Yearly Variations in Fungal Diversity Driven by Rainfall at two Sonoma State University Nature Preserves

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Abstract

It has been well-observed that there is a strong relationship between the abundance of mushroom fruiting bodies (sporocarps) and rainfall (Alday et al. 2017, O'Dell et al. 2000, Ogaya and Peñuelas 2005.) Some research asserts that sporocarps utilize rainfall from 1-2 weeks prior (Bonet et al. 2004) to fruiting, while others suggest that sporocarp fruiting is affected by spring rainfall from the previous year (Krebs et al. 2008) or even weather patterns over decades (O'Dell et al. 2000). We collected a total of 919 sporocarp samples, 683 from the Galbreath Wildlands Preserve (GWP) and 236 from the Fairfield Osborn Preserve (FOP) for 8 years, from 2016 to 2023, on 14 separate mycoblitz events during the winter months. We identified 124 species from FOP and 279 species from GWP. The relationship between sporocarp abundance and rainfall from each water year (mean rainfall from October to September) was examined but we found no correlation between rainfall and species diversity. The highest rainfall was at GWP in 2017 at 4.57mm; however, the most diverse year was 2023 when rainfall was the 3rd highest of the 8 water years at 3.05mm. Additionally, fruiting proportions of observed ectomycorrhizal species were found to be inversely related to rainfall. This opposes the standard understanding that ectomycorrhizal species (plant root symbiotic fungi) need more water to fruit than saprotrophic species (decay fungi). Overall, we observed greater diversity in all years at GWP than at FOP, with saprotrophic species being more diverse at 11 of the 14 mycoblitz events.

Background

The mushrooms we see are the fruiting body (sporocarp) of a much larger fungal organism that lives as a mycelium, or a network of long branching filamentous strands called hyphae extending underground throughout the soil or within wood. The mycelium obtains nutrients for the fungus in a variety of ways; as a saprotroph breaking down the organic molecules in decaying organisms like rotten tree logs or leaf litter, as a predator of small invertebrates, as a parasite, or by engaging in a mutualistic relationship with nearby plants. In this ectomycorrhizal relationship, the mycelium wraps around the roots and the plant provides the fungus with carbon in the form of sugar, produced via photosynthesis, and in turn, the fungus provides the plant with minerals like nitrogen, phosphorus, potassium, calcium, zinc, magnesium and water from the soil.

A key variable in aboveground mushroom abundance from year to year is rainfall; with drier seasons and locations generally yielding less fruiting bodies than in wetter conditions. Prior research suggests that there is a correlation between rainfall and the abundance and diversity of mushrooms (Alday et al. 2017, O'Dell et al. 2000, Ogaya and Peñuelas 2005). Mushrooms often fruit following rain, usually within 5-12 days, but it has been theorized that total rainfall levels from the previous "water year" (the part of the year when rain falls, e.g. from October to September) may affect mushroom abundance in the following season (Krebs et al. 2008). In this study we aim to investigate the relationship between mushroom diversity and rainfall.

SSU's Center for Environmental Inquiry (CEI) manages two educational nature preserves: Fairfield Osborn (FOP) and Galbreath Wildlands (GWP). The FOP, located in Penngrove on Sonoma Mountain, is an oak woodland dominated by coast live oak (*Quercus agrifolia*) and bay laurel (*Umbellularia californica*). The GWP is located in Yorkville (Mendocino Co.), and is a mixed hardwood conifer forest. Since specific fungi will only fruit either on decaying matter or from the ground as part of a relationship with plant roots, knowledge of tree species is crucial for mushroom identification. A community of tree species such as Douglas fir (*Pseudotsuga menziesii*) madrone (*Arbutus menziesii*) and tanoak (*Notholithocarpus densiflorus*), is known to harbor ectomycorrhizal relationships with specific Genera of fungi, while regions that are dense with coast live oak will yield mushrooms that are specific to that species. Because the dominant tree communities vary between the two preserves, and because we expected higher amounts of rainfall to occur at the northernmost preserve in Mendocino County, we predicted a higher proportion of ectomycorrhizal species would be found at GWP than at FOP as well as higher overall diversity in all years. We also expected that in drier years we would encounter more saprotrophs than ectomycorrhizal species at both preserves.

Materials & Methods

In collaboration with the CEI, Dr. Melina Kozanitas and Yorkville community member Lisa Bauer co-founded a citizen science-based program where members of the public were invited to attend annual winter forays at each CEI preserve to conduct a yearly "mycoblitz". From 2016- 2023, 14 forays took place, one per year at each preserve (with the exception of 2020) where all observed species of fungi were either collected or documented in order to be identified. In some cases, a species could not be identified but was still included in the overall diversity total for each event. Conducting a yearly mycoblitz at the same location and at relatively the same time of year for several years allowed us to examine changes in species diversity from year to year and to then correlate this data with long-term weather patterns. For each mycoblitz we calculated rainfall totals (reported in mm) from the previous water year that began in October of the prior year and ended in September of the foray year. Rainfall data was sourced from The National Oceanic and Atmospheric Administration database in inches and then converted to millimeters. For FOP, we used the water meter at the Sonoma Co. Airport in Santa Rosa, and the company "threaded extreme" water meter in Ukiah for GWP. Yearly rainfall was compared to overall diversity at each site to look for patterns. Species identification was completed by Dr. Kozanitas using guide books and online resources specifically 'Mushrooms of the Redwood Coast' by Siegel and Schwartz, Mushrooms Demystified by David Arora, Mykoweb.com and the iNaturalist app. Finally, all identified species were categorized by nutrition type and labeled as either ectomycorrhizal or saprotrophic, comparisons of abundance by group were made for each foray and then correlated with rainfall. We utilized Microsoft Excel to generate the rainfall and biodiversity figures.





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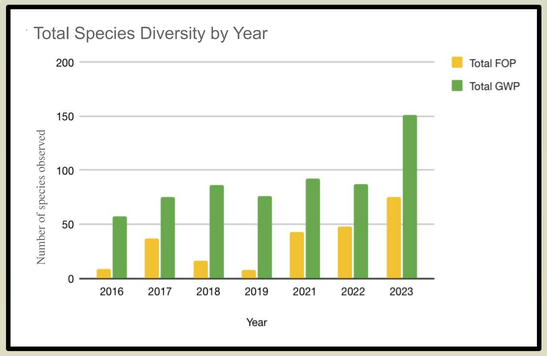
Results



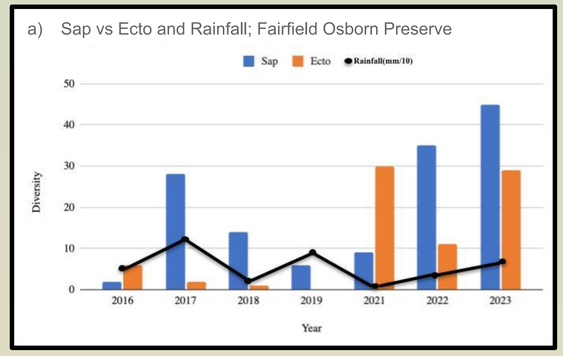


Figure 1: Total number of mushrooms found at each location in each year (2016 to 2023) are displayed. The two locations in comparison are the Fairfield Osborn Preserve and the Galbreath Wildlands Preserve. Diversity counts ranging from 8 to 151

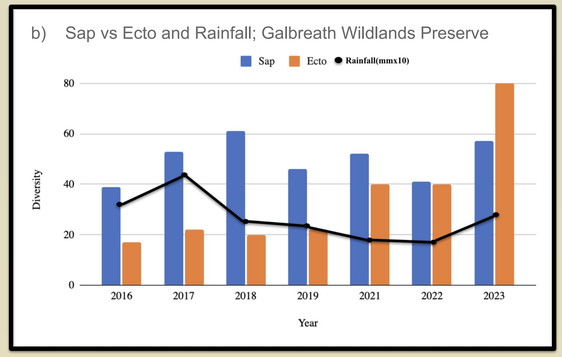


Figure 2: Abundance of saprotrophic vs ectomycorrhizal species observed at each preserve from 2016 to 2023; the black line indicates rainfall level for each water year (FOP: 1mmx10; GWP: 1mm/10)
a) Fairfield Osborn Preserve
b) Galbreath Wildlands Preserve

Figure 3: Examples of mushroom nutrient absorption types;
a) Ectomycorrhizal mushrooms; mutualism with tree roots
b) Saprotrophic mushrooms decaying plant litter
c) Saprotrophic mushrooms decaying wood
Source(https://salepeaket.live/product_details/40369396.html)

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Discussion

In total we collected 919 samples; 683 at GWP and 236 at FOP, and identified 124 and 279 unique species respectively. Our analysis revealed higher species diversity at GWP than at FOP in all years, which can be explained by consistently higher rainfall. GWP had 10x more rain than FOP on average and nearly double the species diversity in 2023. Based on prior literature, we expected that wetter years would correlate with an increase in the diversity of fungi observed. We conclude that due to the varying amounts of yearly foray participants, coupled with increasingly refined mushroom identification, that relationship was not observed. We also examined the relationship between yearly proportions of saprotrophic and ectomycorrhizal species and rainfall at each preserve and found that saprotrophic species were more diverse at 11 of the 14 mycoblitz events which was counter to our expectation and did not correlate with rainfall amounts.

At GWP the highest recorded rainfall in 2017 yielded only 22 ectomycorrhizal species compared to 54 saprotrophic species. Saprotrophic species are thought to rely less on rainfall than ectomycorrhizal species, but are easily found on rotting logs and other debris, which may have influenced their higher rate of observation. While saprotrophic species diversity remained constant over the years, ectomycorrhizal species diversity gradually increased until its peak in 2023. The highest attended foray was in 2023, which can partially explain the increase in diversity despite this particular year not having the most rainfall. At FOP there was much less yearly rainfall, yet in 2021 -when practically no rain fell, over 30 ectomycorrhizal species were collected, and in 2019 -the second wettest year, only saprotrophic species were observed. These results suggest that the previous year's rainfall or the few weeks prior to survey could impact fruiting more than the current water year. Overall diversity did increase over time at FOP as well, especially the diversity of ectomycorrhizal species, which could be due to a shift in foray dates from mid Nov to mid Dec beginning in 2021 (all GWP forays were held in early Dec) and is a likely explanation for the marked increase in numbers of mushrooms collected in 2021 (40), 2022 (50), and 2023 (80).

In the future we hope to continue yearly data collection in order to further examine the relationship between rainfall and species diversity. More rigorous surveys using quadrats in specified regions may lead to more discernible patterns and targeted analyses. Continuing to hold annual December forays at each preserve, along with more consistent funding and research support, could allow us to determine a more accurate measurement of fungal diversity at these locations. Additionally, a regularly offered Mycology course would allow for more consistent student involvement as well as provide opportunities to enhance student field research experience as part of an ongoing applied research program. Future mycologists interested in research at SSU's preserves could obtain a more accurate correlation between long term weather patterns and fungal diversity using this robust dataset.