, especially oaks. Found widely in North America.

DESCRIPTION: Jelly fungi with small uniform yellow-orange fruiting bodies. Branching is sparse, with a pointed to softly round tip. Clusters often occur scattered, although can grow tightly packed. Fruiting body typically 2 cm tall and 3 mm thick. Texture of bodies is smooth, slick, and firm yet gelatinous.

COMMENTS: *Calocera cornea* has a global distribution, and has been observed on the Indian subcontinent (Swapna et al. 2008). This species has been shown to cause four distinct kinds of wood decay, three forms of brown rot, and one form of white rot (Seifert 1983). *C. cornea* is a member of a species complex with several other *Calocera* species. For example, *C. alba* may be a color variant of *C. cornea, C. mucida* may be the same species as *C. cornea,* and *Calocera subsimplex* may be as well (McNabb 1965). In order to properly identify these species, molecular research is necessary due to their morphologically similar traits and overlapping phylogenetic backgrounds.

Cerioporus leptocephalus (Bull.) Courtec. (1994)

FIG 11. *Cerioporus leptocephalus* (Bull.) Courtec. (1994)

MYCOBANK 812037

COLLECTION: EF - Ericaceae Forest, TC - Tsuga Creek #25.62.01.2021

ECOLOGY: Saprobic on hardwood; grows alone or scattered.

DESCRIPTION: Cap 2−7 cm, cream color to pale tan, flat, with an uplifted margin, round to kidney shaped. Pore surface runs onto stem, cream color with pale tan margin. Stem lateral, 1−1.5 cm in length, curved, tapered and black at base.

COMMENTS: This species has a global distribution, and has been well studied in Russia (Zmitrovich et al. 2016). This species has shown to have dual ecology as an "old-forest ecotype," a saprophytic inhabitant on natural, old, mesic forests, or as a "park ecotype" growing as a parasite on large scars left from cut or fallen branches (Niemelä and Kotiranta 1991).

Clitocybe odora (Bull.) P. Kumm (1871)

FIG 12. *Clitocybe odora* (Bull.) P. Kumm (1871)

MYCOBANK 190577

COLLECTION: TC- Tsuga Creek #35.09.01.2021

ECOLOGY: Saprobic, growing on the debris or leaf litter of hardwoods or conifers. Widely distributed. Grows scattered or in patches.

DESCRIPTION: Cap is smooth, convex with an enrolled margin, 2−11 cm long and a light blue-green color. With age, cap fades in color, becomes rougher, and margin becomes lined. Gills are attached and subdecurrent with the stem, crowded and off white to light pinkish. Stem 2−8 cm long, up to 16 mm thick, dry, whitish, slightly hairy, with basal mycelium. Spore print is creamy white to pinkish. The cap turns orange with KOH, and smells and tastes of anise when young.

COMMENTS: The anise scent in *C. odora* is due to the odorous component *p*-Anisaldehyde (Rapior et al. 2002). A novel mycovirus was found in *C. odora* that is similar to *Tanathephorus cucumeris,* but does not currently belong to any existing virus taxa (Heinze 2012). A study comparing and describing the bioactive compounds of several mushrooms found that *Clitocybe odora* has one of the highest ascorbic acid contents (172.65 mg/100 g) among the fungi studied (Vaz et al. 2011).

Entoloma salmoneum (Peck) Sacc. 1887

FIG 13. *Entoloma salmoneum* (Peck) Sacc. 1887

MYCOBANK 195880

COLLECTION: TC - Tsuga Creek #11.13.01.2021

ECOLOGY: Saprobic; growing in moss under conifers and sometimes hardwoods, often growing on decaying conifer logs. This specimen was collected in mossy leaf-litter under conifer trees. Widely distributed throughout Northeast America and Canada.

DESCRIPTION: Found growing alone or scattered. Cap is distinctively pointed, 1−3 cm wide, and vibrant orange-yellow in color, sticky when young and fading to dirty yellow-orange with age. Gills are attached to the stem, distant, often short, with similar coloration to the cap. The stem is likewise salmon colored, although often a darker or dirtier shade, 4−10 cm long, 2 mm thick, hollow, and fragile. At the stem base there can often be found a white to soft orange basal mycelium that connects to surrounding moss or leaf-litter. Odor and taste is not distinctive. Spore print is pink.

COMMENTS: This species is also known as *Entoloma quadratum, Rhodophyllus lactifluus, Inocephalus quadratus* and *Nolanea quadrata* as there is debate over these taxa and overlapping similarities (Kuo 2014). Molecular research is needed in order to properly differentiate these species. Having a singular species thought to be include in multiple genera is unusual, and should be subject to further investigation. This may suggest that the canonical phylogenetic relationships between these genera are inaccurate.

Exidia recisa (Ditmar) Fr. (1823)

FIG 14. *Exidia recisa* (Ditmar) Fr. (1823)

MYCOBANK 157929

COLLECTION: TC - Tsuga Creek #03.14.01.2021

ECOLOGY: Saprobic; found on hardwoods, especially oak. Found globally.

DESCRIPTION: Fruiting body length 2−3 cm, amber in color. No distinguishable stem, but the fruiting body is attached to the surface by a central point. Gelatinous and jelly-like, but holds its shape unless squeezed firmly. Wave-like structure with depressions that cave into the center.

Comments: The species is found worldwide, and one study found it to be abundant in the unburned forests of northwest Arkansas (Alshammari 2019).

Ganoderma tsugae (Murrill) (1902)

FIG 15. *Ganoderma tsugae* (Murrill) (1902)

MYCOBANK 239416

COLLECTION: TC - Tsuga Creek, PC - Pinus Creek #13.16.02.2021

ECOLOGY: Saprobic, or weakly parasitic; grows on dead or severely weakened eastern hemlocks.

DESCRIPTION: Polypore with bracket shelves that become wider and more shell-shaped as mushroom ages. Some specimens have a visible stem that extends perpendicular from the tree. Cap surface is lacquered. Color of the stem and part of the shelf closest to it ranges from dark brown to dark orange. Color becomes progressively more orange, then more yellow as the mushroom extends further out, and the outer edge is white. As the mushroom ages, the color changes first at the outer edge progressively more inward; the white becomes yellow, the yellow becomes more orange, and the orange becomes crimson until the entire mushroom ranges from brick red to deep crimson to deep brown. The hymenophore is covered with small pores that are originally white and darken to brown as the mushroom ages.

COMMENTS: *Ganoderma tsugae* is one species in a group of mushrooms known as reishi, which have long been used in traditional medicine, most notably in China (La Clair et al. 2011). Preliminary research has shown *Ganoderma tsugae* to be effective against allergic asthma (Chen et al. 2015), and ethanol extracts of the species have been found to mitigate prostate cancer cell growth (Huang et al. 2019).

Gymnopus dryophilus (Bull.) Murrill 1916

FIG 16. *Gymnopus dryophilus* (Bull.) Murrill 1916

MYCOBANK 438406

COLLECTION: UR - Upper Ridgeline, TC - Tsuga Creek, EF - Ericaceae Forest, PC - Pinus Creek #24.18.01.2021

ECOLOGY: Saprobic: collected on litter and leaves in both hardwood and coniferous dominant forests, as well as on the side of a fallen log. Globally distributed, found at multiple field sites (Vilgalys and Miller 1983; Vilgalys 1991; Hughes et al. 2010).

DESCRIPTION: Cap 1−7.5 cm, convex to flat, smooth, fleshy, ranging from tan to tawny, to an occasional russet brown. Stipe up to 10 cm long, under 1 cm thick but never wiry. Annulus and volva absent. Gills appearing adnexed to free, depending on sample age; Spore print white.

COMMENTS: Possible anti-inflammatory uses (Zeb and Lee 2021). One sample was collected from the side of a fallen log, despite the fact that many field guides describe *G. dryophilus's* substrate as leaf litter and thoroughly decayed wood exclusively (Kuo 2013a; Baroni 2017). *Gymnopus dryophilus* is sometimes considered to be a species complex due to morphological differences and mating intersterile groups from both North America and Europe (Vilgalys and Miller 1983; Vilgalys 1991; Alfredo et al. 2008). Without microscopic and genetic analysis, the multiple samples found at our field sites could not be identified down to specific variations, however the morphological range of our samples may be indicative of multiple variations within the area.

Helvella crispa (Scop.) Fr. (1882)

FIG 17. *Helvella crispa* (Scop.) Fr. (1882)

MYCOBANK 186148

COLLECTION: LR - Lower Ridgeline #16.19.01.2021

ECOLOGY: Alone or in clusters in hardwoods near hardwoods, on rotting wood or the ground; widely distributed in North America.

DESCRIPTION: Cap 1−5 cm wide, cartilaginous, white to cream with hints of yellow or pink, grainy texture, typically fused with stem only at top, occasionally saddle shaped, frequently with many irregular lobes, furry on underside, thin. Stipe ribbed, 3−10 cm long.

COMMENTS: Common throughout North America and Europe, although studies have cited its collection in South Africa as well (Anderson and Ickis 1921; Dissing 1966; Abbot and Curra 1997a; Abbot and Curra 1997b; Rasalanavho et al. 2019). Similar macrofungi collected in China have previously been identified as *H. crispa,* however recent studies found that these fungi are morphologically and phylogenetically distinct from samples collected in North America and Europe. They may represent a multitude of *Helvella* species (Zhao et al. 2015).

Hygrocybe flavescens (Kaufman) Siger (1951)

FIG 18. *Hygrocybe flavescens* (Kaufman) Siger (1951)

MycoBank 298661

Collection: TC - Tsuga Creek #18.21.02.2021

Ecology: Found growing near conifers on or around hardwood and humus. Can be found growing scattered or in clusters on both coasts of the continental United States.

Description: Yellow colored cap with a diameter of 2−7 cm. Convex in shape while young and flattens out as it matures. The cap is viscous and is sticky to the touch. Beneath the cap are pale-yellow gills that are broadly attached to the stem and are fairly close together. The stem reaches up to 10 cm in height and shares a similar color to the cap, growing paler near the base.

Comments: Can be confused with *H. chlorophana,* as they have a very similar appearance. The stem of *H. flavescens* is sticky as compared to *H. chlorophana.*

Hygrocybe miniata (Fr.) P. Kumm (1871)

Fig 19. *Hygrocybe miniata* (Fr.) P. Kumm (1871)

MycoBank 356816

Collection: TC - Tsuga Creek #18.21.03.2021

Ecology: Found growing near decaying hardwoods or conifers. Grows scattered or in clusters. Widespread range across North America.

Description: Scarlet-orange colored cap ranges from 2−4 cm in diameter and appears convex, then flattens as the mushroom matures. Stem reaches up to 6 cm in height and has a similar color to the cap, with a lighter colored base. Fairly distant gills with broad attachment to the stem that appear yellow, and produce a white spore print.

Comments: A Polish collection of *H. strangulatus* was previously known to be a synonym to *H. miniata* but spore examination revealed differentiation in spore shape, as they were not obpyriform like that of *H. miniata* (Ronikier and Borgen 2010).

Hypomyces camphorati Peck (1906)

FIG 20. *Hypomyces camphorati* Peck (1906)

MycoBank 211976

COLLECTION: TC - Tsuga Creek #20.23.01.2021

ECOLOGY: Parasitic on *Lactarius camphoratus.* Found under *Pinus* spp.

DESCRIPTION: Subiculum white turning yellow, completely covering hymenophore of host. Pileus deformed, irregular, more umbellate than host species, pinkish brown. Stipe lighter than cap with irregular darker zone where *Hypomyces* subiculum meets the stipe upper margin. Stipe shorter and wider than on non-parasitized *L. camphoratus*.

COMMENTS: Rogerson & Samuels (1994) treat *H. camphorati* as a synonym for *H. lateritius*, however they acknowledge that *Hypomyces* on *L. camphoratus* display "a yellowish subiculum and slightly larger ascospores." Genetic analysis is required in order to determine accurate speciation.

Hypomyces chrysospermus Tul. & C. Tul (1860)

FIG 21. *Hypomyces chrysospermus* Tul. & C. Tul (1860)

MYCOBANK 204359

COLLECTION: TC - Tsuga Creek, BR - Betula Ridge #20.23.02.2021

ECOLOGY: Parasitic on *Boletaceae.* Found under *Tsuga, Acer*, and *Betula.*

DESCRIPTION: Subiculum white, powdery, fluffy, turning yellow with age, covering pileus, stipe, and hymenophore on fully colonized specimens. Inner flesh soft, occasionally displaying guttation. Most host specimens are unrecognizable with the exception of one partially colonized *Leccinum* spp. (pictured).

COMMENTS: There are 10 recognized species of Boleticolous *Hypomyces.* The bright yellow coloration of older specimens is consistent with descriptions of *H. chrysospermus*, but microscopic analysis is required for confirmation of the species (Rogerson and Samuels 1994). *H. chrysospermus* is the teleomorphic stage of this unusual ascomycete, while the anamorphic stage is labeled *Sepedonium chrysospermus* (Rogerson and Samuels 1989). This distinction represents a vestige of dual nomenclature within mycology (Hawksworth 2011).

Hypomyces hyalinus (Schwein.) Tul. & C. Tul (1860)

FIG 22. *Hypomyces hyalinus* (Schwein.) Tul. & C. Tul (1860)

MYCOBANK 211382

COLLECTION: BC - Betula Creek, PC - Pinus Creek #20.23.03.2021

ECOLOGY: Parasitic on *Amanitas* (Rogerson & Samuels 1994). Likely *A. rubescens* and *A. frostiana* were hosts for our specimens. Found under *Pinus* and *Tsuga*.

DESCRIPTION: The teleomorphic form of this fungus deforms the host *Amanita*, resulting in a bulbous, occasionally shaggy stipe, a small subglobose cap, and a white subiculum covering the entire fruiting body. On *Amanita rubescens*, the subiculum occasionally retains pinkish brown staining from the host, between 10 and 20 cm high. On *Amanita frostiana,* coloration is tawny on the stipe and yellow on the pileus. Occasionally universal veil remnants ("warts") are still visible beneath subiculum on both hosts.

COMMENTS: Specimens recognized by coloration, stature, and proximity to non-parasitized fruiting bodies. No ascospore germination, nor consistently associated anamorphs, have yet been observed (Rogerson and Samuels 1994).

Hypomyces lactifluorum (Schwein.) Tul. & C. Tul (1860)

FIG 23. *Hypomyces lactifluorum* (Schwein.) Tul. & C. Tul (1860)

MYCOBANK 212693

COLLECTION: BC - Betula Creek #20.23.04.2021

ECOLOGY: Parasitic on *Russula* and *Lactarius* species (Harrison & Grund 1977), particularly members of the *R. brevipes* species complex (Laperriere et al. 2018). Found in mixed hardwood forest.

DESCRIPTION: Reddish orange subiculum forms a powdery coating on its host mushroom, deforming the shape of the pileus and covering the gills completely. Some specimens within the same patch displayed a white subiculum.

COMMENTS: Rogerson & Samuels (1994) delineate the white form as *Hypomyces macrosporus* based on a negative KOH reaction on the white parts compared to a purple KOH reaction on the red form, while Harrison & Grund (1977) label both forms as *H. lactifluorum* based on microscopic characters. Further research is needed to determine if these different phenotypes constitute separate species.

Hypomyces luteovirens Tul. & C. Tul (1860)

FIG 24. *Hypomyces luteovirens* Tul. & C. Tul (1860)

MYCOBANK 210237

COLLECTION: EF - Ericaceae Forrest #20.23.05.2021

ECOLOGY: Parasitic on *Russula*, found under *Acer*. Widely distributed in northern temperate regions.

DESCRIPTION: Subiculum yellow-green, covering hymenophore and stipe. Portions on the pileus turning dark green to grey-black with age. Pileus convex to concave, centrally depressed, irregular and conspicuously lined margin.

COMMENTS: *H. luteovirens* is macroscopically distinctive from other H*ypomyces* by its yellow-green coloration, and microscopically distinctive by its large ascospores and perithicial apex displaying moniliform chains of cells extending from the papilla surface (Rogerson & Samuels 1994).

Imleria badia (Vizzini) Fr. (2014)

FIG 25. *Imleria badia* (Vizzini) Fr. (2014)

MYCOBANK 550569

COLLECTION: EF - Ericaceae Forest #05.23.01.2021

ECOLOGY: Mycorrhizal with *Tsuga*, *Pinus,* and other conifers. Our sample was found in pine needle duff. In North America this species is most common in upper midwest, northeast, and the Appalachian mountain range.

DESCRIPTION: Cap convex, chestnut brown, sticky after rainfall, leathery when dry. Pores dull olive-yellow or off-white, bruising first blue, then turning brown. Stipe thick, with red reticulated pattern, becomes paler towards the base.

COMMENTS: *Imleria badia* is a popular edible mushroom. It contains the antioxidant compound theanine and other anti-inflammatory compounds, and is purported to have anti-cancer properties (Muszyńska et al. 2020).

Lactarius camphoratus (Bull.) Fr. (1838)

FIG 26. *Lactarius camphoratus* (Bull.) Fr. (1838)

MYCOBANK 233655

COLLECTION: TC - Tsuga Creek #28.26.01.2021

ECOLOGY: Mycorrhizal with conifers and hardwoods; found growing alone, scattered, or gregariously. Widely distributed in eastern North America. Often found on steep slopes.

DESCRIPTION: Cap 0.5−5 cm wide, convex, often becoming centrally depressed with age, smooth, moist to touch, centrally rusty brown, radially turning cinnamon to pale brown, to pale pink margins with age. Gills subdecurrent to decurrent; buff to pale pink, turning a darker pale cinnamon with age. Stipe 1.5−5 cm long; 0.5−1 cm thick. Pale rusty brown at base; buff to pale pink, becoming paler toward apex. Latex exudate color whitish to a watery white. Odor sweet, reminiscent of maple syrup. Odor becomes stronger when specimens are dried.

COMMENTS: The extract of this species has broad prospects of natural antiseptic uses (Ling et al. 2000).

Leotia lubrica (Scop.) Pers. (1797)

Fig 27. *Leotia lubrica* (Scop.) Pers. (1797)

MYCOBANK 168198

COLLECTION: TC - Tsuga Creek #21.28.01.2021

ECOLOGY: Saprobic; growing gregariously under hardwoods and conifers. Often found growing in moss, occasionally found on rotting wood. Widely distributed throughout North America.

DESCRIPTION: Cap 1−1.5 cm, convex with irregular lobes and undulations, with the margin rolled inward, bald. Texture sticky, color yellow to light ochre. Stem 1−2 cm long, 0.5 cm wide. Flesh gelatinous when fresh, and odorless.

COMMENTS: This species has been observed in Argentina, and throughout South and Central America. (Lorenzo and Messuti 2013). Research conducted in Central America indicates this species forms arbutoid mycorrhiza, a type of ericoid mycorrhiza distinguished by penetration of host cortical cells, and partners with a tropical woody plant *Comarostaphylis arbutoides.* (Kühdorf et al. 2015) Analyses of the three morphologically defined species, *L. lubrica, L. viscosa,* and *L. atrovirens* showed none of them to be monophyletic which indicates that there may be more genetic variation among *Leotia* than is commonly recognized. (Zhong and Pfister 2004).

Leotia viscosa *(*Fr.) (1822)

Fig 28. *Leotia viscosa (*Fr.) (1822)

MYCOBANK 191170

COLLECTION: TC - Tsuga Creek #21.28.02.2021

ECOLOGY: Saprobic; found in small clusters growing near conifers, on decaying hardwood or humus. Also found growing near moss. Widely distributed throughout North America.

DESCRIPTION: Cap is dark green and ranges from 1−3 cm in diameter. Viscid when young, hence its Latin name "viscosa," which translates to sticky. Stem reaches up to 6 cm in height, is white in color, and turns yellow as the mushroom matures.

COMMENTS: This mushroom shares similar characteristics to *L. lubrica,* and studies suggest that the cap color is not a reliable way to differentiate these species, as relatives *L. lubrica* and *L. atrovirens* likely polyphyletic (Zhong and Pfister 2004). Molecular data are needed for higher fidelity species identification.

Marasmius capillaris Morgan (1898)

FIG 29. *Marasmius capillaris* Morgan (1898)

MYCOBANK 150332

COLLECTION: EF - Ericaceae Forest, TC - Tsuga Creek #22.30.01.2021

ECOLOGY: Saprobic; samples collected from leaf litter in both hardwood and softwood dominant forests. Ecologically distinct from the morphologically similar *Mirasmius rotula* which grows exclusively on wood. Global distribution (Rout et al. 2020).

DESCRIPTION: Cap 5−20 mm, cream to light tan, often slightly translucent, pleated with a central depression. Stipe wiry, dark reddish-brown to black, turning yellow near cap. Gills are similar in color to cap, evenly spaced, thick, impacting cap surface texture, attaching to a ring around the stem. Fruiting bodies tend to grow in patches and clusters.

Marasmius pulcherripes Peck (1872)

FIG 30. *Marasmius pulcherripes* Peck (1872)

MYCOBANK 157758

COLLECTION: TC - Tsuga Creek #22.30.02.2021

ECOLOGY: Saprobic. Grows in clusters. Our sample was found growing on hardwood leaf litter, also commonly found on needle duff of conifers, especially *Pinus strobus*. Common throughout eastern North America.

DESCRIPTION: Cap < 1 cm, convex or bell-shaped, pleated, pale pink to light fuchsia cap with a darker pink point in the center. Stem is long, thin, wiry and dark colored. Gills are white or light pink and distantly spaced.

COMMENTS: Global distribution; found in countries such as South Korea (Cho and Chung 2020), India (Gogoi and Parkash 2015), and Cameroon (Enow 2013).

Marasmius rotula (Scop.) fr., (1838)

FIG 31. *Marasmius rotula* (Scop.) fr., (1838)

MYCOBANK 156778

COLLECTION: TC - Tsuga Creek #22.30.03.2021

ECOLOGY: Saprobic; samples collected from hardwood. This species is ecologically distinct from the morphologically similar *Mirasmius capillaris,* which grows exclusively on leaf litter.

DESCRIPTION: Cap 5−20 mm, cream to light tan, often slightly translucent, pleated with a central depression. Stipe wiry, dark reddish-brown to black, turning yellow near cap. Gills similar in color to cap, evenly and distantly spaced, thick, attaching to a ring around the stem. Pleated pattern of cap maps onto placement of gills. Tends to grow in patches and clusters.

COMMENTS: Distributed globally (Boskovic et al. 2019; Rout et al. 2020). Caps have been shown to yield high quantities of aromatic peroxygenase, an enzyme used in the synthesis of cyclophosphamide metabolites for toxicological studies on human cancer cells (Gröbe et al. 2011; Yarman et al. 2012; Steinbrecht et al. 2020).

Panellus stipticus (Bull.) P. Karst. (1879)

Fig 32. *Panellus stipticus* (Bull.) P. Karst. (1879)

MYCOBANK 355858

COLLECTION: TC - Tsuga Creek #23.33.01.2021

ECOLOGY: Saprobic; growing on dead and rotting hardwoods, often in shelving clusters. Global distribution.

DESCRIPTION: Cap 0.5−3 cm wide, convex, and has an enrolled margin with a semicircular to kidney shape. Cap is dry, smooth to velvety and often becomes cracked with age. Color ranges from off-white to brown. Gills end at the stem, are crowded, often forked or short, containing cross-veins, and are a light golden brown. Stem grows off center and is often indistinguishable from its cap. Taste is bitter. Spore print is off white. Gills bioluminescent when young.

COMMENTS: Commonly known as both the bitter oyster and the luminescent panellus, this species has several unique features. The origin of bioluminescence in the gilled mushrooms is understudied, but is hypothesized to be monophyletic (Oliveira et al. 2012). Luminosity in this species is inherited by a single pair of alleles, with luminosity being dominant over non-luminosity (Macrae 1942). More research is required to understand the phylogenetic history of luminescent fungi, their dominant characteristics, and their relationship with gilled fungi as a whole. *P. stipticus* has also been used in traditional Chinese medicine as a blood thickener (Hobbs 2003) and has shown the potential to be used in bioremediation (Sato et al. 2002).

Pleurocybella porrigens (Pers.) Singer (1947)

FIG 33. *Pleurocybella porrigens* (Pers.) Singer (1947)

MYCOBANK 289763

COLLECTION: TC - Tsuga Creek #22.34.01.2021

ECOLOGY: Saprobic; grows scattered or gregariously on decaying conifer logs, especially *Tsuga canadensis*, often accompanied by large patches of moss. Distributed worldwide.

DESCRIPTION: Cap 2.5−10 cm; shelf-like, fan-shaped, smooth, pliable, thin, fleshy and relatively fragile, color white to pale cream. Gills are white and crowded. Occasional pseudo stipe is present.

COMMENTS: Though a popular edible in Japan, *P. porrigens* caused fatal acute encephalopathy in 17 humans in the country in 2004 due to the presence of the toxic amino acid pleurocybellaziridine in the mushrooms (Wakimoto et al. 2011). It was found that of the 55 people affected in the outbreak, most were suffering from renal failure, likely causing an inability of their kidneys to filter out the amino acid (Kawaguchi et al. 2010).

Pseudohydnum gelatinosum (Bres.) Kobayasi (1954)

FIG 34. *Pseudohydnum gelatinosum* (Bres.) Kobayasi (1954)

MYCOBANK 352437

COLLECTION: PC - Pinus Creek #34.36.01.2021

ECOLOGY: Saprobic on the wood and debris of conifers. Found growing alone, scattered, or gregariously, sometimes in overlapping clusters.

DESCRIPTION: Cap 1−3 cm across, tongue-shaped to kidney-shaped, flat, tacky, translucent white, margin turned slightly inward when young. Hymenophore consists of spines that run down the stem, translucent white to pale gray. Stem up to 3 cm long. While some mushrooms found growing on sides of logs or on sticks have lateral or absent stems, those found growing on terrestrial woody debris have vertical stems, similar color to cap. Flesh translucent, gelatinous.

COMMENTS: The ontogeny of the gelatinous flesh of this species begins with mesh-like, non-gelatinous hyphal central tissue. As the hyphae grow, they begin to deteriorate, and a gel is produced. An exterior rind is formed encasing the gel discretion, which becomes denser and more gelatinous (Moore 1965).

Radulomyces copelandii (Bull.) P. Karst (1879)

FIG 35 *Radulomyces copelandii* (Bull.) P. Karst (1879)

MYCOBANK 355858

COLLECTION: EF - Ericaceae Forest #27.37.01.2021

ECOLOGY: Saprobic; growing on decaying hardwood logs or standing dead trees, especially *Quercus* and *Acer*. Global distribution.

DESCRIPTION: Fruiting bodies grow resupinate in the cracks of the wood they inhabit. No distinguishable cap, stem, or gills. Individual teeth are short, thin, and string-like, appearing as light-tan to brown, and usually in dense clusters. Individual teeth are approximately 1−2 cm long, but densely packed clusters can grow to 30 cm or more.

COMMENTS: Distribution of this fungus is not well understood. It was first reported in the United States in 2009 and has spread rapidly in the last decade (Roehl 2019). This species was once considered in the genera *Radulodon* but is now placed in *Radulomyces* (Nakasone 2001). This fungus bears the common name 'Asian beauty'.

Scleroderma citrinum (Pers.) (1801)

FIG 36. *Scleroderma citrinum* (Pers.) (1801)

MYCOBANK 181865

COLLECTION: EF - Ericaceae Forest #29.40.01.2021

ECOLOGY: Mycorrhizal fungi found growing on thoroughly decayed hardwoods and conifers and in the surrounding duff. This mushroom can be found in clusters or alone, and is widely distributed across North America.

DESCRIPTION: Fruiting bodies are 2−10 cm in diameter and can reach up to 4 cm in height. The exterior is covered in brown scales. The stem on this mushroom is absent, as it connects itself to the substrate using mycelial cords. The inside of the puffball harbors a purple-black spore mass that produces black colored spores.

COMMENTS: *S. citrinum* has been found to contain a 4,4'-Dimethoxymethyl vulpinate which was shown inhibit plant pathogenic fungi (Soytong et al. 2014).

Strobilomyces strobilaceus (Scop.) Berk. (1851)

FIG 37. *Strobilomyces strobilaceus* (Scop.) Berk. (1851)

MYCOBANK 238002

COLLECTION: BR - Betula Ridge #05.44.01.2021

ECOLOGY: Mycorrhizal with hardwoods, especially *Quercus*, growing alone, scattered, or gregariously. Widely distributed.

DESCRIPTION: Cap 5−10 cm, convex to broadly convex, whitish to light gray, covered with erect fibrillose, black scales, margin hung with the remains of a partial veil. Pore surface buff, and covered with a thin whitish membrane when young, turning grayish to brown with age. Stem 4−10 cm long, buff, reticulate near apex, dark gray and shaggy when young, with remains of partial veil. Flesh white throughout, turning reddish brown when sliced or bruised. No distinctive odor.

COMMENTS: DNA sequencing has detected 14 distinct lineages among *Strobilomyces* species. All 14 of the detected lineages share morphological characteristics, making it difficult to definitively identify this species (Sato et al. 2007) In North America, the name *Strobilomyces strobilaceus* is contested, and may be replaced with *Strobilomyces floccopus* due to differences between North American and European samples (Kuo 2013b). It is likely there are new species of *Strobilomyces* on the North American continent, and identifications of this species should be seen as tentative until further studied using DNA sequencing.

Suillus granulatus (L.) Roussel (1806)

FIG 38. *Suillus granulatus* (L.) Roussel (1806)

MYCOBANK 291277

COLLECTION: TC - Tsuga Creek #32.45.01.2021

ECOLOGY: Mycorrhizal with *Pinus* spp. Found growing alone or gregariously. Widely distributed.

DESCRIPTION: Cap 3−7 cm, broadly convex, slimy, and buff in color. Pore surface buff, quickly turning yellowish with age, non-bruising, pores about 1 mm wide. Stem 3−4 cm long, 1−1.5 cm thick, white turning to yellow, with tiny brown glandular dots on the upper half and with brighter yellow color near the apex.

COMMENTS: Research on tetraprenyl-phenol extracts from this species indicated possible antimicrobial and antitumor properties (Triangali et al. 1989)

Tapinella atrotomentosa (Batsch) Sutara (1992)

FIG 39. *Tapinella atrotomentosa* (Batsch) Sutara (1992)

MYCOBANK 360246

COLLECTION: PC - Pinus Creek #33.46.01.2021

ECOLOGY: Saprobic; commonly growing on conifers. Our sample was found on decaying *Tsuga canadensis*. Widely distributed in North America.

DESCRIPTION: Cap velvety and slightly convex to vase-shaped, dark brown in center, fading to tan on outer edges. Thick stem with velvety fuzz, dark brown to dark tan. Gills decurrent, close, white to pale tan in color.

COMMENTS: This species has been observed in Central Europe and is commonly mistaken for *Paxillus involutus* (Sutara 1992). Several compounds extracted from *Tapinella atrotomentosa* were found to have antioxidant effects (Béni et al. 2018).

Trametes versicolor (L.) Lloyd (1920)

FIG 40. *Trametes versicolor* (L.) Lloyd (1920)

MYCOBANK 281625

COLLECTION: EF - Ericaceae Forest #25.47.02.2021

ECOLOGY: Saprobic; commonly found on decaying tree trunks, branches, and logs. We collected multiple samples that were found on decaying tree trunks and branches. *T. versicolor* has a wide distribution and can be found across North America as well as parts of Asia and Europe.

DESCRIPTION: Found in shelf-like clusters that can range from 2−10 cm in length. Has grayish-brown layers of color with white ends, although specimens in other regions may have more diverse coloration. This fungus is thin and has a pliable texture when freshly picked but turns stiff when left to dry. Has a non-distinctive taste. Hymenophore creamy white, with small pores. Produces white spores.

COMMENTS: This white rot fungus uses laccase to oxidize lignins in wood (Jönsson et. al. 1995). The polysaccharide peptide Krestin, found in *T. versicolor,* is believed to play a positive role in both concurrent and adjuvant treatment for breast cancer patients (Standish et al. 2008).

Trichaptum biforme (Fr.) Ryvarden (1972)

FIG 41. *Trichaptum biforme* (Fr.) Ryvarden (1972)

MycoBank 324867

Collection: UR - Upper Ridgeline #25.49.01.2021

Ecology: Saprobic: found growing on conifer trees. Fruiting bodies can be found year-round. Distribution is widespread. This is one of the most common fungi in eastern North America.

Description: Fruiting bodies range from 1−4 cm in length and are slightly convex. Cap surface velvet to smooth in texture, often striped white and brown, with violet margins. Hymenophore surface covered in small pores, maturing to toothed surface with age, often tinged with violet coloration. Stipe absent. Spore print white.

Comments: Extracts from *Trichaptum biforme* have been found to be effective antimicrobial agents against several species of Gram-negative bacteria (Chikwem et al. 2020).

Xylaria polymorpha (Pers.) Grev. (1824)

Fig 42. *Xylaria polymorpha* (Pers.) Grev. (1824)

MycoBank 246876

Collection: UR - Upper Ridgeline #36.52.01.2021

Ecology: Saprobic; our sample was found growing on decaying hardwood while other clusters appeared to grow terrestrially, most likely on decaying wood buried beneath the topsoil. Widely distributed throughout North America.

Description: Fruiting bodies 4−10 cm tall, initially white in color, and becoming more gray and later black as they mature. This mushroom has a slightly rough texture with an undifferentiated cap and stem. Flesh hard and firm. The odor and taste of *Xylaria polymorpha* is not distinctive. The spores are dark brown or black (Baroni 2017).

Comments: Extracts from this species have been found to have antimicrobial activity against several bacterial species including *E. coli*, *S. aureus*, *Pseudomonas aeruginosa*, and others (Hacioglu et al. 2011). Distinction between *X. polymorpha* and *X. longipes* or *X. schweinitzii* requires microscopy.

Additional taxa

In addition to the species described above, a number of species were found that could only be identified to the genus level. Many specimens require molecular research or microscopic analysis for proper identification. Without these tools, several specimens could not be firmly placed in a specific species. Table 1 lists all the fungi documented by our survey and then housed at Binghamton University. While not all observed fungi were identified to the species level or fully described, they are nonetheless documented here and assigned an identification number for future studies. There are a total of 41 families, 60 genera, and approximately ~90 species documented in our surveys of the East Brook Valley.

TABLE 1. Observations / collections of mushrooms with herbarium number.

Family	Genus	Species	Identification #
Agaricaceae	*Lychoperdon*	*Lycoperdon perlatum*	01.29.01.2021
		Lycoperdon pyriforme	01.29.02.2021
Amanitaceae	*Amanita*	*Amanita biosporigera*	02.01.01.2021
		Amanita flavoconia	02.01.07.2022
		Amanita frostiana	02.01.02.2021
		Amanita frostiana	02.01.02.2022
		Amanita fulva	02.01.03.2021
		Amanita muscaria var. *guessowii*	02.01.04.2021
		Amanita rubescens var. *alba*	02.01.05.2021
		Amanita spp.	02.01.06.2021
		Amanita spp.	02.01.06.2022
Auriculariaceae	*Exidia*	*Exidia recisa*	03.14.01.2021
Auriscalpiaceae	*Artomyces*	*Artomyces pyxidatus*	04.02.01.2021
Boletaceae	*Boletellus*	*Boletellus chrysenteroides*	05.03.01.2021
	Boletinellus	*Boletinellus merulioides*	05.60.01.2022
	Boletus	*Boletus subvelutipes*	05.04.01.2021
	Butyriboletus	*Butryiboletus brunneus*	05.06.01.2021
	Imleria	*Imleria badia*	05.24.01.2021
	Leccinum	*Leccinum* spp.	05.27.01.2021
	Strobilomyces	*Strobilomyces strobilaceus*	05.44.01.2021
	Tylopilus	*Tylopilus rubrobrunneus*	05.51.01.2021
Bondarzewiaceae	*Bondarzewia*	*Bondarzewia berkeleyi*	06.05.01.2021
Cantharellaceae	*Cantharellus*	*Cantharellus* spp.	41.61.01.2021
		Cantharellus spp.	41.61.02.2022
Clavariadelphaceae	*Clavoriadelphus*	*Clavoriadelphus* spp.	37.54.01.2021
Clavulinaceae	*Clavulina*	*Clavulina cristata*	07.08.01.2021
Cortinariaceae	*Cortinarius*	*Cortinarius* spp.	38.55.01.2021
Crepidotaceae	*Crepidotus*	*Crepidotus applanatus*	08.10.01.2021
Cudoniaceae	*Spathulariopsis*	*Spathulariopsis velutipes*	09.43.01.2021
Dacrymycetaceae	*Calocera*	*Calocera cornea*	10.07.01.2021
	Dacrymyces	*Dacrymyces chrysospermus*	10.11.01.2021
Entolomataceae	*Entoloma*	*Entoloma salmoneum*	11.13.01.2021
Fomitopsidaceae	*Daedalea*	*Deadalea quercina*	12.12.01.2021
	Fomitopsis	*Fomitopsis betulina*	12.15.01.2021
Ganodermataceae	*Ganoderma*	*Ganoderma applanatum*	13.16.01.2021
		Ganoderma tsugae	13.16.02.2021
Geoglossaceae	*Glutinoglossum*	*Glutinoglossum* spp.	14.17.01.2021
Gomphaceae	*Turbinellus*	*Turbinellus floccosus*	15.50.01.2021
Helvellaceae	*Helvella*	*Helvella crispa*	16.19.01.2021

Hydnaceae	*Hydnum*	*Hydnum* spp.	17.20.01.2021
		Hydnum spp.	17.20.02.2022
Hygrophoraceae	*Hygrocybe*	*Hygrocybe cantharellus*	18.21.01.2021
		Hygrocybe flavescens	18.21.02.2021
		Hygrocybe miniata	18.21.03.2021
Hymenochaetaceae	*Inonotus*	*Inonotus obliquus*	19.25.01.2021
Hypocreaceae	*Hypomyces*	*Hypomyces camphorate*	20.23.01.2021
		Hypomyces chrysospermus	20.23.02.2021
		Hypomyces hyalinus	20.23.03.2021
		Hypomyces lactifluorum	20.23.04.2021
		Hypomyces luteovirens	20.23.05.2021
		Hypomyces spp.	20.23.06.2021
Leotiaceae	*Leotia*	*Leotia lubrica*	21.28.01.2021
		Leotia viscosa	21.28.02.2021
Marasmiaceae	*Megacollybia*	*Megacollybia rodmani*	22.31.01.2021
	Pleurocybella	*Pleurocybella porrigens*	22.34.01.2021
	Marasmius	*Marasmius capillaris*	22.30.01.2021
		Marasmius pulcherripes	22.30.02.2021
		Marasmius rotula	22.30.03.2021
Mycenaceae	*Panellus*	*Panellus stipticus*	23.33.01.2021
	Mycena	*Mycena leaiana*	23.32.01.2021
		Mycena spp.	23.32.02.2021
		Mycena spp.	23.32.03.2021
		Mycena spp.	23.32.04.2021
Omphalotaceae	*Gymnopus*	*Gymnopus dryophilus*	24.18.01.2021
Physalacriaceae	*Hymenopellis*	*Hymenopellis* spp.	43.59.01.2022
Pluteaceae	*Pluteus*	*Pluteus cervinus*	42.58.01.2022
		Pluteus chrysophlebius	42.58.02.2022
Polyporaceae	*Trichaptum*	*Trichaptum biforme*	25.49.01.2021
	Polyporus	*Polyporus radicatus*	25.35.01.2021
		Polyporus radicatus	25.35.01.2022
	Royoporus	*Royoporus badius*	25.53.01.2022
	Trametes	*Trametes hirsute*	25.47.01.2021
		Trametes versicolor	25.47.02.2021
	Cerioporus	*Cerioporus leptocephalus*	25.62.01.2021
Pyronemataceae	*Scutellinia*	*Scutellinia scutellate*	26.41.01.2021
Radulomycetaceae	*Radulomyces*	*Radulomyces copelandii*	27.37.01.2021
Russulaceae	*Lactarius*	*Lactarius camphoratus*	28.26.01.2021
		Lactarius spp.	28.26.02.2022
	Russula	*Russula emetica*	28.39.07.2022
		Russula fragrantissima	28.39.01.2021
		Russula rosea	28.39.02.2021
		Russula spp.	28.39.03.2021
		Russula spp.	28.39.04.2021
		Russula spp.	28.39.05.2021
		Russula spp.	28.39.06.2021
Sclerodermataceae	*Scleroderma*	*Scleroderma citrinum*	29.40.01.2021
Sebacinaceae	*Sebacina*	*Sebacina schweinitzii*	30.42.01.2021

	Tremellodendron	*Tremellodendron pallidum*	30.48.01.2021
Suillaceae	*Suillus*	*Suillus granulatus*	32.45.01.2021
		Suillus spraguei	32.45.02.2021
Tapinellaceae	*Tapinella*	*Tapinella atrotomentosa*	33.46.01.2021
Thelephoraceae	*Thelephora*	*Thelephora* spp.	40.56.01.2021
Tremellaceae	*Pseudohydnum*	*Pseudohydnum gelatinosum*	34.36.01.2021
Tricholomataceae	*Clitocybe*	*Clitocybe odora*	35.09.01.2021
	Resupinatus	*Resupinatus alboniger*	35.38.01.2021
Xylariaceae	*Xylaria*	*Xylaria polymorpha*	36.52.01.2021

Discussion

This study documented the fruiting of macrofungi within the East Brook Valley in July and August of 2021. During this period we documented 41 species across 31 genera, 23 families, 10 orders, 5 classes, and 2 phyla (see Figure 43 below).

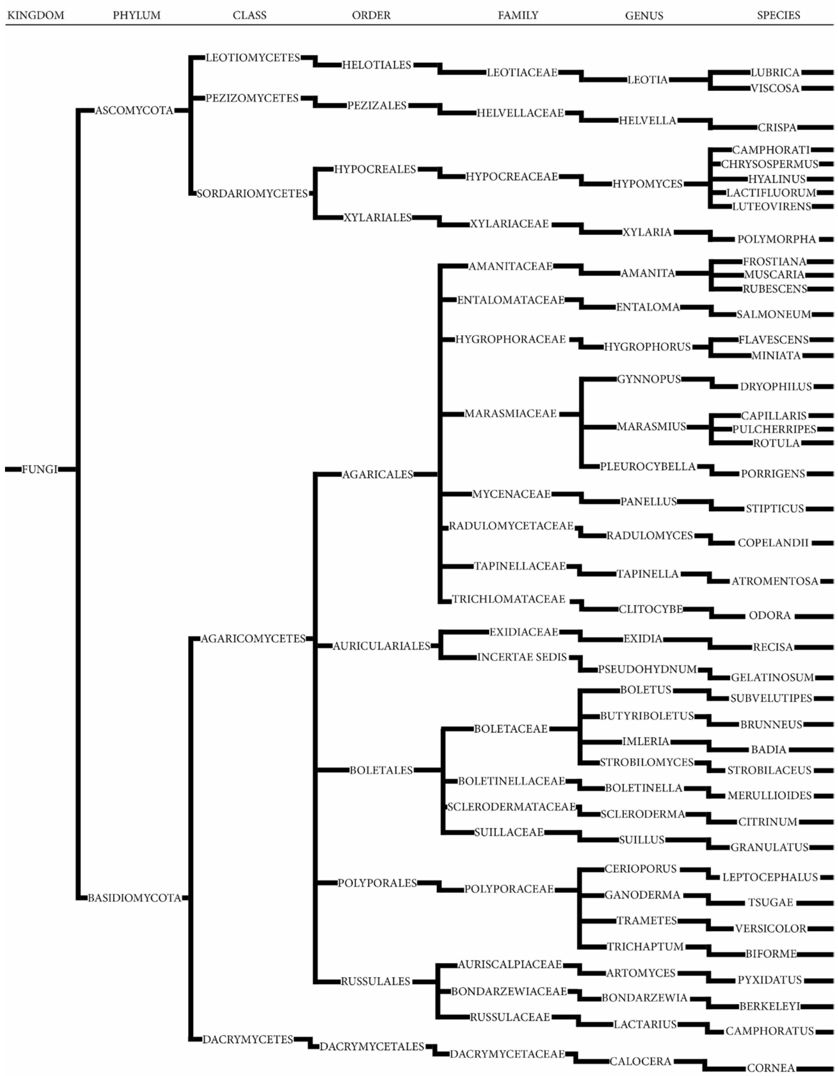

FIG 43: A phylogeny of all macrofungi observed during the study.

Our results are a useful contribution to the body of knowledge regarding fungal distribution, as well as a model for future small scale citizen science projects. This empirical documentation of fungi is useful during an era of mass extinction, and could ultimately contribute to fungal conservation efforts.

Our study is limited by our focus on the fruiting bodies of macrofungi and our opportunistic sampling methods, however these methods have significant advantages for a project of this scope. While studies utilizing soil samples to document fungal diversity are able to more reliably document all soil-inhabiting fungi present, they can be prohibitively costly, do not reflect which species are fruiting, and fail to capture lignicolous species (Schmidt and Lodge 2005). Likewise, our use of classical methods of macroscopic fungal taxonomy, rather than DNA-based research, has both limitations and benefits. While PCR sequencing could have increased the accuracy of our macroscopic identifications, sequencing is prohibitively costly (Baldrian et al. 2022). Morphological taxonomic classification still has its place, and species lists found in classical studies like ours regularly provide useful data for meta-analysis (Schmidt and Lodge 2005). While our opportunistic sampling methods limit the quantifiability of our data, and may have caused us to overlook more inconspicuous and cryptic fungi, they allowed us to identify the maximum number of charismatic fungal species (Schmidt and Lodge 2005), which are better able to generate public interest in fungal conservation (Irga et al. 2020).

Our research methods allow us to bridge the gap between amateur and academic mycology. Of this paper's authors, only Theresa Kadish has academic training in mycology. Jules Amanita Griffin's taxonomic field knowledge is self-taught, and the rest of the authors were trained in the field by Kadish and Griffin. Our collective level of expertise, rather than solely being a handicap, also allowed us to conduct this study with significantly lower operation costs than comparable surveys. Due to the lack of funding for mycological research, there are fewer mycologists who receive institutional support than there are botanists, zoologists, or microbiologists (Irga et al. 2020). However, there are many knowledgeable and dedicated amateur mycologists who are members of local mushroom clubs, overarching organizations such as the North American Mycological Association, and online forums such as iNaturalist, Mushroom Observer, and Facebook Groups who are capable of robust mycological inquiry at low cost (Irga et al. 2020). These citizen scientists have been commissioned by projects such as the Lost and Found Fungi Project in the UK (Douglas et al. 2018) and the Fungal Diversity Survey in the United States (Sheehan 2020). These citizen science projects engage in mycological inquiry that is simultaneously both rigorous and accessible to non-scientists.

Projects like ours that center on citizen science contributions have the power to shape public perception of fungi. According to David Arora, North American culture has inherited a fear of and disgust for fungi from British culture (Arora 1986). He asserts that this fungiphobia, also called mycophobia (Kaishian and Djoulakian 2020), derives from an association of fungi with death and decay, which entirely ignores the important role of mycorrhizal fungi in the survival of forests, grasslands, and other plant communities. Often, conservation decisions are driven by public sentiment directed at some popular species to the exclusion of others, rather than a gestalt understanding of the ecosystems in need of protection (Irga et al. 2020). Engaging in fungal biodiversity surveying with citizens helps shift conservation narratives towards full ecosystems and our interactions with them.

Despite widespread mycophobia, the gaining popularity of celebrity mycologists and accessible mycological literature may be improving public perception of fungi. Bestselling books like Mycelium Running by Paul Stamets, Entangled Life by Merlin Sheldrake, and Finding the Mother Tree by Suzanne Simard demonstrate that there is a widespread and growing interest in mycology (Stamets 2005; Sheldrake 2021; Simard 2021). Additionally, social media such as Instagram and TikTok provide a platform to connect professional and amateur mycologists with interested members of the public. Both Kadish and Griffin have a significant social media presence within the mycology niche of TikTok, and other creators such as Alexis Nicole Nelson, Dr. Gordon Walker, and Gabrielle Cerberville frequently post content on TikTok and Instagram educating the public about fungi. Research like ours can introduce myco-curious individuals to a vast body of mycological knowledge and encourage further scientific research and conservation work.

In addition to its use of citizen science research methods, our study is significant in its documentation of natural history in this specific historical moment. Climate change is drastically altering the ecosystems of the northeast, which will likely in turn alter fungal biodiversity (Hawksworth and Lücking 2017). Climate change is predicted to result in increased rainfall in Northeastern North America (National Academy of Sciences 2018), and indeed, we observed record rainfall during the 2021 collection phase of our study (National Oceanic and Atmospheric Administration 2021). Simultaneously, the increasing range of southern trees and decline of northern native trees (Iverson et al. 2008) may cause some specialist mycorrhizal, saprobic, and parasitic fungi to decline with their hosts, while also introducing new specialist fungi to the region (Bennett and Classen 2020).

While the IUCN has evaluated some North American fungi for conservation status through the Fungal Red List Project, the Endangered Species Act still does not protect any non-lichenized fungi (Allen and Lendemer 2015). Given the lack of government interest in fungal conservation, independent researchers like the authors of this study are needed to gather the raw data required for conservation decisions (Irga et al. 2020).

Research like ours also draws attention to fungi as non-timber forest products. We found several fungi that have been studied for potential medicinal properties, such as *Ganoderma tsugae* (La Clair et al. 2011) and *Trametes versicolor* (Standish et al. 2008). Though further research is required to understand the impact these fungi can have on human health, they are already part of a multibillion-dollar wellness industry (Chang 2006). Additionally, ten of the fungal species we found are good or “choice” edibles, several with existing commercial markets such as *Cantharellus* spp., *Hypomyces lactifluorum*, and *Lactarius camphoratus.* Non-timber forest products demonstrate the economic value of intact forests, including old growth, which may otherwise only be considered valuable if logged (Arnold and Pérez 1998). Increasing awareness of non-timber forest products could contribute positively to forest conservation (Arnold and Pérez 1998), however more research on harvesting practices is required in order to ensure the sustainable harvesting of these products (Alexander and McLain 2001).

Finally, our macrofungi observations suggest novel cladistic questions. We found several fungi, such as *Hypomyces camphorati* and *Leotia lubrica / Leotia viscosa*, that require further research in order to establish reliable speciation. Some of the mushrooms we found may be moved to different genera as more fungal genomes are sequenced and analyzed. Macroscopic taxonomy like that performed in our study would be ideally paired with molecular analyses of taxonomically informative gene regions of samples from a variety of field sites in order to establish a thorough understanding of phylogenetic diversity within this collection. We anticipate that the samples preserved in our herbarium at Binghamton University will be of use to future scientists approaching these phylogenetic questions using molecular analysis.

In summary, this study created an educational environment that allowed amateur mycologists to document the fungal biodiversity of the East Brook Valley. Our research methods were highly replicable, and provide a model for citizen science engagement elsewhere in the world. This study contributes data for future meta-analyses about the distribution and taxonomy of the species we found, which will hopefully lead to future conservation efforts.

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