Macrofungi from the Hebron and Jerusalem Hills of Palestine

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ABSTRACT—This study is based on specimens of macrofungi collected from biodiversity hotspots in the southern West Bank of occupied Palestine during a four-week survey period in December and January 2018–19. We identified 27 macrofungi species representing 39 genera from six field sites. Samples were collected, photographed, and archived in the Palestine Museum of Natural History herbarium. Species descriptions, field site details, and a cladogram of the observed fungi are provided. The importance of citizen science and accessible taxonomic inquiry is also discussed.

KEYWORDS—diversity, taxonomy

Introduction

Macrofungi are a polyphyletic fungal group which have spore-bearing structures visible to the naked eye (mushrooms, brackets, puffballs, cup fungi) and there are estimates of 53,000–110,000 species worldwide (Mueller et al et al. 2007). Macrofungi typically fall under one of three clades: Basidiomycota, Ascomycota, and (occasionally) Zygomycota. Finer cladistic resolution, especially at the species level, is notoriously difficult to obtain with certainty but advances in DNA sequencing technology have expanded knowledge dramatically (Hibbet et al. 2016). But as our phylogenetic knowledge of macrofungi is increasing, climate change, habitat loss, and other anthropogenic forces are driving many species to extinction before they are even described (Lees and Pimm 2015).

Macrofungi diversity in most western Asian regions remains understudied, but in recent years a handful of studies have been published in the region including Iran (Amoopour et al. 2016), Turkey, (Kaya 2009, Acar et al. 2015), Iraqi Kurdistan (Suliaman et al. 2017, Toma et al. 2013), Saudi Arabia, (Abou-Zeid & Altalhi 2006), Jordan, (Al Momany 2018), Egypt (Abdel-Azeem 2010), and Syria (Abdel-Hafez 1983). Many of these studies comment on the paucity of mycological data and need for additional studies.

Indeed, some key regions remain completely unstudied. For example, in a recent survey of *Morchella* and *Helvella* in Israel, Barseghyan & Wasser (2008) shows collections mostly in the Galilee and coastal areas of Historic Palestine but largely excluded collections from the occupied West Bank; and the few samples included from the region were all collected prior to 1971. The ecology of the occupied West Bank has deteriorated significantly in the decades since, making a thorough diversity survey of the area more urgent than ever. This current study focuses on macrofungi diversity in selected vulnerable areas of the Southern part of the occupied Palestinian territories.

Since 2014, the Palestine Museum of Natural history has been working to fill this gap in our ecological knowledge of the region. Teams of citizen scientists, made up of native Palestinians and international researchers, have conducted surveys throughout those pockets of biodiversity remaining in the West Bank. The importance of this is twofold: Firstly, as the region has experienced unprecedented human population growth, the ecosystem services

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provided by undeveloped areas have become increasingly valuable. The most common landscape of our surveying was semi-feral olive terraces, where olive trees from a previous era were interspersed with wild scrub plants. These terraces provide a home to so far uncounted numbers of fungal species, whose impacts on soil fertility (and therefore olive harvests) are likely substantial and varied. Secondly, in a region so starkly maligned by issues of land access and ownership, few Palestinians are easily able to experience the landscape outside of developed urban centers. This research provides opportunities for Palestinians to develop a relationship with their environment which is rooted in an understanding of the living world.

Materials and Methods

Mushrooms were photographed and collected from six areas in the southern part of West Bank (Fig. 1) over a period of 24 days, from December 13, 2018 to January 6 2019. Our main sampling areas were the steep valleys west of Bethlehem, which are noted biodiversity hotspots (Garstecki et al. 2010) but are also endangered by political turmoil (Abdallah et al. 2011, Isaac & Hilal 2011).

Brief notations on each study site with longitudes and latitudes

1) Wadi Quff – 31.579896, 35.038929

Wadi Quff protected area of 2500 dunums is located in the western part of the Hebron Governorate, and consists of two confluent valleys between Beit Kahil and Tarqumiya. The habitat is dominated by oak (*Quercus caliprinos*) and introduced pine trees (*Pinus halepensis*). The area has been studied for plants and animals, (see Qumsiyeh et al. 2016) but never for fungi.

2) Al Qarn – 31.619556, 35.127159

Al-Qarn is a hill of 50 dunums overlooking Beit Ummar town and Al Aroub Refugee camp in the Hebron District. Its habitat is similar to Wadi Quff but there are more *Arbutus andrachne* (strawberry tree) and less introduced pine trees.

3) Wadi Husan – 31.717958, 35.130733

This valley is not considered a protected area like the previous two localities. However, it is part of the biodiversity rich valley system that connects areas 3, 4, & 5.

4) Al Makhrour – 31.718557, 35.156388

Wadi Al-Makhrour is a valley located about 7 km south of the old city of Jerusalem and about 6 km northeast of the old city of Bethlehem. It is connected to a larger valley system which stretches southwest of Jerusalem. Water flows from the Walaja and Cremisan valleys and then converges with waters from Al Makhrour itself (between Beit Jala, Al-Khader, and Al-Walaja), to then drain into Battir and then Husan (locality 3 above) and Nahhalin valleys. Al Makhrour is the central part of the system that refills the water aquifer of Bethlehem District area. Its many fresh water springs irrigate old growth olive groves. Al Makhrour is also recognized as a UNESCO world heritage site because of its rich agricultural heritage and beautiful ancient landscape.

5) Cremisan Valley – 31.728257, 35.175298

Cremisan Monastery is the reason this valley was named. The valley belongs to the Beit Jala and Al-Walaja areas but much of it was taken for colonial Israeli settlements. The lower parts of the valley, and those closest to Beit Jala are cultivated (almonds, apricots, olives, figs). Highland regions of the valley are protected from cultivation by inaccessibility and contain natural habitats rich in live oak and native flowering annuals.

6) PMNH Mar Andrea – 31.717711, 35.205431

This site of about 12 dunums was included in the study because it is essentially an oasis in the urban areas of Bethlehem (see Qumsiyeh et al. 2017).

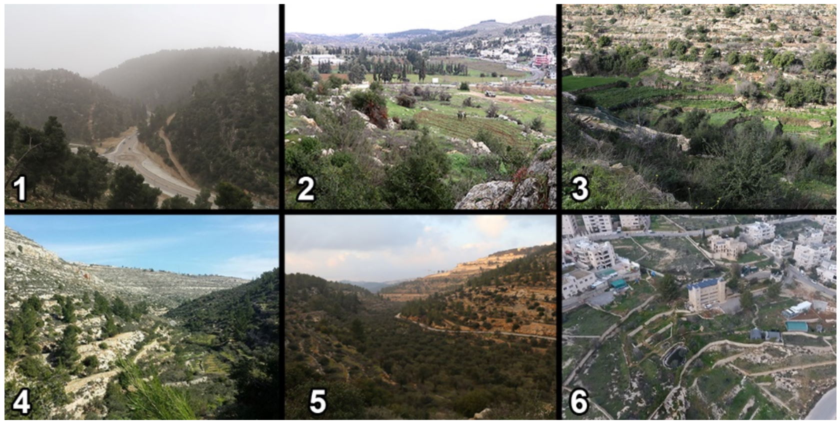

FIG 1: Photographs of typical habitats for each sample area. 1) Wadi Quff 2) Al Qarn 3) Wadi Husan 4) Al Makhrour 5) Cremisan Valley 6) PMNH Mar Andrea Campus

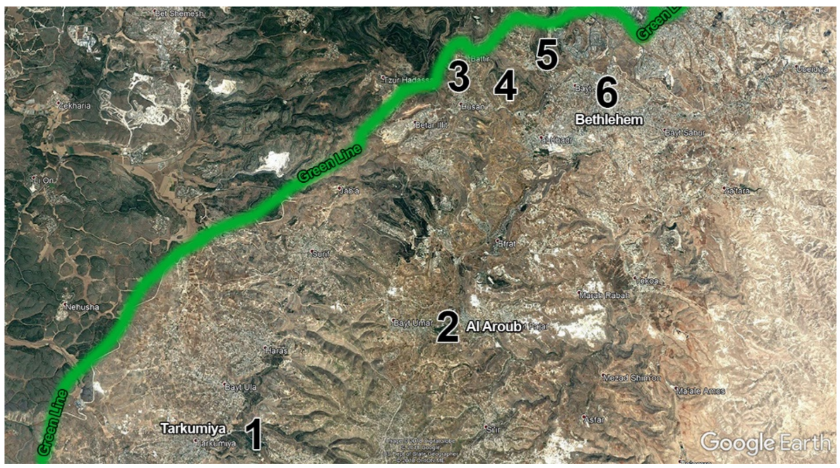

FIG 2: A map of our study sites. Numbers as in FIG 1

Survey Methods

Survey methods consisted of traveling to our selected field sites, walking across promising areas (habitats with high moisture) and sampling for macrofungi. Mushrooms were collected and taken back to the lab at the Palestine Museum of Natural history for spore prints and further microscopy. Some more delicate species were photographed and then left in the field.

Collected mushrooms were dried slowly over a period of days using solar radiation in a well aerated hallway (window drying). Larger samples were dried in a conventional toaster oven set to 100 degrees Fahrenheit in one-hour long increments until dry. Once fully dried, samples were numbered, labeled, and stored in plastic for archival purposes. Mushrooms were identified using guidebooks and consulting websites such as www.mushroomexpert.com. We received many useful identifications through discussions and photo uploads on online mycological communities like www.mushroomobserver.org. Photographs of mushrooms were uploaded to mushroomobserver.org under the username "maximusthaler", and tagged with PMNH herbarium numbers, for future reference. (https://mushroomobserver.org/observer/observations_by_user/6055).

Where appropriate, samples were examined using a Labomed optical light microscope. Slides of spores were prepared using distilled water, and photographed through a 100x oil immersion lens. We were unable to gather genetic data from these samples, and so all of our species level identifications remain somewhat tentative, and contingent upon higher quality molecular analysis. While we are confident in the species level identifications we provide, in some cases the information available to us was only sufficient to identify the sample in question to the genus level (see results).

Specimens are kept at the Palestine Museum of Natural History fungi collection (PMNH-F).

Results

We found 39 genera of mushrooms and were able to identify the following 27 macrofungi species:

Agaricus campestris L. (1753)

MycoBank 356498

Collection: Al Qarn PMNH-F-1019

Ecology: Saprotrophic, grows in grass (Kuo 2018a). Our samples were found on a mixed woodland hillside.

Description: Cap 3–6 cm wide, white, with fine hairs sometimes visible. Gills free from stem, pale pink aging to brown, covered with a partial veil in button stage. Stem 3–5 cm tall, 1–3 cm wide, with white remnants of a partial veil in a ring. Spores globose to subglobose.

Comments: This species is a dominant mushroom in grazing areas (Roberts and Evans, 2011, Abate 1999), hence its common name of Horse Mushroom. This species is characterized by a white cap. Its lamella has initially a pinkish color and eventually becomes dark brown. It can be further identified by a negative KOH reaction (Mitchell and Walter 1999, Kerrigan et al. 2005).

Fig 3. *Agaricus campestris* L. (1753)

Amanita ovoidea (Bull.) Link (1833)

MycoBank 156329

Collection: Al Makhrour PMNH-F-1011, Cremisan (photographed)

Description: Cap 15–25 cm, convex, flattening with age, creamy white, with veil fragments hanging from the cap margin when young. Gills free from the stem, crowded, white. Stem 7–15 cm tall, 3–6 cm wide, white, with powdery ring of veil remnants, emerging from a white volva underground.

Ecology: Ectomycorrhizal; found under deciduous trees, notably oaks, sometimes olive, on lime or alkaline soil (O'Reilly 2016). Our samples were found emerging deep from the ground in a recently plowed olive grove.

COMMENTS: This species is part of a larger, more ambiguous group: *Amanita* sect. *Lepidella*. Our samples may actually be *Amanita gilbertii* or one of several other *A.* sect. *Lepidella* members. While we are confident in this identification of *Amanita ovoidea*, *A.* sect. *Lepidella* remains underspecified and difficult to differentiate. Given the understudied nature of the occupied Palestinian bioregion, there is a distinct possibility that this sample belongs to some other *A.* sect. *Lepidella* species. Molecular analysis (outside the scope of the current study) is required for completely confident identification.

FIG 4. *Amanita ovoidea* (Bull.) Link (1833)

Arrhenia rickenii (Hora) Watling (1989)
MYCOBANK 125095
COLLECTION: Al Makhrour PMNH-F-1052
DESCRIPTION: Cap 5–25 mm wide, pale brown, convex funnel shaped, radially lined. Gills decurrent, widely spaced, sometimes branching near cap margins. Stem 5–30 mm long, 1–3 mm wide.
ECOLOGY: Saprophytic, nearly always on mosses on alkaline soil (O'Reilly 2016). Our samples were found on moss-covered limestone gravel.

FIG 5. *Arrhenia rickenii* (Hora) Watling (1989)

Coprinellus micaceus (Bull.:Fr.) Vilgalys, Hopple & Jacq. Johnson (2001)
MYCOBANK 474361
COLLECTION: PMNH Mar Andrea PMNH-F-1037
DESCRIPTION: Cap 2–4 cm, radially lined, amber, covered in fine mica-like flakes. Gills attached to the stem, pale at first, then darkening and dissolving with age into black ink. Stem 2–5 cm long, 2–4 mm thick, pale amber, ridged.
ECOLOGY: Saprotrophic, grows in clusters on decaying wood. Its substrate is often buried, causing the mushrooms to appear terrestrial (Kuo 2008a). Our samples were found in grass at the base of an almond tree.

Fig 6. *Coprinellus micaceus* (Bull.:Fr.) Vilgalys, Hopple & Jacq. Johnson (2001)

Coprinopsis friesii (Quél.) P. Karst. (1872)

MycoBank 318302

Collection: Al Makhrour PMNH-F-1053

Description: Cap 5–15 mm, radially lined, grey, dissolving with age into black ink. Gills free, black. Stem 1–3 cm long, 1–2 mm thick.

Ecology: Saprotrophic, can be found in grass (Wood and Stevens 2015). This sample was found in a grassy olive grove.

Comments: This species is part of a larger, more ambiguous group *Coprinopsis* sect. *Picacei,* 'stirps *Friesii*', and the specific identification as *Coprinopsis friesii* is tentative. Species in this group can only be accurately identified using molecular methods beyond the scope of this study. The name *Coprinopsis friesii* should be viewed mostly as a placeholder until higher fidelity analysis can occur.

Fig 7. *Coprinopsis friesii* (Quél.) P. Karst. (1872)

Coprinus comatus (O.F.Müll.) Pers. (1797)

MycoBank 148667

Collection: Al Makhrour PMNH-F-1042

Description: Cap 3–7 cm wide, cylindrical when young, then expanding and dissolving into black ink with age. Cap surface white, tending to dark tan in the center, with radially flaking scales. Gills free from the stem, initially white, aging to black ink. Stem 5–12 cm long, 1–2 cm wide, separates easily from the cap.

Ecology: Saprotrophic, grows in grass, on wood chips, or hard-packed ground (Kuo 2008b). Our samples were found at the base of pines

FIG 8. *Coprinus comatus* (O.F.Müll.) Pers. (1797)

Cortinarius infractus (Pers.) Fr. (1838)

MYCOBANK 218869

COLLECTION: Al Qarn PMNH-F-1067

DESCRIPTION: Cap 4–10 cm wide, olive brown, convex, flattening with age, sticky when young. Gills attached to the stem, densely packed, aging to deep orange brown as spores mature, with weblike remnants of orange cortina hanging. Stem 4–8 cm long, 2–3 cm wide. Spores subglobose.

ECOLOGY: Mycorrhizal, found in association with hardwoods (Kuo 2012). Our samples were found near *Quercus* and *Arbutus*.

COMMENTS: *Cortinarius* is one of the largest fungal genera, containing over 1000 species, many of which can only be identified molecularly (Kuo 2012). *Cortinarius* distribution and diversity in the eastern Mediterranean is understudied, and molecular phylogenetic research has shown this genus is significantly more complex than previously thought (Garnica et al. 2003). Mycorrhizal host interactions with *Cortinarius* can be extremely species specific, and there are likely *Cortinarius* species with ecologies specific to the region which remain undescribed. While we are reasonably confident in our determination of the species of this sample to be *C. infractus*, it should be emphasized that our use of the name more accurately refers to a group of closely related fungi rather than a unique species. Genetic analysis, and closer analysis of our sample's ecological interactions with its host are both required for a more confident, regionally specific identification to be established. Brondz and Høiland (Brondz and Høiland 2009) showed that *Cortinarius infractus* contains many alkaloid compounds in the 5-Hydroxytriptophane synthesis pathway (5-HTP is an over the counter antidepressant). Habitats containing *Cortinarius infractus* are thus of notable biomedical importance.

FIG 9. *Cortinarius infractus* (Pers.) Fr. (1838)

Cryptomarasmius corbariensis (Roum.) T.S. Jenkinson & Desjardin (2014)

MYCOBANK 561778

Collection: Al Makhrour PMNH-F-1059

Description: Cap 2–3 mm, amber, radially lined. Gills white, free from stem, widely spaced. Stem 2–4 cm tall, <1 mm wide, shiny black.

Ecology: Saprotrophic, grows on rotting leaves of olive and other trees (Bozok et al. 2018). Our samples were found growing on damp olive leaves.

Fig 10. *Cryptomarasmius corbariensis* (Roum.) T.S. Jenkinson & Desjardin (2014)

Cyathus olla (Batsch) Pers. (1800)

MycoBank 215509

Collection: Al Qarn PMNH-F-1012

Description: Peridium 1 cm high, 1 cm wide. Cone shaped, with margins trumpet shaped, cracking with age. Outer surface grey and rough. Inner surface silvery and smooth. Peridioles flat, circular, lentil shaped, grey, with mycelium emerging centrally from a lateral side and connecting to the base of the peridium.

Ecology: Saprotrophic; can be found on the ground, in grass, woody debris, or dead plant stems (Kuo, 2014). Our sample was found in grass in a mixed wood hillside.

Fig 11. *Cyathus olla* (Batsch) Pers. (1800)

Geopora arenosa (Fuckel) S. Ahmad (1978)

MycoBank 314400

Collection: Cremisan PMNH-F-1014, Wadi Quff (photographed)

Description: Cup 1–2 cm across. Inner surface white, smooth. Outer surface brown, rough. Margin irregularly cracked. Stem absent.

Ecology: Thought to be mycorrhizal (O’Reilly 2016). Our samples were found closely associated with moss, on limestone soils.

FIG 12. *Geopora arenosa* (Fuckel) S. Ahmad (1978)

Helvella lacunosa Afzel (1783)

MYCOBANK 147441

COLLECTION: Husan valley (PMNH-F-1065), Cremisan valley, Wadi Quff (photographed)

DESCRIPTION: Cap 2–3 cm, irregularly shaped, sometimes resembling a saddle, black. Stem 3–4 cm long, 1–2 cm wide, grey, deeply ribbed with multiple holes.

ECOLOGY: Ectomycorrhizal, associated with oaks and pines (Nguyen et al. 2013). Our samples were found near live oak.

COMMENTS: This species is common, and has global distribution. However, Nguyen et al. (2013) note that what has historically been considered a single species can actually be divided into several distinct clades. Nguyen has described new *Helvella* species unique to western North America, and identifiable by ectomycorrhizal host. *H. vespertina* is associated with pine, while *H. dryophila* is associated with oak. While molecular data continues to corroborate the global distribution of *Helvella lacunosa* (Nguyen 2013 describes some *Helvella* samples from Minnesota and Japan as 99% genetically similar), it is highly likely that there are unidentified species being misidentified as *Helvella lacunosa* in less studied regions, such as occupied Palestine. Given the extreme partner specificity common in ectomycorrhizal fungi, it seems possible that what we have identified as *H. lacunosa* could actually be a new Helvella species, adapted to the live oak and pine species native to Palestine. Genetic analysis is required to determine the relationship between our samples and *H. lacunosa* collections from elsewhere in the world.

FIG 13. *Helvella lacunosa* Afzel (1783)

Hypomyces cervinigenus Rogerson & Simms (1971)

MYCOBANK 315654

COLLECTION: Wadi Quff PMNH-F-1071

DESCRIPTION: Powdery, pink and white aging to brown.

ECOLOGY: Parasitic on other fungi, this ascomycete is exclusively found growing on *Helvella* species (Kuo 2006).

Comments: This species has global distribution and is found wherever its host, *Helvella lacunosa*, is found. However, recent studies have noted that *H. lacunosa* is actually several distinct species, and these distinctions have ramified into isomorphic speciations among its parasites (Nguyen et al. 2013). Given the extreme host specificity of *Hypomyces*, combined with the ectymycorizial partner specificity of its *Helellva* host, it seems probable that what we have identified as *Hypomyces cervinigenus* could actually be a new *Hypomyces* species, adapted to the (potentially also unique) local *Helvella* population native to Palestine. Genetic analysis is required to determine the relationship between our samples and *Hypomyces* collections from elsewhere in the world.

Fig 14. *Hypomyces cervinigenus* Rogerson & Simms (1971)

Irpex lacteus (Fr.) Fr. (1828)

MycoBank 177211

Collection: Al Qarn PMNH-F-1000

Description: Fruiting body white, mixed with shades of brown. Underside spore surface developing small toothlike structures.

Ecology: Saprotrophic, grows in clumps upon the undersides of fallen hardwood (Kuo, 2007). Our samples were found on hardwood in a mixed woodland hillside.

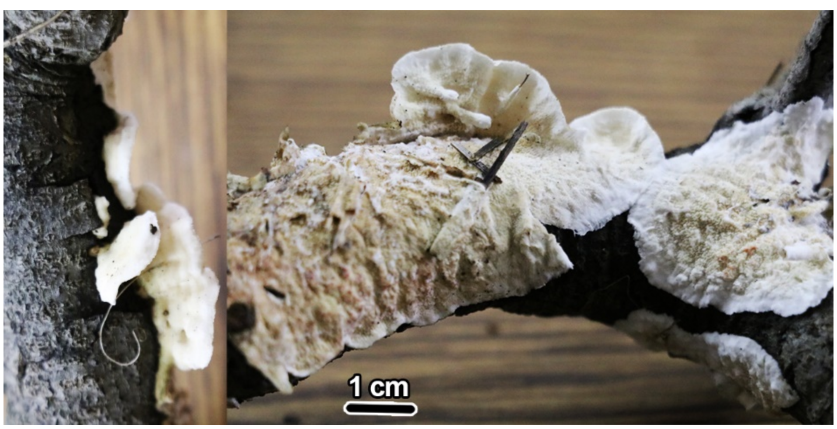

Fig 15. *Irpex lacteus* (Fr.) Fr. (1828)

Lentinus arcularius (Batsch) Zmitr. (2010)

MycoBank 543135

Collection: Al Makhrour PMNH-F-1006

Description: Cap 1–3 cm, usually convex, light brown covered in darker brown concentric scales. Pores 0.5 – 2mm, smaller on cap margins and on the stem apex. Stem 2–4 cm long, 2–4mm wide. Dark brown at the top, whiter towards the base.

Ecology: Saprobic, grows on decaying deciduous wood, often oak. Sometimes these mushrooms grow from buried wood and appear terrestrial. Our samples appeared terrestrial and were found near live oak.

COMMENTS: Detailed anatomy and morphological development were studied by Hibbet et al. (1993). Some samples found in occupied Palestine lack the conspicuous hairs on the cap fringe which North American records attest to (Kuo 2008c), and in this way the samples more closely resemble *L. brumalis*. But pore structure and ecology (samples were found amidst *Quercus*) make *L. arcularius* more likely. There is some possibility that this is a new species or sub-species (or at least a notable phenotypic pattern) unique to the region. Genetic analysis is required to test this hypothesis.

FIG 16. *Lentinus arcularius* (Batsch) Zmitr. (2010)

Lepista sordida (Schumach.) Singer (1951)

MYCOBANK 299524

COLLECTION: Al Makhrour PMNH-F-1020, Cremisan (photographed)

DESCRIPTION: Cap 3–8 cm, weakly convex, flattening with quickly with age. Lilac purple when young, aging to pale tan. Gills free from the stem, crowded, also lilac purple aging to pale tan. Stem 2–4 cm tall, 1–2 cm wide, lilac-tan, appressed-fibrillose. Spores spheroid, with thin walls.

ECOLOGY: Saprotrophic, in open woody areas, usually where leaf litter collects and rots (O'Reilly 2016). Our samples were found at the base of olive and oak.

FIG 17. *Lepista sordida* (Schumach.) Singer (1951)

Lycoperdon perlatum Pers. (1797)

MYCOBANK 220647

COLLECTION: Al Makhrour PMNH-F-1009

DESCRIPTION: Fruiting body 2–3 cm wide, inverted pear shaped, tan, covered in small spines. Interior white, aging to olive. Spores emerge from a spilt at the apex of the fruiting body with age. Spores globose, smooth walled.

ECOLOGY: Saprotrophic; can be found on the ground or on deadwood, or brush. These samples were found on bare soil surrounded by loose twigs and leaf mulch.

Fig 18. *Lycoperdon perlatum* Pers. (1797)

Omphalotus olearius (DC.) Sing. (1948)

MycoBank 288943

Collection: PMNH Mar Andrea PMNH-F-1061

Description: Cap 8–12 cm, orange, appressed-fibrillose, Bioluminescent when very young. Gills orange, decurrent. Stem 4–6 cm long, 1–2cm wide.

Ecology: Saprotrophic; grows on stumps, buried roots, or on the base of hardwoods, especially oaks and olive (Kuo, 2015b). This sample was found growing at the base of olive.

Fig 19. *Omphalotus olearius* (DC.) Sing. (1948)

Peziza badia Pers. (1800)

MycoBank 141966

Collection: Al Qarn PMNH-F-1013, Wadi Quff (photographed)

Description: Cup 1–2 cm across, pale brown, darker and smoother on the inner surface. Margin inturned. Stem absent.

Ecology: Saprotrophic, can be found on compacted heavy soils, particularly forest footpaths (O'Reilly 2016). Our sample was found in a mixed wood hillside.

FIG 20. *Peziza badia* Pers (1800)

Psathyrella bipellis (Quél.) A.H.Sm. (1946)

MYCOBANK 438921

COLLECTION: Al Makhrour PMNH-F-1024, Cremisan PMNH-F-1064

DESCRIPTION: Cap 2–4 cm, radially lined, hygraphanous deep brown aging to dull tan. Gills attached to the stem, deep brown. Stem 4–7 cm long, 2–5 mm thick.

ECOLOGY: Saprotrophic; grows in groups on lawns or in decaying plant matter (Kuo 2011). Our samples were found in damp decaying leaves, mostly olive and oak.

FIG 21. *Psathyrella bipellis* (Quél.) A.H.Sm. (1946)

Pseudoplectania nigrella (Pers.) Fuckel (1870)

MYCOBANK 188201

COLLECTION: Wadi Quff PMNH-F-1073

DESCRIPTION: Cup <1 cm across, black. Inner surface smoother than outer surface. Stem absent.

ECOLOGY: Saprotrophic, grows on decaying pine debris (Dennis 1969). Our samples were found in mossy limestone soils amid pine, cedar, and oak.

COMMENTS: This species has global distribution, and has been described in regions between the Caribbean, South America, and Japan (Dennis 1954, Mardones-Hidalgo & Iturriaga 2011, Paden 1983). It has also previously been described in Israel (Barseghyan and Wasser 2008). Barseghyan and Wasser (2008) note that Israel has high biodiversity of *Pezizomycetes*; its varied terrain and proximity to both northern Africa and western Asia supports *Pezizomycetes* from both continents, 115 species in total. We too noted a high diversity of *Pezizomycetes* in the field site of this collection, Wadi Quff. We found five *Pezizomycetes* species in this small protected area, of which we were able to identify three. This species is notable for its blackish cup or disc shaped apothecia (Korf 1973, Le Gal 1953, Medel et al. 2006). The mushroom forms cup shaped and as it ages the disc flattens and sometimes can even become planar (Seaver 1913). Seaver (1913) demonstrates that the cup margin has very small hairs, 5 mm to 1.5 cm in diameter.

Fig 22. *Pseudoplectania nigrella* (Pers.) Fuckel (1870)

Sarcomyxa serotina (Pers.) P. Karst. (1891)

MycoBank 304280

Collection: Cremisan PMNH-F-1080

Description: Cap 3–10 cm, kidney shaped, light brown. Gills white, adnate. Stem reduced pseudostem.

Ecology: Saprotrophic, grows on hardwoods and occasionally conifers (Kuo 2017). Our samples were found at the base of live oak.

Fig 23. *Sarcomyxa serotina* (Pers.) P. Karst. (1891)

Suillus collinitus (Fr.) Kuntze (1898)

MycoBank 306571

Collection: Cremisan PMNH-F-1007, Mar Andrea & Al Makhrour (photographed).

Description: Cap 4–11 cm, covered in an easily pealed brown cuticle which is viscid when damp. Stem 3–7 cm tall, 1–2 cm wide, often covered in brown markings. Spore surface pale yellow, aging to brown. Spores irregularly ellipsoidal, some with pointed ends.

Ecology: Mycorrhizal, associated with pines, and prefers limestone soils (Assyov 2018). Our samples were all found within 10 meters of a pine species.

Fig 24. *Suillus collinitus* (Fr.) Kuntze (1898)

Tapinella panuoides (Batsch) E.-J. Gilbert (1931)

MycoBank 253796

Collection: Cremisan Valley PMNH-F-1018

Description: Cap 3–6 cm, light brown, fan shaped, with fine hairs along the fringe. Stem absent. Gills often crimped, white to beige. Spores ellipsoid, smooth walled.

Ecology: Saprotrophic, grows on conifers (Kuo 2015a). Our samples were found at the base of fallen pine.

Comments: This species is fairly common, and an occasional subject of biomedical research. Schneider et al (2008) have isolated atromentin compounds, and their associated genes from this species. These compounds have been shown to have antibiotic and anti-cancer properties (Zheng et al. 2006, Kim & Lee 2009). Thus ecosystems containing *Tapinella panuoides* are of notable biomedical importance.

Fig 25. *Tapinella panuoides* (Batsch) E.-J. Gilbert (1931)

Trametes hirsuta (Wulfen) Pilát (1939)

MycoBank 267192

Collection: Cremisan PMNH-F-1001

Description: Fruiting body forming bracket shelves 3–6 cm wide. Shelf surface covered in concentric rings of white to brown hairs. Pore surface forms maze-like structures close to the origin of growth, which condense into deep pores towards cap margins.

Ecology: Grows on stumps and fallen hardwood (Kuo 2010). Our samples were found on fallen hardwood (likely almond) in an olive grove.

Comments: Puri et al. (2006) found that it could be utilized as a novel source of aryl tetralin lignans, which are important compounds used for the synthesis of topoisomerase inhibitors. Habitats containing *Trametes hirsuta* are thus of notable biomedical importance.

Fig 26. *Trametes hirsuta* (Wulfen) Pilát (1939)

Tubaria furfuracea (Pers.) Gillet (1876)

MycoBank 197499

Collection: Wadi Quff PMNH-F-1029

Description: Cap 1–2 cm, orange. Convex at first and broadening with age. Radially lined at the edge where cap flesh is thinner. Gills adnate, orange. Stem hollow, 2–5 cm long, 2–4 mm wide.

Ecology: On twigs and other woody debris (O'Reilly 2016). Our samples were found amidst pine.

Comments: Common name is scurfy twiglet.

Fig 27. *Tubaria furfuracea* (Pers.) Gillet (1876)

Volvopluteus gloiocephalus (DC.) Vizzini, Contu & Justo (2011)

MycoBank 518592

Collection: Al Makhrour PMNH-F-1003

Description: Cap 5–10 cm, brown, darkening to black at the center. Sometimes sticky when young. Appressed-fibrillose and radially lined towards the margins where cap flesh is thinner. Gills free from the stem, crowded fairly densely. Pale at first but quickly darkening to a deep brown. Stem 6–13 cm long, 2–3 cm wide, enlarging at the base. Grey, covered with a fine white powder. Stem emerges from a white volva. Spores ellipsoidal.

Ecology: Saprotrophic, terrestrial, in grassy areas or composting organic matter (Justo et al. 2011a). Our samples were found in thick grass.

Comments: Kuo (2018b) notes that samples from California have streaked greyish caps, while samples on the eastern side of North America are whiter. All of the samples we found in occupied Palestine have streaked brown caps and deep brown gills. Justo et al. (2011b) notes that the species has global distribution and it is unsurprising that superficial morphology would vary with geography. There are likely underlying genetic and environmental causes (and sub-species level taxonomic patterns) which are responsible for this morphological variation. Genetic analysis of our samples is required to determine how phylogenetically distinct they are from *V. gloiocephalus* elsewhere in the world.

FIG 28. *Volvopluteus gloiocephalus* (DC.) Vizzini, Contu & Justo (2011)

Xerocomellus redeuilhii Simonini, Gelardi & Vizzini (2016)
MYCOBANK 818381

COLLECTION: Al Makhrour PMNH-F-1005

DESCRIPTION: Cap 2–5 cm, red to yellow and cracking with age. Stem 3–4 cm tall, 1–2 cm wide, yellow with red streaks, becoming more concentrated at the base. Spore surface yellow.

ECOLOGY: Mycorrhizal, associated with hardwoods, often oaks. Found on calcareous soil (Simonini et al. 2016). These samples were found at the base of live oak.

COMMENTS: The taxonomy of the red capped, yellow spore surfaced boletes is in an unusually large state of flux. Several genera, including *Xerocomellus* and *Hortiboletus,* have been segregated from *Boletus* sensu lato, and distinguishing between these genera can often only be accomplished with genetic data. While we are reasonably confident in our identification of this sample as *Xerocomellus redeuilhii,* other species in the genus, or perhaps even *Hortiboletus* remain possible alternatives. Differentiating between these closely related taxa is not within the scope of this diversity study. Genetic analysis is required for full confidence in this species identification.

FIG 29. *Xerocomellus redeuilhii* Simonini, Gelardi & Vizzini (2016)

Other taxa

In addition to the species detailed above, we made many observations of fungi that could only be identified accurately to the genus level. Table 1 reports all the genera observed, whether we were able to identify to species level or not. In total, we recorded 39 genera, from 29 families (7 orders, 3 classes, 2 phyla) with at least 59 species (27 identified to the species level), from six field sites over of 24 days, from December 13 2018 to January 6 2019.

Table 1. Observations /collections of mushrooms identified to the genus level.

Genus Name	*Number of Species*	*Observation Identification Numbers*
Agaricus	2	PMNH-F-1019, PMNH-F-1004
Amanita	1	PMNH-F-1011
Arrhenia	1	PMNH-F-1052
Auricularia	1	PMNH-F-1016
Clavaria	1	PMNH-F-1017
Clitocybe	>5	PMNH-F-1015, PMNH-F-1025, PMNH-F-1027, PMNH-F-1036, PMNH-F-1044, PMNH-F-1046, PMNH-F-1049, PMNH-F-1050, PMNH-F-1051, PMNH-F-1062, PMNH-F-1078, PMNH-F-1083, PMNH-F-1084, PMNH-F-1086
Coprinellus	4	PMNH-F-1022, PMNH-F-1037, PMNH-F-1039, PMNH-F-1060
Coprinopsis	1	PMNH-F-1053
Coprinus	1	PMNH-F-1042
Coriolopsis	1	PMNH-F-1023
Cortinarius	2	PMNH-F-1067, PMNH-F-1074
Cryptomarasmius	1	PMNH-F-1059
Cyathus	1	PMNH-F-1012
Geopora	1	PMNH-F-1014
Gomphidius	1	PMNH-F-1079
Helvella	1	PMNH-F-1065
Hypomyces	1	PMNH-F-1071
Inocybe	>5	PMNH-F-1031, PMNH-F-1032, PMNH-F-1033, PMNH-F-1034, PMNH-F-1035, PMNH-F-1038, PMNH-F-1040, PMNH-F-1043, PMNH-F-1047, PMNH-F-1056, PMNH-F-1068, PMNH-F-1081, PMNH-F-1082
Irpex	1	PMNH-F-1000
Lactarius	1	PMNH-F-1070
Lentinus	1	PMNH-F-1006
Lepista	1	PMNH-F-1020
Lycoperdon	1	PMNH-F-1009
Melanoleuca	>1	PMNH-F-1028, PMNH-F-1030, PMNH-F-1075
Mycena	1	PMNH-F-1026
Nolanea	1	PMNH-F-1085
Omphalotus	1	PMNH-F-1061
Parisola	1	PMNH-F-1010
Peziza	1	PMNH-F-1013
Psathyrella	>5	PMNH-F-1021, PMNH-F-1024, PMNH-F-1041,PMNH-F-1045, PMNH-F-1048 PMNH-F-1054, PMNH-F-1057, PMNH-F-1058, PMNH-F-1063, PMNH-F-1064, PMNH-F-1069
Pseudoplectania	1	PMNH-F-1073
Sarcomyxa	1	PMNH-F-1080
Suillus	2	PMNH-F-1007, PMNH-F-1076
Stereum	1	PMNH-F-1077
Tapinella	1	PMNH-F-1018
Trametes	1	PMNH-F-1001
Tubaria	>2	PMNH-F-1008, PMNH-F-1029, PMNH-F-1066, PMNH-F-1072
Volvopluteus	1	PMNH-F-1003
Xerocomellus	1	PMNH-F-1005
Total	*>59*	*PNMH-F-1000 – PNMH-F-1086*

Discussion

In four weeks of surveying in December and January 2018–19, we identified 27 macrofungi species from six field sites in the southern West Bank. We made further observations of fungi which could be identified to the genus level, for a total record of 39 genera containing at least 59 species. This survey represents the first attempt since the British mandate period (nearly a century ago) to document the diversity of macrofungi in this region of historic Palestine (Reichert 1940). While this survey is by no means exhaustive, it nonetheless makes a significant contribution to our understanding of the biodiversity of this understudied region. Climate change, combined with eight decades of geopolitical unrest, have synergistically degraded Palestinian ecosystems at an unprecedented rate (Qumsiyeh 2018). Thus, it is now more important than ever to document the fungal species present in the region. As climate change and the occupation continue to interact, the macrofungal species diversity will very likely be reduced in future decades. This in turn will almost certainly impact agricultural yields, particularly in areas which have been traditionally used as village commons that provide polycultures of minimally managed food sources.

The Palestine Museum of Natural History is building its capacity in mycological work starting from the interest of a small staff and volunteers with limited resources. This study represents an example of grassroots Citizen Science, the value of which has become more widely appreciated in recent years (Silverton 2009). Silverton notes that "projects that fit uneasily into the standard model of hypothesis-testing research" still often have great value. Thoroughly documenting the diversity of the region is critical for any conservation efforts, as it is widely acknowledged that diversity is the primary indicator of the wellbeing of ecological systems (Magurran 1988).

As this research continues, and more sophisticated methods are implemented, we expect the number of unique species identified to grow. Our study mostly used ecological markers and macroscopic morphological features. Microscopy was used sparingly for the analysis of spore prints, and no genetic data were gathered. As we implement molecular methods in future studies, we expect to find that some fungi initially identified as a common species with Eurasian or global distribution will actually prove to be locally adapted variants. Most keys available were developed for Europe or North America, and can only be applied superficially to Palestinian fungi. Indeed, because global fungal diversity remains poorly understood and many species are yet to be described (Mueller et al. 2007), it would be surprising if there *weren't* unique Palestinian species to be found.

For example, our observations point to two morphological oddities (already described in the results section) which merit further inquiry: 1) North American descriptions of *Volvopluteus gloiocephalus* describe it as having grey or white caps, and light-colored gills, while the Palestinian samples we found have brown cap and dark brown gills. This discrepancy likely has phylogenetic significance. 2) North American descriptions of *Lentinus arcularus* describe the mushroom as exhibiting a hairy fringe along the cap, but the Palestinian samples we found were mixed (some with fringes and some without). Future studies should compare North American and European samples to the Palestinian specimens we collected to clarify these issues.

Figure 30 shows the phylogeny of the genera of macrofungi we identified in Palestine. It is remarkable that they represent 29 families in a preliminary study like this. With the advent of molecular methodologies, we will proceed now to do DNA sequence analysis on expanded surveys of mushrooms from throughout the region (and not just from the described areas of the southern West Bank). For example, we did not sample in areas like the Jordan Valley and the arid regions of Palestine which include Irano-Turanian, Saharo Arabian, and Ethiopian-Sudanese phytogeographic elements (see Soto-Berelov et al. 2015).

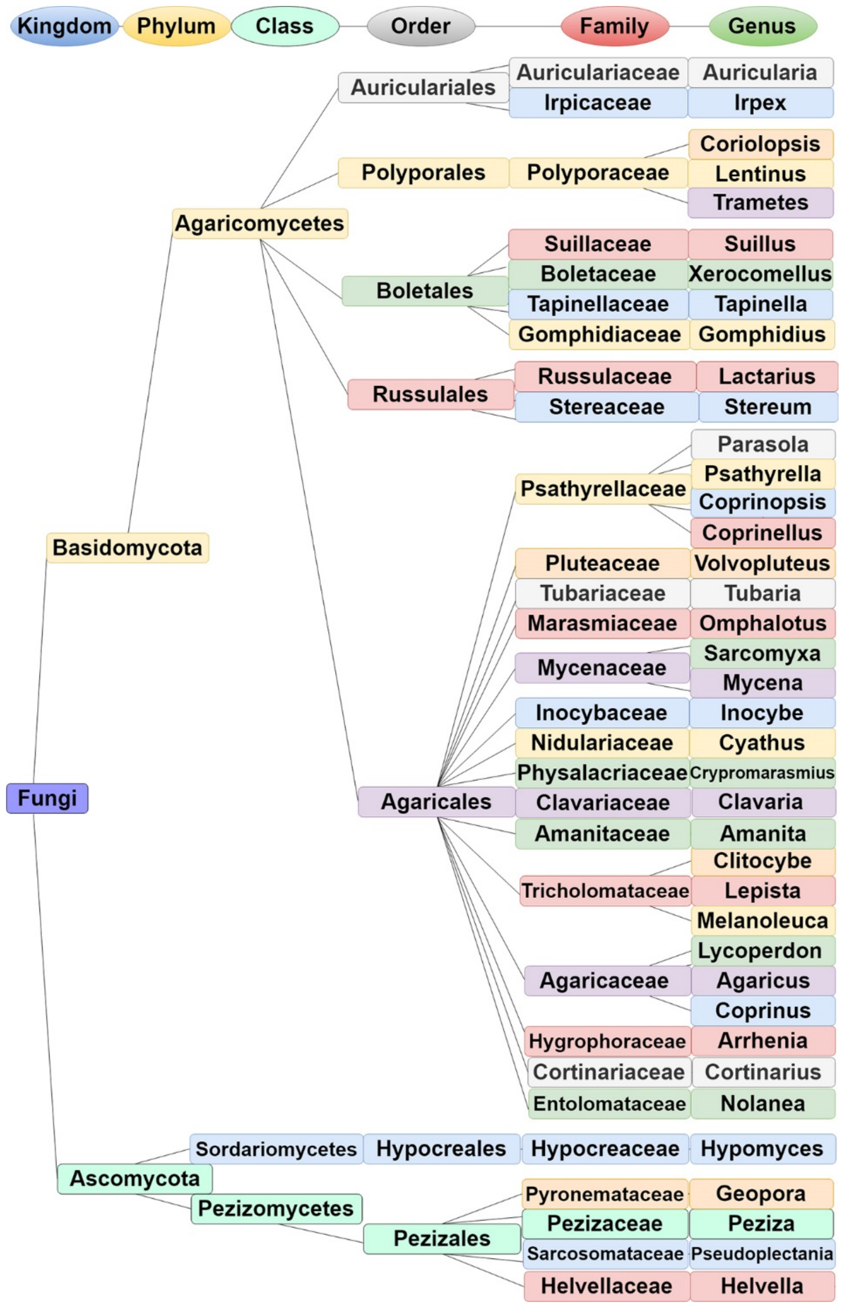

Fig 30: A phylogeny of all macrofungi observed during the study

Future research should continue our efforts to map macrofungal diversity in occupied Palestine, with the ultimate aim of generating a thorough distribution map of all genera and species present in the region. Furthermore, it should be emphasized that for these types of diversity studies, the collaborative methods used are just as important as the results. While our methods were simple, they allowed for a passionate community of citizen scientists to re-open the field of Palestinian mycology after nearly a century of neglect.

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