Restoration Mycology

Mycoremediation and Mycorrhizal Inoculation as a Complement to Ecological Restoration

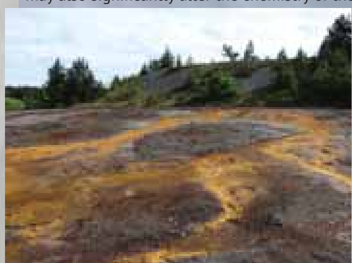
MATTHAEI BOTANICAL GARDENS
UNIVERSITY OF MICHIGAN

Poster by Andrew Harmon
Staff Supervisor: Steven Parrish

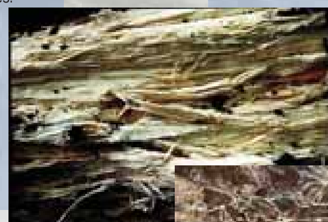
Special Thanks to the Friends of the Matthaei Botanical Gardens

Degraded Lands

Sites targeted for ecological restoration may have been substantially altered by exposure to agricultural and industrial pollution over the span of many years. These toxins could include heavy metals, petroleum hydrocarbons, plastics, radioactive material and a host of other unpleasant products of derived from sources like explosives, drugs, pesticides, solvents, and dyes. These chemicals represent a growing hazard to human health. They may also significantly alter the chemistry of the soil, changing site conditions from historic norms, preventing the establishment of desirable native plants, and thwarting efforts to restore ecological function.

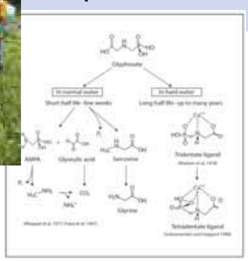


Heavy metal contamination near a coal mine colors the earth orange



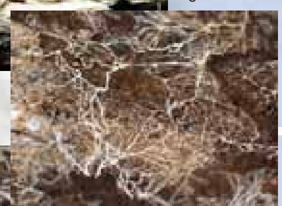
Herbicide in Restoration

Even in higher quality sites management activities for conservation and restoration may result in changes to soil chemistry and biology over time. For example, glyphosate herbicide is routinely used as part of a strategy to control invasive plants in natural areas. Glyphosate was originally patented as a descaling agent used to remove mineral deposits from appliances due to its ability to chelate, or strongly bond to, a range of elements. When glyphosate reaches the soil it has the ability to bind to a number of elements and make them biologically unavailable to the flora and fauna present in the soil. These elements include zinc, copper, manganese, iron, calcium, and magnesium which are necessary for plants as secondary and trace nutrients. These bonds can last for many years in the soil. In addition many of the inert ingredients in pesticides have not been thoroughly researched and may have impacts of their own. Again, **changes in soil chemistry further perturb the site away from historical conditions and complicate maintenance or reestablishment of historic vegetation.**



Left: Herbicide being applied to invasive prairie plants at MBG

Right: An example of how herbicides can form secondary compounds that will persist in the environment

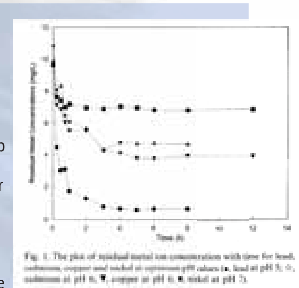


Above: fungal mycelium work their way through decomposing material while foraging for food, much like how plat roots explore the soil

Why Fungi?

Although many mechanical, chemical, and biological methods have been targeted for the remediation of these pollutants **fungi hold particular promise due to their unique life history.**

Fungi are osmoheterotrophs, meaning that they absorb their food from the environment around them. In order to digest their food source **they produce a number of unique digestive enzymes** that they secrete into the environment around them and ahead of their growing mycelia (the fine, thread-like vegetative structure of the fungi).



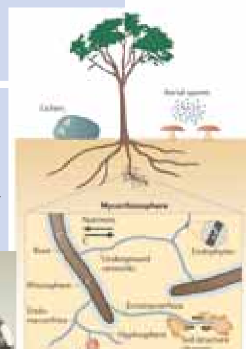
Some fungi have the ability to substantially alter the makeup of these enzymes to more appropriately match conditions of their immediate environment. Fungi are also unique in that they can grow very quickly in favorable conditions and can be produced and employed en masse using relatively simple technologies.

Generalist Feeders

White rot fungi produce a number of non-specific **enzymes such as peroxidases and laccases that help break down molecules with tight bonds and complex chemical structures as might be found in the lignin of wood or toxic contaminants.** Perhaps the best known example of this group is the oyster mushroom, which has been known to digest the fuel in diesel soaked wood chips. In cases where toxins are absorbed into the fungal tissue, they may be concentrated (or hyperaccumulated) and removed from the environment. Many fungi will also transport toxins into their temporary reproductive structures, where the material could be harvested and disposed of. Mushrooms are used to remove waste and can be thought of as fungal toilets, which is why it is not wise to harvest morels in orchards that might be contaminated with lead.

Protecting Plants

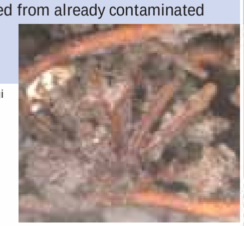
Other fungi commonly found in soils can also play a role in remediation. Such fungi can produce metabolites that can mediate certain metal and mineral transformations as part of the fungus' foraging strategy. Mycorrhizal fungi, those that maintain a close, symbiotic relationship with plant roots can detoxify soils and prevent translocation of toxins into their associated plant tissue. Furthermore, **the large volume of fungal filaments can increase the volume of soil treated** over the area covered by plant roots in typical phytoremediation approaches.



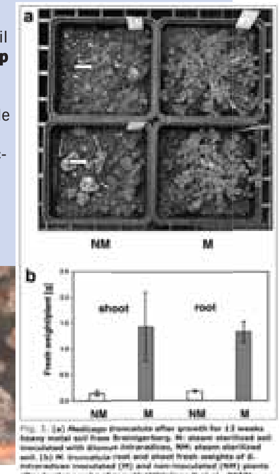
Mycorrhizal fungi help plant roots explore larger volumes of soil while foraging for otherwise unavailable nutrients

Encouraging Revegetation

Mycorrhizal fungi provide nutrients for their plant hosts in exchange for some of the energy that plants store during photosynthesis. This interaction is not particularly beneficial in conditions of high nutrient availability and in such cases may even lower the fitness of the host plant. However, in areas where nutrients are in short supply, such as those that have altered soil chemistry due to contamination, **the relationship with fungi can dramatically improve plant germination, growth and survival.** In addition to providing nutrients the fungi can also play a role in protecting the plants from toxins in the soil by excluding them from their hyphae and reducing the quantity of contaminants at the root interface. Where fungi are not currently tolerant of certain contaminants they are much quicker to speciate and adapt than are plants, so fungal partners isolated from already contaminated sites may provide additional resilience.



Some mycorrizal fungi form distinct nodules on the roots of their plant hosts



Future Directions

Although **mycoremediation shows clear potential** as a complementary addition to more traditional restoration activities there are many questions left to be answered. Mycology still has a long way to go in describing fungal diversity, let alone understanding the roles of individuals in the environment. It is not clear how various species will react under varying chemical, climatic, and ecological conditions. There is no clear protocol for collecting, assaying, producing, and deploying fungal cultures in restoration. Research in mycorrhizal inoculations has found that inoculums can provide widely differing results depending on specific site conditions. **Improving our understanding in these areas could provide a more clear path forward** as we attempt to heal and restore our lands.