Using Local Ecological Knowledge to Assess Morel Decline in the U.S. Mid–Atlantic Region[1]

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Using Local Ecological Knowledge to Assess Morel Decline in the U.S. Mid–Atlantic Region. Morels (*Morchella spp.*) are prized wild edible mushrooms. In the United States, morels are the focus of family traditions, local festivals, mycological society forays, and social media, as well as substantial commercial trade. A majority of the anglophone research on morels has been conducted in Europe and in the U.S. Pacific Northwest and Midwest. This literature provides insights into a diverse and plastic genus, but much of its biology and ecology remains a mystery. In 2004, we initiated a study of morel mushroom harvesting in the U.S. Mid–Atlantic region in response to concerns that morels might be in decline in the national parks in that area. This paper presents results from that research with an emphasis on morel hunters' local ecological knowledge of morel types, phenology, habitat, vegetative associations, and responses to disturbance. We conclude that experienced morel harvesters possess local ecological knowledge that complements scientific knowledge and can increase our understanding of the complex and regionally variable ecology of *Morchella* and inform conservation efforts.

Key Words: Non–timber forest products, Mushrooms, Fungi, Land management, National parks, *Morchella*, Local ecological knowledge.

> It's part of my family history, kind of my connection to Appalachia.
>
> —Mid–Atlantic morel hunter

Introduction

Many people are passionate about morel mushrooms (*Morchella spp.*). In the United States they are the focus of local festivals, mycological forays, family traditions, and social media (Fine 2003:13; Hufford 2006; Kuo 2008; Morels.com 2009). In the U.S. Pacific Northwest, morels are a source of income for commercial harvesters and make up a substantial portion of the multi–million dollar export of wild edible mushrooms to the European Community and Asia (Pilz et al. 2007). In spite of this, morel ecology is poorly understood and current scientific understanding offers an incomplete foundation for management of the genus. Based on research conducted with morel hunters in the U.S. Mid–Atlantic region (including a portion of the central Appalachians), we suggest that local ecological knowledge can augment scientific knowledge to provide a more complete basis for understanding and conserving morels.

Traditional and/or local ecological knowledge is often proposed and, occasionally, used in tandem with scientific ecological knowledge to address complex resource management challenges (Ballard et al. 2008; Huntington 2000; Moller et al. 2004; Olsson and Folke 2001). Considerable scholarly effort has gone into identifying, defin-

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ing, and validating traditional ecological knowledge (Berkes et al. 2000; Kimmerer 2000; Pierotti and Wildcat 2000; Turner and Berkes 2006), with an emphasis on what Berkes (1999) has called the knowledge–practice–belief systems of indigenous peoples. Berkes and others also have noted that non–indigenous people can develop extensive knowledge of the resources they use and the larger ecosystems containing them (Berkes et al. 2000; Emery 2001; Huntington 2000; Olsson and Folke 2001). We do not wish to enter the debate as to whether such knowledge may be considered traditional ecological knowledge and, thus, refer to the information base of the largely European American participants in the study reported here as local ecological knowledge. We note, however, that much of what has been attributed to traditional ecological knowledge also characterizes local ecological knowledge. For purposes of the current discussion, we define local ecological knowledge as information on the social and ecological characteristics of a location and species of interest, acquired through experience in a place over time (Emery 2001). It may include strategies for managing resources from the individual plant to the ecosystem level (Anderson 1996; Emery 2001; Olsson and Folke 2001; Peacock and Turner 2000), as well as a knowledge system that is drawn on to explain and predict environmental conditions (Huntington 2000).

Research has identified a number of advantages to incorporating local ecological knowledge into planning for resource management. Local resource users often possess detailed information about species and ecosystem dynamics (Berkes et al. 2000; Olsson and Folke 2001). In some cases, this information may be longitudinal, drawing on the experience of multiple generations (Turner and Berkes 2006) or records kept by individuals over several decades (Barron and Emery 2009; Emery 1998). It can contribute a baseline for monitoring and insights for interpretation of data produced through standard scientific methods, as well as for management planning (Ballard and Huntsinger 2006; Berkes et al. 2000; Huntington 2000; Pilz et al. 2006; Ticktin and Johns 2002).

Information on local social and ecological systems from local ecological knowledge can support efforts to scale down from the general level of most scientific ecological knowledge to the local level, at which day–to–day management occurs (Roth 2004). The information contained in local ecological knowledge may be particularly valuable in planning for the resilience of complex social–ecological systems in the face of change and surprise (Berkes et al. 2000). It has been suggested that co–production of information (Ballard et al. 2008; Roux et al. 2006) through the engagement of knowledgeable local resource users, scientists, and managers would increase the efficacy of conservation prescriptions (Ticktin and Johns 2002) and redress inequities in resource management policies (Ballard et al. 2008; McLain 2008).

There are cautionaries amidst scholarly enthusiasm for the incorporation of local ecological knowledge (or traditional ecological knowledge) with scientific ecological knowledge. The knowledge held by individuals and groups is a function of social identity as well as the length of experience with a resource in a particular place. As a result, local ecological knowledge is not evenly distributed. As Emery has noted elsewhere, "To the extent that the activities of individuals are conditioned by social characteristics such as age, gender, class, and ethnicity, local knowledges may be similarly differentiated." (Emery 2001:126). An uncritical engagement with local ecological knowledge can reinforce existing disparities in access to information and resources (Agrawal 1995), while social structures may make it difficult for some knowledgeable individuals to initiate or sustain involvement with collaborative processes (Ballard et al. 2008). Also, local ecological knowledge, like science, is partial; there may be aspects of local social and ecological systems that are not incorporated into individual or collective understandings (Ticktin and Johns 2002) and larger scale processes that are not evident to local actors and interests (Roth 2004). Thus, while celebrating the richness of local ecological knowledge, most scholars in the field call for thoughtfully designed partnerships between local ecological knowledge and science to address complex resource management issues (Ballard et al. 2008; Emery 2001; Kimmerer 2000; Moller et al. 2004; Olsson and Folke 2001; Ticktin and Johns 2002).

In this paper we integrate findings from research on local ecological knowledge of Mid–Atlantic morels with scientific literature on *Morchella* in the U.S. Pacific Northwest and Midwest. Following a brief overview of morel biology and ecology, we describe the study background and methods. The paper then details local ecological knowledge of Mid–Atlantic morels in the context of scientific literature on the genus in the U.S. Pacific Northwest and Midwest. We conclude by suggesting that experienced harvesters possess information that can increase understanding of the complex and regionally variable ecology of *Morchella* and inform conservation efforts.

Morel Biology and Ecology

Morels grow throughout the northern hemisphere as well as in some subtropical and Mediterranean regions and the Middle East (Pilz et al. 2007). The formal literature available in English reports on morel research conducted primarily in Europe, the U.S. Pacific Northwest, and Midwest (Buscot 1994; Kellner et al. 2005; Kuo 2005; Pilz et al. 2007; Wipf et al. 1997; Wurtz et al. 2005). Findings are as complex as the genus itself. We rely here on Pilz et al. (2007) as the basis for a very abbreviated summary of the current scientific understanding of *Morchella* biology and ecology.

Morels are classified as ascomycetes, which are fungi that produce their spores inside an internal sack called an ascus. Like most fungi, a majority of the organism is located below ground, with only the highly sought–after fruiting bodies (commonly referred to as mushrooms) appearing above the soil. Morels have been found to reproduce from several structures of the organism through strategies that are sometimes heterogenous, sometimes clonal. Given suitable temperature and moisture conditions, morels exhibit at least three types of fruiting patterns: 1) regularly, if not annually, in a particular location, 2) upon the death of an ectomycorrhizal associate, and 3) following major disturbance such as wildfire or insect outbreak (Pilz et al. 2007; Wurtz et al. 2005).

Morels can be either saprobic, deriving nutrients by breaking down dead materials, or ectomycorrhizal, deriving nutrients through a symbiotic relationships with a photosynthesizing plant. They form these relationships with deciduous and evergreen tree species and, occasionally, with woody shrubs. Host species vary throughout the range of *Morchella*. Morels are cold tolerant and have been observed to fruit at temperatures less than 42 degrees Fahrenheit.

Morel biology is well adapted to a wide variety of ecological communities and environments. The plasticity of the genus produces high variability over the extent of its range as well as in individual locations. Consequently, many aspects of morel biology and ecology remain mysteries and there is a dearth of formal scientific research on the genus in much of its range, including the U.S. Mid–Atlantic region.

Study Background and Methods

In 2004, at the request of the U.S. National Park Service (NPS), we initiated a study of morel mushroom harvesting in the Mid–Atlantic states (northwestern Maryland, eastern West Virginia, and southeastern Pennsylvania; Fig. 1). Local ecological knowledge is a central focus of the research. Morel hunting by local communities is an ongoing tradition that predates the establishment of national parks in the region. Today, harvesting for personal use is allowed, subject to volume limits in some parks. NPS personnel had received anecdotal reports of declines in morels and wished to have additional information before deciding whether to take further measures to conserve morels and manage morel harvesting.

We used a suite of methods to provide that information, including oral histories guided by a semi–structured protocol and participant observation to document the knowledge of long–time mushroom hunters. Oral histories resulted in approximately 40 hours of audio digital files and 1,034 pages of transcripts, which were analyzed using Microsoft Excel and NVivo7 software (QSR International 2006).

Results reported here derive from our engagement with 41 individuals (hereafter referred to as "participants") in 2005 and 2007. Participants were recruited through press releases, recommendations by National Park Service staff, presentations at community meetings, and snowball sampling (Patton 2002). Ages ranged from young adults (18 to 24 years old) to individuals 65 years of age and older, with a majority (27) over 45 years of age. Occupations included blue and white–collar work (17 and 9 individuals, respectively). Eleven participants were retired. The highest reported annual income range was $60,000 to $99,999 (13 people), the lowest less than $14,999 (six people), with eight people declining to report annual earnings. Length of time harvesting morels in the study area ranged from less than 10 years to more than 30 years (3 and 28 people, respectively).

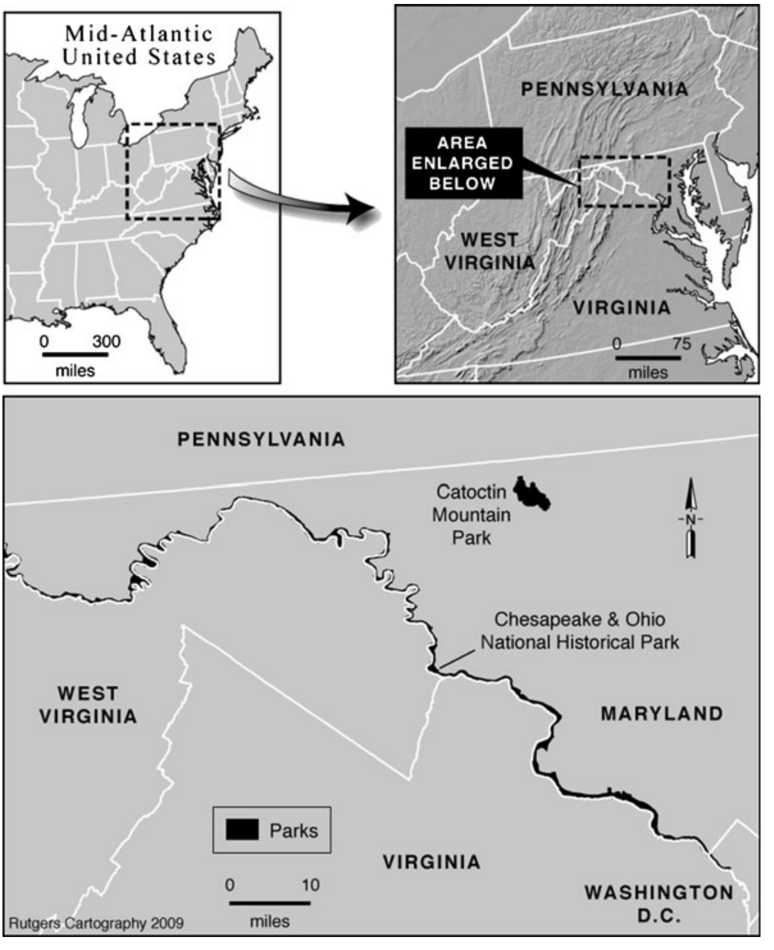

Fig. 1. Study area.

Results: Local and Scientific Ecological Knowledge of *Morchella*

Morel hunting signals the arrival of spring in the Mid–Atlantic region. The tradition of morel hunting and locations of hunting spots typically are passed down from grandparents, parents, aunts, and uncles to younger family members. As a result of this intergenerational process, local ecological knowledge of morels is grounded in both individual experience and that of one to two prior generations. It includes information about types of morels, habitat, tree associates, disturbance, and seasonality. We present that information here, followed by corresponding information from the scientific literature.

Morel Types

As a group, participants in this study identify five to six types of morels: Yellow (Fig. 2), cappy (Fig. 3), black (Fig. 4), white or gray (Fig. 5), and poplar (not pictured). We suspect that "white" and "gray" refer to the same type of morel and treat them as such for the remainder of the paper.

Morels exhibit a wide variety of forms and their taxonomy continues to challenge mycologists. The use of genetic analysis has led to a clearer understanding of the genus, but not of species within it. Instead, researchers continue to revise species distinctions based on both genetic analysis and morphological descriptions (Kuo 2005; O'Donnell et al. 2003; Pilz et al. 2007).

Fig. 2. Harvester photo of yellow morels (1988).

Morel nomenclature also is challenging. Most North American morels have been given the names of European species, although it is likely they are distinct (Dewsbury and Moncalvo 2007). Hence few, if any, eastern North American morels presently have scientific names that meet the standards of the International Code of Botanical Nomenclature (Pilz, personal communication, 2008).

Habitat and Tree Associates

Participants describe morel habitat in terms of site characteristics and tree associates. With some exceptions, the following patterns are reported consistently in the oral histories.

Ideal soil for morels is described as dark, loamy, rich, black, and fertile, often with a thick organic layer. One participant notes, "You tell by the texture of the ground…it's black, very fertile." Another participant specifies limestone soil as a good substrate. Contraindicated soils are high in clay, slate, and shale and are reddish in color. Suitable soil moisture is neither extremely mesic nor extremely xeric. Blacks are found at higher elevations more frequently than whites or yellows. (Elevations in the study area range from approximately 90 meters to 450 meters above sea level.) In the mountains, eastern and southern aspects are widely known to be early season habitat for morels. Northern and western aspects produce toward the end of the season, if at all.

Some tree species are considered good indicators of the potential presence of morels. A retired man who says he has hunted morels in the Mid–

Fig. 3. Cappy (Photo taken by E. S. Barron, May 8, 2007).

Fig. 4. Black morel (Photo taken by E. S. Barron, April 28, 2007).

Atlantic region all his life indicates, "If I had never hunted mushrooms in this area…the thing I would start looking for is [tulip] poplar, ash, and elm." Many other participants echo this observation. A total of 105 associations between particular types of morels and tree species were mentioned in 21 oral histories (Table 1). Four tree species account for a majority (89 percent) of reported associations: Apple (*Malus pumila* Mill.), ash (*Fraxinus americana* L.), elm (*Ulmus americana* L.), and tulip poplar (*Liriodendron tulipifera* L.). Black morels are most frequently observed to be found in association with tulip poplar and/or ash (73 percent of mentions), although one participant describes them as growing "everywhere." Cappies also are said to be indiscriminate in terms of tree associates by one individual, although two others believe they observe a relationship with tulip poplar. Gray or white morels are reported to be found with apple, ash, elm, and tulip poplar in 93 percent of these oral histories. As their name would imply, poplar mushrooms presumably occur most often in association with tulip poplar trees but this may have been considered so self–evident that few participants mentioned it. Participants indicate that yellow morels are especially likely to be found in proximity to elm trees. As elms have become a diminishing part of the forest, participants are most likely to seek and find yellow morels around apple and ash. Intriguingly, two participants indicate that they have found yellow morels around white pines, while another two individuals have found unspecified types of morels in a similar association. We note, however, that other participants state that morels never grow in association with pine.

Tree health is a factor in many of these associations. Participants note that morels are most likely to be found in association with dying

Fig. 5. Harvester identified gray morels (Photo taken by E. S. Barron May 2005).

TABLE 1. FREQUENCY OF MENTION OF ASSOCIATIONS BETWEEN MOREL TYPES AND TREE SPECIES BY PARTICIPANTS IN 21 ORAL HISTORIES WHERE SUCH RELATIONSHIPS WERE MENTIONED. MULTIPLE MOREL TYPES AND TREE SPECIES WERE GIVEN BY EACH PARTICIPANT.

	Apple[a]	Ash[b]	Nut[c]	Cherry (wild)[d]	Dog-wood[e]	Elm[f]	Maple[g]	Oak[h]	Tulip poplar[i]	White pine[j]	Total
Black	2	7	0	0	0	2	1	1	12	0	25
Cappies	0	0	0	0	0	0	0	0	2	0	2
Gray/white	8	8	0	0	1	5	0	1	6	0	29
Poplar	0	0	0	0	0	0	0	0	1	0	1
Yellow	7	7	3	1	0	13	0	0	3	2	36
Unspecified	2	3	0	0	0	2	0	0	3	2	12
Total	19	25	3	1	1	22	1	2	27	4	105

[a] *Malus pumila* Mill.; [b] *Fraxinus americana* L.; [c] *Juglans nigra* L. and *Juglans cinerea* L.; [d] *Prunus serotina* Ehrh.; [e] *Cornus spp.*; [f] *Ulmus americana* L.; [g] *Acer spp.*; [h] *Quercus spp.*; [i] *Liriodendron tulipifera* L.; [j] *Pinus strobus* L.

and recently dead apples and around elms when the bark is peeling in the years immediately following a tree's death. In contrast, morels reportedly are found only around live ash and tulip poplar. Unfortunately, the arrival of the emerald ash borer, an insect that feeds on and kills ash trees, may result in widespread loss of yet another morel associate.

Literature on morels in the U.S. Midwest reveals similarities and differences between the findings of mycologists there (professional and amateur) and the observations of participants in the Mid–Atlantic region. In the Midwest, morels commonly are found in rich woodlands, along river bottoms and flood plains, and in association with wood chips. Less frequently, they are observed in locations such as fields and dunes (Kuo 2005; Thompson 1994 as cited in Pilz et al. 2007; Weber 1988).

Observations of tree associates vary among regions, with those in the Midwest displaying substantial concurrence with the Mid–Atlantic region. Weber (1988) and Kuo (2005) note that Midwestern morels grow in association with elm, ash, tulip poplar, and fruit trees, including apples, as well as tree species and forest types not common in the Mid–Atlantic states. However, oak and white pine appear to be more strongly associated with morels in the Midwest than in the Mid–Atlantic area. Our findings suggest overlaps between the Mid–Atlantic and Pacific Northwestern morel tree associates are more limited. The most striking difference is the strong association between coniferous species and morels in the Pacific Northwest.

DISTURBANCE

Study participants report both positive and negative effects of disturbance on morel fruiting. Heavy logging or blow–downs were noted to adversely impact morel fruiting, especially if they affect tree associates. Flooding also appears to suppress morel fruiting for a time. As one man noted, "When we get high water, get a lot of silt… you don't find them for two or three years." One individual believes he has observed an increase in morels on the sides of recently graded dirt roads although another reports that he has not observed such an association.

The mycological literature also documents the role of disturbance in morel fruiting. Thompson (1994) indicates that heavy flooding eliminates morels, at least for a time. Weber et al. (1996) state that mechanical disturbance of soils increases abundance of *M. esculenta* and *M. semilibera*. Fire is known to produce especially large flushes of the darker mushrooms, particularly in the Pacific Northwest (Pilz et al. 2007; Weber 1988; Weber et al. 1996; Wurtz et al. 2005). Tree mortality as a result of insect or disease also is associated with bursts of morel abundance in the Pacific Northwest and Midwest (Kuo 2005; Pilz et al. 2007; Thompson 1994; Weber 1988).

PHENOLOGY

Participants identify weather conditions as the most significant determinant of morel seasons. Ideal weather conditions are described as daytime temperatures in the 70 s, paired with overnight temperatures in the 50 s, in combination with rain on soils already moist from the melting of a good snow pack. Participants note that such conditions occur only every few years and without exception express concern that they are becoming less frequent than in the past.

The timing of the Mid–Atlantic morel season also has changed, according to participants, although specific dates cited vary, possibly as a function of the areas and elevations in which individuals hunt. Several older mushroom hunters believe that the overall trend of the last several years has been toward an earlier season onset, perhaps by as much as two weeks. In the past, at lower elevations the season typically began in earnest around the second week of April and lasted approximately one month. Records kept by one man for 29 years indicate that previously the most productive point in the season occurred around April 28. His notes suggest the high point of the season now occurs closer to April 20. The end of the season also appears to have advanced. Another participant observes, "I always hunted big mushrooms the last week of May. Now they're over by 15th, 18th of May."

The scientific literature affirms participants' description of the weather associated with morel season. Weber (1988) puts season onset in the Midwest at two to three weeks after the last hard frost. Pilz et al. (2007:13) describe the climatological conditions necessary for morel fruiting as "when winter snow has melted, the soil is beginning to warm, and the air is still humid." A progression of fruiting from low elevations and south–facing slopes to higher elevations and northern aspects similar to that described by our study participants has been noted in the Ozark Mountains (Low 1995).

Mid–Atlantic Morel Decline?

Taken together, local ecological knowledge and scientific information provide insights into reported declines in Mid–Atlantic *Morchella*. Mycologists identify large–scale habitat destruction, climate change, and pollution as significant threats to fungi in general (Egli et al. 2006; Moore et al. 2001; Watling 2005). When asked what they considered to be the top three threats to morels, study participants mention habitat destruction and climate change but add that there also may be more immediate social reasons for declining harvests.

Loss of habitat almost certainly contributes to reduced morel–hunting success in the study area and development is a major concern for participants. The counties in which participants live have experienced rapid population growth ranging from 7 percent to 30 percent in the period from 1990 to 2000 (Social Science Data Analysis Network 2008). Associated development included loss of woodlands and apple orchards (Baker 2010).

Changing weather patterns and pollution also may result in a decline in morels. In the state of Maryland, mean winter and spring temperatures have increased nearly one degree Fahrenheit over the last three decades (National Climatic Data Center 2009a, b) while winter precipitation has declined 0.44 inches per decade since 1970 (National Climatic Data Center 2009c). Acid rain and nitrogen deposition are known to have a negative effect on mycorrhizal fungi (Watling 2005). In the eastern United States, the effects of acid deposition on water chemistry and tree health are well documented (Aleksic et al. 2009; Borer et al. 2005; Lawrence et al. 2008) and may contribute to declines of morel populations and/or their ability to garner nutrients for fruiting (Pilz, personal communication, 2008). Several participants believe that the spray used to fight gypsy moth infestations kills morels, while Weber (1988) states that morels do not fruit in orchards where fungicides have been used. In 2008, 3,370 acres of one national park in our study area were sprayed with the bacterium *Bacillus thuringensis* (Btk). Pilz (personal communication, 2008) speculates that if there is an association between use of Btk and reduced morel fruiting, it may be attributable to improvements in the health of host trees.

Research on other wild edible fungi has concluded that there is no measurable negative impact strictly due to harvesting (Egli et al. 2006; Norvell 1995) and within the mycological community harvesting is not generally considered a significant threat to edible species (Moore et al. 2001). The opinion of participants in this study was mixed as to whether over–harvesting is a factor in reported morel decline. Many participants believe that there are more people hunting morels today than in the past and several note that what they perceive as a decline in morels may actually be increased competition for them. Some reason that their own decreased annual yield may be due to increasingly busy lives, resulting in less time to get out and hunt.

Changing disturbance regimes likely contribute to actual or perceived declines in morels. Yellow morels, in particular, may have declined after a spike in fruiting due to the crash in the elm population. Participants also mention increasing populations of some wildlife species. Dramatic increases in turkey populations over the past 30 years (Long 2007) could be affecting morels and other fungi as turkeys scratching for insects may damage fruiting bodies and mycelia.

Conclusions

Neither our results nor the mycological literature originating in the U.S. Pacific Northwest and Midwest provide conclusive evidence that confirms or refutes reports of *Morchella* decline in the Mid–Atlantic region. Certainty on this question will require greater understanding of morel biology and ecology, as well as the cultural and economic contexts of use. The local ecological knowledge reported here makes an initial contribution to such an effort. Expanding the geographic coverage of research to include the U.S. Mid–Atlantic states provides a basis for generating testable hypotheses about diversity in the genus and life strategies throughout its range. We suggest several areas for future research that would combine local and scientific ecological knowledge.

Participants' identification of morel types could be used to guide the selection of specimens for research on Mid–Atlantic *Morchella* genetics and taxonomy. Local ecological knowledge of morel habitat and tree associates suggests that research on changes in forest composition and land use/ land cover may provide insights into reported declines in mushroom productivity. Research on the role of disturbance in Mid–Atlantic morel fruiting might include exclosure studies designed to examine the effects, if any, of deer, turkey, and other wildlife species on morel mushrooms. Written records kept by four participants on the quantity and quality of their mushroom harvests through the years may be useful in future monitoring efforts. While their value for capturing broad trends is constrained by the highly personal nature of the data, such records provide the only known windows into Mid–Atlantic morels in the 20th century. It is likely that similar records exist elsewhere. Examined as a group, they could serve as a basis for further inter–regional comparison. Finally, multi–decadal observations of relationships between weather, seasonal onset, and duration of fruiting could serve as early data on fine–scale effects of global climate change, as well as a starting point for probing the implications of climate change for fungi and their role in forested ecosystems.

Results from the study also suggest opportunities to incorporate morels into forest management. Pilz et al. (2007:112) recommend "managing forests for a mixture of stands in various age classes and in sufficiently close proximity for morels to spread their spores between stands." On public lands where substantial tree harvesting is not an option, such as national parks, other strategies can be pursued to ensure favorable forest conditions. For example, recently fallen elms may be rotated off paths rather than removed. Exclosures to protect saplings from large deer populations can emphasize known tree associates of morels.

This study begins the process of systematizing Mid–Atlantic morel hunters' local ecological knowledge and articulating it with scientific ecological knowledge to increase understanding and conservation of morels. The suggestion of one participant who has been hunting morels for nearly 60 years illustrates the capacity of long–time mushroom hunters to contribute to research on *Morchella*. When asked for ideas about work that could be undertaken with scientists, he proposed a harvest impact study similar to research designed by mycologists in the U.S. Pacific Northwest:

> You got to take a section where you know they grow, at least 100 feet square…that you can keep people out of…Pick 'em off of this end, say 25 feet here and let the next 25 feet be. And then pick over here 25 feet, let these be. Then try to get an idea how many is in these areas that you let be…then the next year come back, see what you got…[do this] over at least a five–year period.

This is just one of many possible opportunities to engage in co–production of information about morels. Our research demonstrates that long–time morel hunters possess substantial local ecological knowledge about the genus *Morchella* in their area. Such information can complement scientific ecological knowledge and help to increase our understanding of this complex genus. In doing so, it lays the foundation for future conservation of a culturally and economically significant species that in many respects remains a mystery.

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