IMPLEMENTATION OF A MUSHROOM GARDEN

Millard Learning Centre, Galiano Conservancy Association

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ER 412: Advanced Principles and Practice in Ecological Restoration

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1. EXECUTIVE SUMMARY

The ER 412 “Advanced Principles and Practice in Ecological Restoration” course from the University of Victoria took place on Galiano Island, BC, from May 5th to May 14th 2017. This course was offered in partnership with the Galiano Conservancy Association (GCA), a local NGO on the island that promotes conservation, environmental education and sustainable agricultural practices. During this time, students became involved with the different on-going ecological restoration projects managed by the GCA, as well as being familiarized with different field measurement techniques within the ecological restoration field.

A specific outcome of this course was the development of a design project, where, in partnership with the Galiano Conservancy Association, students would be able to apply the knowledge acquired during the course in a concrete manner and propose at the same time a project that would fall in line with the GCA’s land management goals.

The following report will present the possible implementation of a mushroom garden at the Millard Learning Centre, one of the properties on which the GCA has implemented various restoration activities. Sections on mushroom ecology and reproduction will be presented, so that growers can understand the basic mechanisms involved in the cultivation of mushrooms. Nutritional and medicinal benefits of different mushroom species will be discussed, as well as the inoculation process and materials required for a successful production. The proposed site for the garden as well as specific project goals will be presented, along with an estimated budget for the first 3-4 years of the operation. Finally, the bioremediation potential of the chosen species will be assessed, and a section on invasive species will discuss possible measures to adopt in order to minimize the risk of having this garden spread out of control.

2. GALIANO CONSERVANCY ASSOCIATION

The Galiano Conservancy Association is a community based land-trust created in 1989 in order to respond to community and ecological needs (Galiano Learning Centre Management Plan, 2013). Its main goals are to "hold, own and protect land through different legal mechanisms, while allowing opportunities for public education, sustainable land management practices and ecological monitoring and restoration" (Keith Ericsson, personal communication). In total, the GCA owns and manages approximatively 200 hectares of land on Galiano Island, BC (see Figure 1). DL57 is a 76 hectares property, acquired in 2012, and hosts the Millard Learning Centre, the area in which the proposed mushroom garden will be implemented.

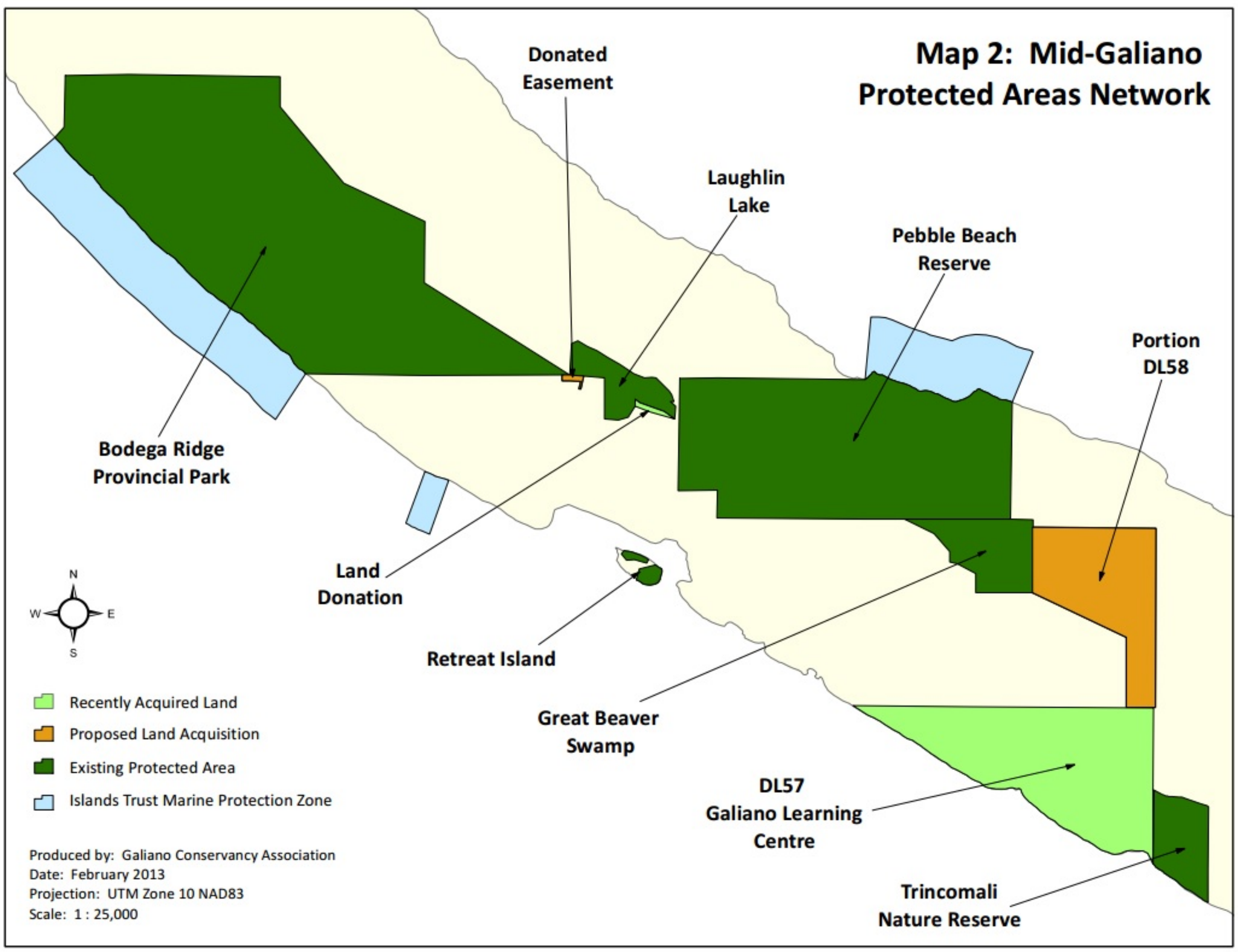


Figure 1. Total acquired and proposed land acquisition by the Galiano Conservancy Association as of February 2013. Dark green areas represent already protected provincial areas.

2.1 FOREST GARDEN PROJECT

The forest garden project was an initiative which began in 2013 as part of the food security and sustainable agricultural goals within the GCA's mandate. At that time, an agricultural survey and the sampling of five soil sites were performed on the Learning Centre property in order to determine potential for agroforestry uses (Pringle, 2013). It was determined that a site at the northwestern end of the property was the most suited for agricultural purposes, as it possessed very good soil and drainage as well as good sun exposure (Figure 2).

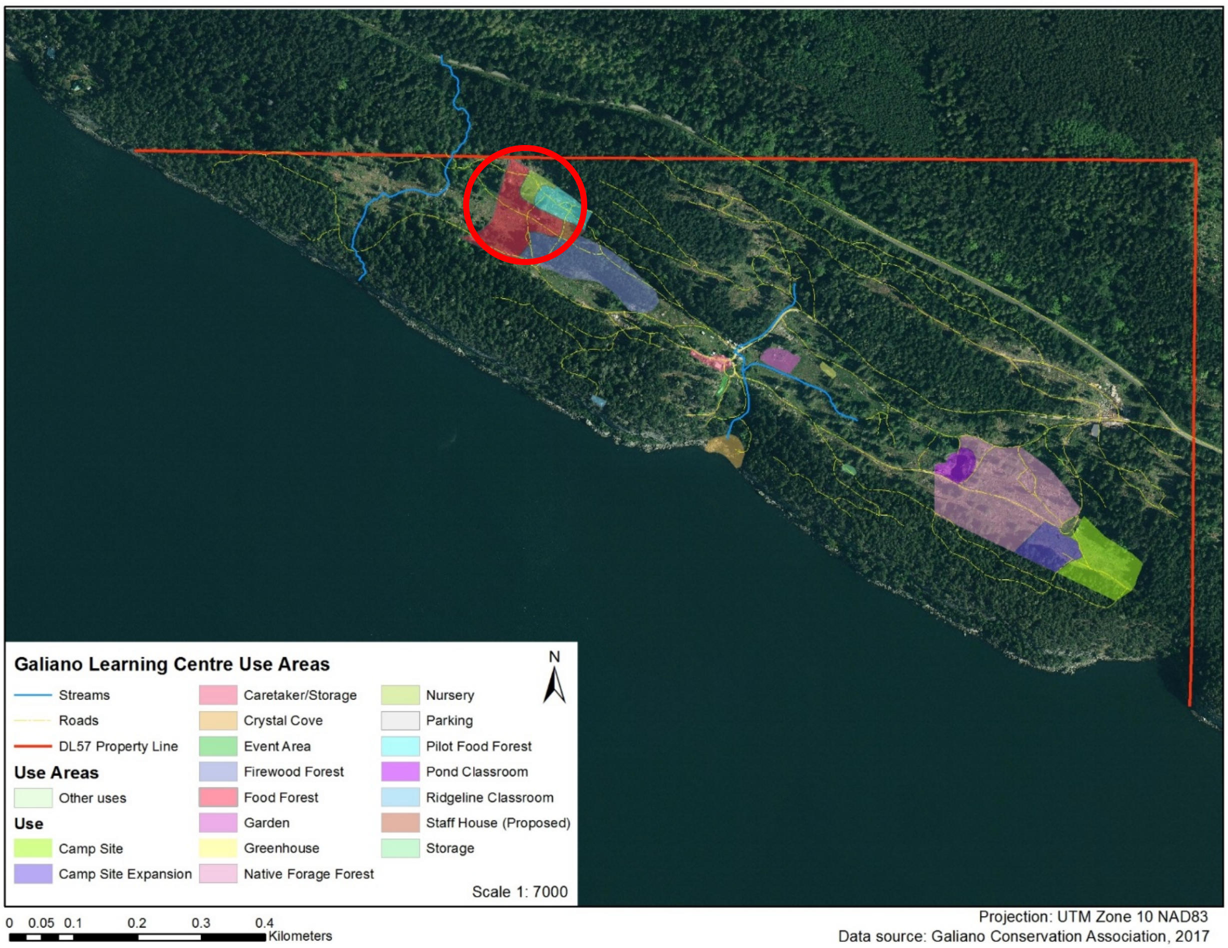


Figure 2. Chosen forest garden site (red circle) on the Millard Leaning Centre property.

The forest garden project was thus implemented in the fall of 2015. It is mainly composed of trenches mixed in with rooting wood, which were covered with good soil and mulch. "Hugelkultur" principles are also applied, which consist in raised beds that hold moisture and heat and can help to enhance the overall fertility of the soil (Cedana Bourne, personal communication). Plants chosen for the garden are mainly resilient perennials, self-seeding annuals and a variety of pollinator plants, which will be beneficial for an upcoming apiary project (start date summer 2017). The main goal of this project is to mimic a natural forest. In other words, it is hoped that over time, the different plant layers will act as a natural forest and possess similar structure and function, as well as requiring minimum human management intervention (Cedana Bourne, personal communication). Additional goals include an educational component, whereby local school children and community members can come and learn about the garden and its plants, as well as sustainable partnerships with local businesses, where forest garden plants could be commercialized for restaurant/café consumption. The proposed mushroom garden aims to fit into those objectives by promoting opportunities for sustainable agriculture, education and local commercialization.

The following sections will provide information on mushroom ecology and the associated nutritional and medicinal benefits of mushroom culture, as well as describe the goals the project, where it is meant to be located and how it is to be implemented.

3. MUSHROOM ECOLOGY

In order to be able to properly cultivate mushrooms, it is important to understand their role in forested ecosystems, as well as their reproductive cycle, presented below. Mushrooms have been defined as "macrofungi with a distinctive fruiting body which can be either above ground or underground, are large enough to be seen with the naked eye and can be picked up by hand" (Chang and Miles, 1992). They belong to either of the basidiomycetes or ascomycetes phyla, depending on how their spores are formed and the shape of their sexual organ (Savoie and Lagerteau, 2011). Mushroom can then be further divided into four categories, depending on how they acquire their food sources. The first category is called "saprophytic"; they are the most abundant group and are decomposers, which means that they get their nutrients by degrading available food sources on the forest floor (Stamets, 2005). Decomposing mushrooms occupy essential functions within an ecosystem, such as the cycling of carbon, nitrogen and other essential elements, which enriches the soil substrate and increases nutrient availability for other plants and animals (Hill and Buck, 2000). All chosen species for this project are part of the saprophytic group. Mushrooms can also be "mycorrhizal, endophytic and parasitic" (Stamets, 2000). Mycorrhizal species are usually those involved in beneficial symbiotic relationships with other plants, whereby the mycelium root structures of mushrooms are able to bring in nutrient from distant sources to the plants, while the host plants provide direct access to essential processed sugars and other food sources (Chang and Miles, 2004). Endophytic mushrooms provide many of the same benefits to nearby plants and trees as mycorrhizal species, in particular disease prevention due to their secretion of specific mycotoxins which are very efficient against insect and parasite attacks (Stamets, 2005). However, the mycelia of this group of mushrooms does not penetrate the plant cells and as such their effects are less direct than those from mycorrhizal relationships. Finally, parasitic mushrooms are those which negatively affect the health of their host plants by degrading their nutrients without providing anything in return (Chang and Miles, 2004). However, research on parasitic mushrooms has shown that even though those species can destroy acres of forests, they may end up increasing the overall biodiversity of an area by providing new habitat and food sources for other birds and animals (ex: rotting trees for woodpeckers) (Stamets, 2005, Muller and Butler, 2010).

3.1 MUSHROOM LIFE CYCLE

Before proceeding with mushroom cultivation it is essential that growers familiarize themselves with the life cycle of a fungi and most importantly, how they reproduce (see Figure 3 below for associated illustrations). A fungi will begin its life cycle once spores from mature mushrooms have been released and transported to a new substrate, which may be nearby the parent source or very far away, depending on how it was transported (Stamets, 2000). Once spores germinate onto the new material, they form the "hyphae", which are similar to the roots of a plant and are the main form of vegetative growth in fungi (Marshall and Nair, 2009). The grouping of the hyphae is actually what forms the mycelium, which are important for capturing nutrients from nearby sources as well as occupying essential functions in ecosystems, as was mentioned above (Savoie and Lagerteau, 2011). As the mycelium grows and expands, it is able to capture nutrients from its environment by releasing special enzymes which are able to degrade and convert complex molecules such as lignin and plant cellulose into simpler organic compounds which they can absorb (Marshall and Nair, 2009). When colder winter temperatures begin to be more frequent, the mycelium forms the "sclerotia", a bulb like structure which allows it to store energy and nutrient over winter. The process by which sclerotia begin to switch from conservation of energy to fruit production is still relatively poorly understand and simply called a "biological switch" (Stamets, 2000). What is known is that some sort of environmental trigger is required, either naturally through a shift in temperature and moisture conditions or manually induced. Once that shock is perceived, the mycelium enters a "survival mode" in which the primary goal is to produce a mature fruit and release spores in order to find a more adequate substrate (Chang and Miles, 2004). The sclerotia then forms into the "primordia", which is the initial stage of the formation of the fruit body (i.e. the mushrooms). If moisture is sufficient the primordia cells will begin to differentiate and produce mushroom tissue, which in turn will differentiate again into the known mushroom structures such as the cap, the gills, the stem, etc. (Stamets, 2000). Complete mushroom development can take anywhere between four days to a week and once the mushroom is fully grown and mature, it is ready to release its spores into nature and the cycle begins anew (Aloha Medicinals, 2017).

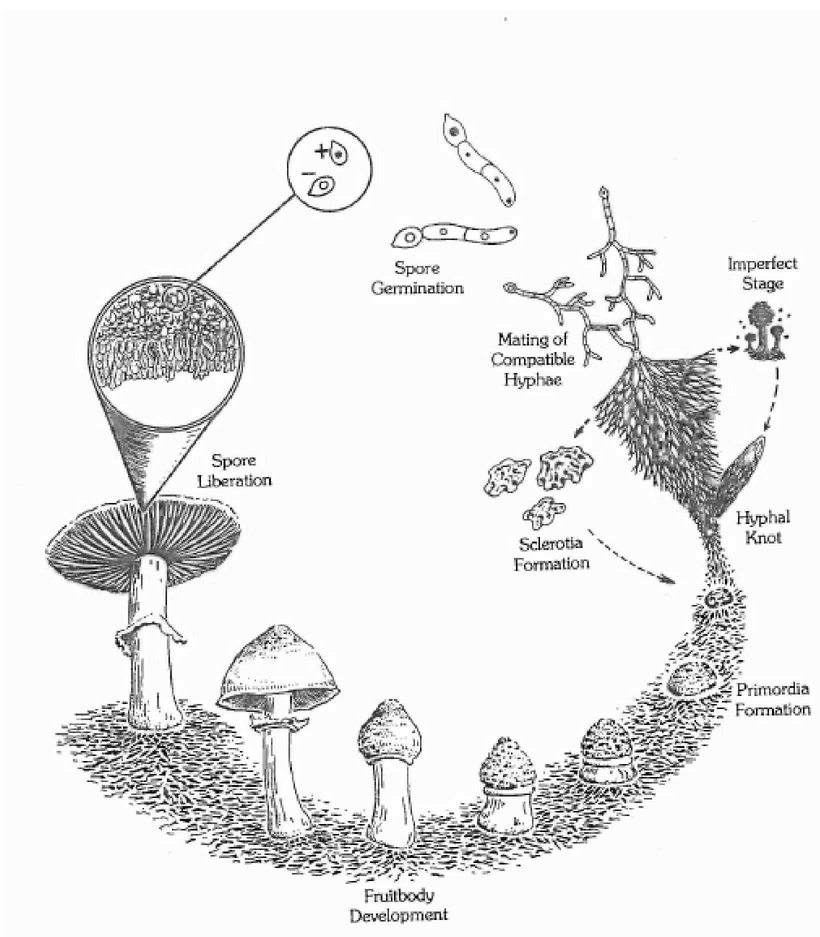


Figure 3. The different stages in the life cycle of a mushroom. Image source: Stamets, 2000.

3.2. NUTRITIONAL AND MEDICINAL BENEFITS

It is estimated that the number of fungi on Earth ranges between 500 000 and 10 million different species, however only 100 000 of those have currently been described (Wasser, 2010). Out of those, it is estimated that 2500 are edible mushroom species, out of which 80 species have been experimentally grown and only 40 have been commercially cultivated (Yun and Hall, 2004, Savoie and Lagerteau, 2011). The potential to discover and commercially grow new species of mushrooms is thus enormous. Mushroom harvesting has had a long history of use, especially in Asia where cultivation and management of the Wood ear (*Auricularia auricular*) began as early as 600 A.D., and expanded into fully commercialized operations in Europe by the 17th century (Aida et al. 2009). Indeed, the high nutritional values and medicinal properties of mushrooms make them very desirable products to cultivate and commercialize. First of all, they are a rich source of protein (15-35% of dry weight) and amino acids and are low in fat and calories, thus making them excellent substitutes in a vegetarian diet or as food supplements for weight reduction plans (Erjavec et al. 2012, Gargano et al. 2017). Mushrooms also contain many vitamins, particularly B1, B12, C and vitamin D, as well as many mineral elements such as calcium, magnesium, phosphorus, iron and potassium (Guillamon et al. 2010). Finally, they are very rich in antioxidants and contain important polysaccharides, which confers them with specific medicinal attributes that can be used against a variety of diseases, tumors and existing medical conditions.

Many studies have shown that different mushroom enzymes and extracts have anti-inflammatory, antibacterial, antidepressive, digestive and neuroprotective properties (Ghorai et al. 2009, Erjavec et al. 2012, Gargano et al. 2017). Overall, a total of 126 medicinal functions have been associated with mushroom consumption (Wasser, 2010). Main medicinal substances associated with the some of the most common cultivated species along with their biological targets are presented in Table 1 below.

Table 1. Bioactive proteins and protein extracts from mushrooms selected according to their biological activity (Adapted from Erjavec et al. 2012)

Substance/extract with bioactivity	Mushroom species	Biological target(s)
Antifungal		
eryngin	Pleurotus eryngii	F. oxysporum, M. arachidicola
ganodermin	Ganoderma lucidum	B. cinerea, F. oxysporum,
lentin	Lentinus edodes	P. piricola, B. cinerea,
pleurostrin	Pleurotus ostreatus	F. oxysporum,
RNase	Pleurotus sajor-caju	F. oxysporum, M. arachidicola
a lectin	Ganoderma lucidum	Fusarium oxysporium,
Antibacterial		
RNase	Pleurotus sajor-caju	P. aeruginosa, P. fluorescens Staphylococus aureus
extract	Lentinus edodes	Prevotella intermedia
Antiviral		
GFAHP	Grifola frondosa	herpes simplex virus-1
laccase	Lentinus edodes	HIV-1 reverse transcriptase
Antiproliferative and antitumour		
Flo, Flo-A FIII-1-a/b, FIII-2-a/b, PCP-3A and KS-2 glycoproteins	Pleurotus citrinopileatus, Ganoderma tsugae, Lentinus edodes	Various cancer and tumor cells
Gl-PP	Ganoderma lucidum	
lectins	Ganoderma lucidum Grifola frondosa Hericium erinaceum Laetiporus sulphureus Pleurotus ostreatus	
extract	Pleurotus ostreatus, Grifola frondosa, Hericium erinaceus	
Immunomodulatory		
MLP fraction	Grifola frondosa	Immune system
protein fraction	Ganoderma lucidum	
LZ-8, FIP-fve, FIP-vvo,	Ganoderma lucidum,	
glycoprotein PCP-3A	Pleurotus citrinopileatus	

4. MUSHROOM GARDEN

4.1 GOALS

The goal of the mushroom garden project is twofold. First, the project is to fit within the Galiano Conservancy Association's integrated land management goals, specifically as an integral part of the GCA's forest garden project. This incorporates:

- Promoting food security and partnerships with local businesses
- Ecological stewardship of the land, encouraging opportunities for sustainable agroforestry
- Promoting public education & community participation

The second goal of the project is to offer distinctive opportunities for ecological restoration. This includes:

- Soil bioremediation/mycorestoration of potentially contaminated areas (on the property or elsewhere on the island)
- Improve soil fertility & function at the forest garden site from mushroom products & by-products
- Use mushroom substrate as a rich compost material for the garden and other growing projects

4.2. PROPOSED LOCATION

In order to be able to grow and develop, mushrooms need two basic elements: shade and moisture. Without these, they will lack the necessary nutrients and energy needed to develop; they will dry out. The proposed site for the mushroom garden has therefore been chosen as a shady patch underneath a grove of cedars, right below the forest garden (Figures 4 and 5). The shade provided by the trees will protect the mushrooms from direct sunlight and the lower topography of the land at that particular spot will ensure that the soil maintains adequate moisture levels throughout the year. This site is also situated near the proposed fuelwood forest project, whose timber may be used as potential substrate for log inoculation. Finally, there is already an established path/trail that is situated right behind the proposed site, which means that no additional infrastructure work/clearing will be required for access.

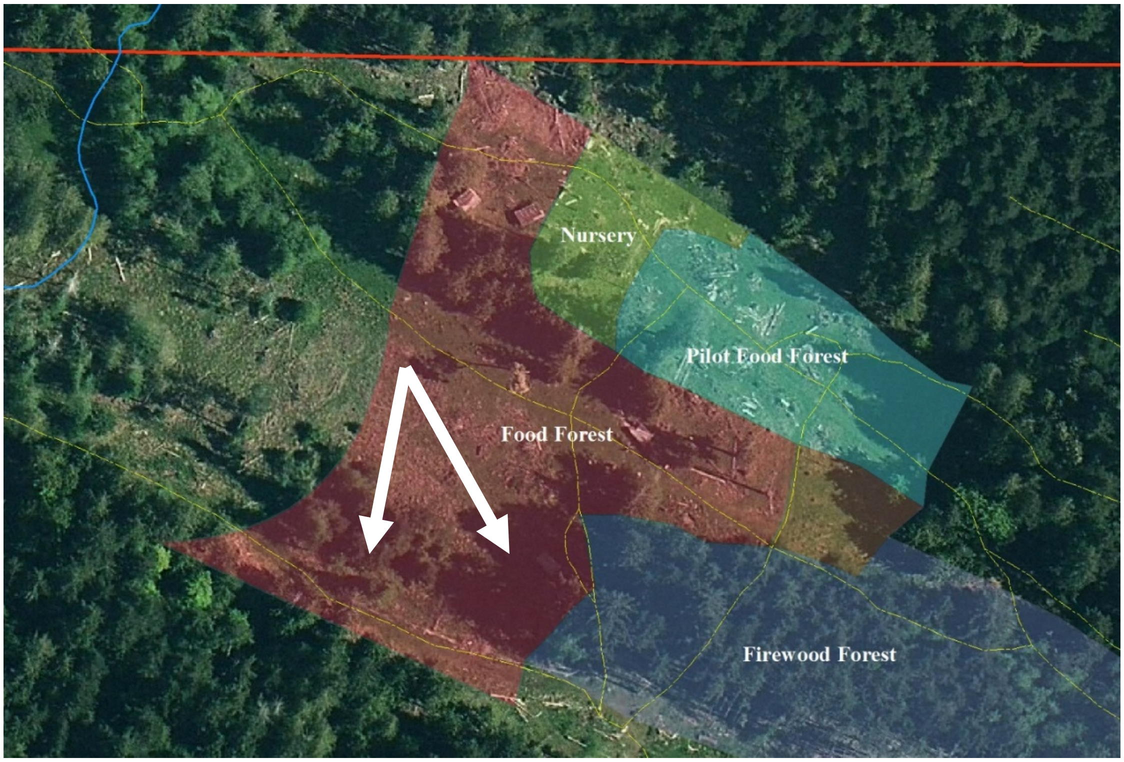


Figure 4. Proposed mushroom garden site (white arrows).

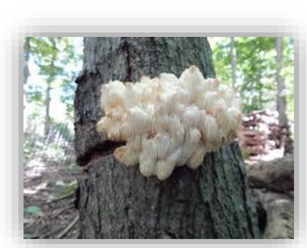
Figure 5. A) & B). Visual appearance of the cedar grove site, proposed location for the mushroom garden project.
Photo credit: S.Voicescu

4.3. CHOSEN SPECIES

Important factors to consider when first implementing a mushroom garden are: the resilience of the chosen species to environmental conditions, their already existing commercial production (as higher availability of successful spawns on the market will decrease contamination potential and harvest failures), the inoculation method for each species and the availability of inoculation material, nutritional and medicinal properties and the potential for bioremediation of the selected mushrooms. As production evolves and growers become more familiar with the inoculation and growth processes they may choose to experiment and diversify their garden with different and perhaps more sensitive species.

The following seven species were chosen for the mushroom garden project, based on the fact that they fit the above mentioned criteria: Shiitake mushroom (*Lentimula edodes),* Oyster mushroom *(Pleurotus ostreaus),* Reishi *(Ganoderma lucidum),* Maitake/Hen-of-the-woods *(Grifola frondosa),* Lion's mane *(Hericium erinaceus),* Wine cap/King Stropharia *(Stropharia rugoso-annulata),* and Chicken-of-the-woods *(Laetiporus sulphurous).* Although some of these species are native to North America, most are originating from Asia and Europe. All of these mushrooms, except for the Wine cap, are also known to grow very well on logs, which is the proposed main method of inoculation (explained in section 5). Table 2 below presents some of the main nutritional and medical benefits of these chosen species.

Table 2. Medicinal and nutritional properties of chosen edible mushrooms (Adapted from Ghorai et al. 2009, Hill, 2013 and Tyrant Farms, 2015)

Fungi (Common name)	Appearance	Nutritional properties and taste	Medicinal properties
Lentimula edodes (Shiitake)	Dark brown cap with white stalk. 	Contains high proteins and essential amino acids; natural source of vitamin D; adenine and choline content effective in preventing the occurrence of cirrhosis of the liver and vascular sclerosis.	Tyrosinase contained in *Lentinula edodes* tends to lower blood pressure. Lentinam, an active polysaccharide a (1–3) b-D-glucan helps to combat cancer, lowers cholesterol and enhances TH1 response. Also reduces the formation of dental plaque, thus working against the formation of cavities.
Pleurotus ostreaus (Oyster mushroom)	White, gray-brown or ivory coloured and resembles oyster shell like shape. The white gills run down its short, off-centered white stalk. 	Unique flavor and aromatic properties; considered to be rich in protein, fiber, carbohydrates, vitamins and minerals.	Promising medicinal mushroom, exhibiting hematological, antiviral, antitumor, antibiotic, antibacterial, hypocholesterolic and immunomodulation activities.
Ganoderma lucidum (Reishi)	Large, hard and leathery fungus with a “kidney shape” dark red/mahogany top 	Used in dietary preparation and to make tea or soup. Protein comprises only 7.3% of dry weight.	GLIS, a proteoglycan isolated from the fruiting body is a B cell stimulating factor, activates lymphocytes and helps with the proliferation, differentiation and production of immunoglobulins.
Grifola frondosa (Maitake/Hen-of-the-woods)	Grows in a series of shelf/fan-like forms, which are brown with white markings around the edges 	Valued culinary mushroom, with a mild taste. Excellent in soups or soup stocks. Important source of vitamin D.	Immunity system booster, antiviral properties, lowers blood sugar content (can help with type 2 diabetes by managing blood glucose levels, can assist with heart/blood problems.
Hericium erinaceus (Lion’s mane)	Large (up to 6ft diameter) mushroom, with creamy white “hair-like” structure, giving it the appearance of a “mane” 	Taste and structure similar to crab meat. Great sautéed or shredded into soups or as a thickener for stews.	Powerful and regenerative effects on brain cells, making them a potential treatment for dementia and Alzheimer’s. They can also help to reduce blood glucose levels (good for type 2 diabetes control), and have many of anti-carcinogenic compounds.

Fungi (Common name)	Appearance	Nutritional properties	Medicinal properties
Stropharia rugoso-annulata (Wine cap or King Stropharia)	White stem with a ruby red top, can grow to large sizes (1ft diameter) 	Nutrient rich, high in protein, amino acids, and minerals. Tastes like a combination of potatoes and red wine.	Can improve overall nutrition by increasing vitamin D levels, boosting immune functions and improving digestion.
Laetiporus sulphurous (Chicken-of-the-woods)	Shelf-like mushroom of orange/rust colour with bright orange markings around the edges, grows very well on logs 	High protein source, have the same texture and taste like chicken.	Can inhibit gram-positive bacteria and Candida, and helps in diabetes prevention/control, and the inhibition of HIV-1 reverse transcriptase.

4.4 GARDEN PLAN

The following plan represents the utilization of the proposed space for the mushroom garden. It is recommended that for the first years/cycle of production, only one log stack, comprised of 20 logs, be attempted for each species, in order to see how they perform and if their chosen habitat is suitable enough for long term production. As previously mentioned, all of the chosen species grow well on logs, except for *Stropharia rugoso-annulata*, the Wine cap mushroom, which performs better when spread on mulch and wood chips.

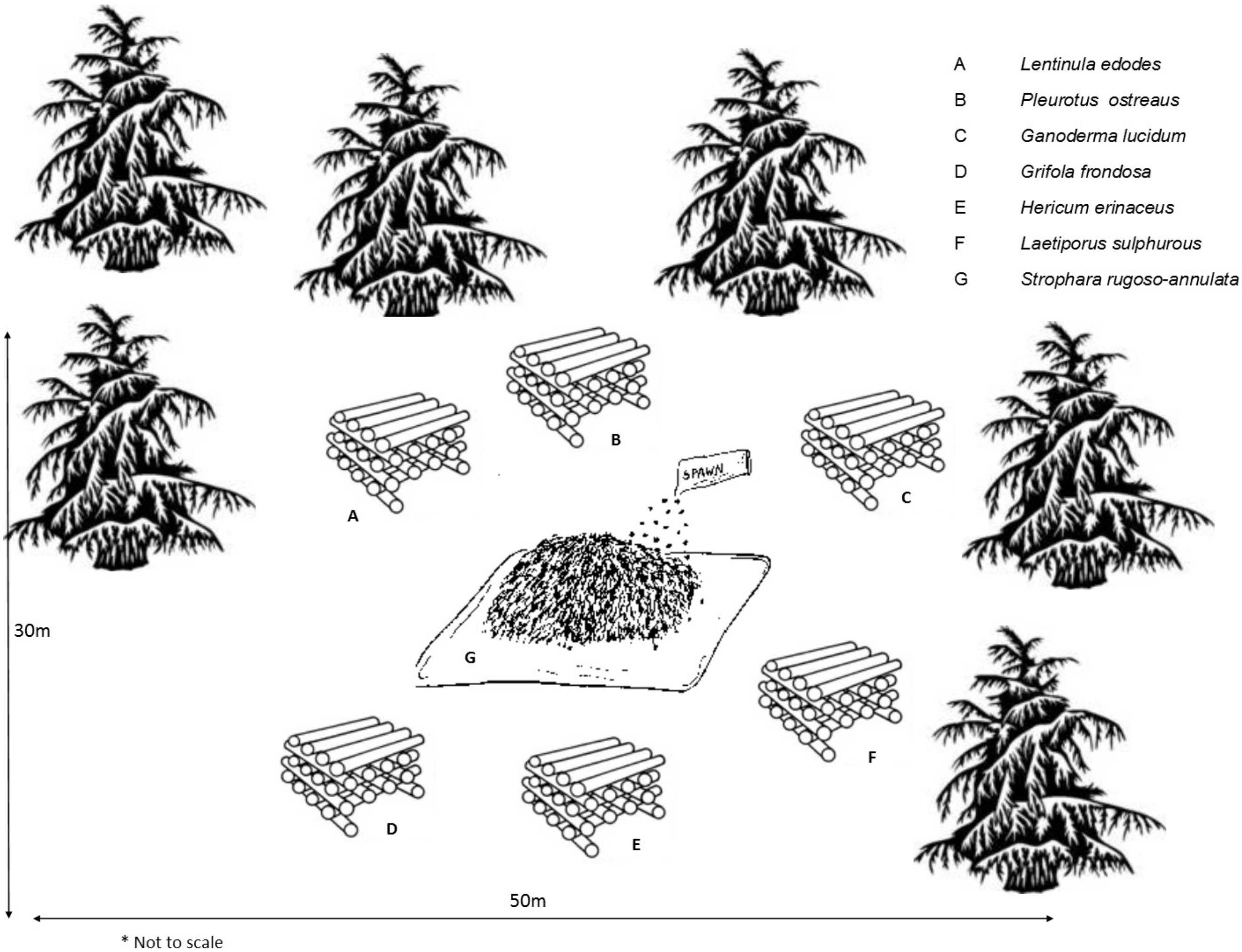


Figure 6. Plan of the proposed mushroom garden site following log and mulch inoculation. Initial pilot garden assigns 1 stack of 20 logs for each chosen species and a mulch spread site for the Wine cap mushrooms.

5. MUSHROOM CULTIVATION: SPAWNS & LOG CULTURE

Mycelium and their associated fruiting bodies have been known to grow on a variety of substrates, particularly woody materials rich in lignin such as cardboard, sawdust, mulch, straw and of course, logs (Baysal et al. 2003). In order to maintain the principles and goals of the GCA's forest garden project, it is proposed that the future mushroom garden be cultivated mainly on logs, in order to be an inclusive part of the food forest.

While log inoculation in itself is not a complicated process, logs will nonetheless need regular visits in order to ensure that they remain properly hydrated and that no other fungi has contaminated the culture (Tokimoto, 2005). Indeed, in their review of factors affecting mycelia fructification, Pinna et al., 2010, determined that soil temperature and moisture are some of the main factors associated with a strong fruiting response. Logs that do not receive enough water either through natural precipitation or from manual watering will therefore dry out, which will inhibit the formation of the mushroom fruits (Tipton-Fox, 2016).

Before beginning with the cultivation process, cultivators must choose and prepare the method to use in the inoculation phase. There are three main methods that are usually employed in mushroom inoculation: spores, stem butts and spawns (Stamets, 2005). As was explained in the above sections, mushrooms reproduce through their spores, which are easily carried by air, water or animals to other substrates on which they can develop. A simple way to collect spores is by placing a mature mushroom cap on a piece of paper, gill or pores down and gathering the dust-like spores once they settle (Chang and Miles, 2004, Stamets, 2005). The spores can then be germinated within a variety of water-based mediums, depending on the specific species chosen for consumption. Stamets, 2005, recommends soaking spores in a sugar and salt broth in order to ensure there are enough nutrients for a quick and productive germination. Once spores have germinated, they can be spread onto the desired growth substrate for inoculation. Stem butts inoculation is also relatively easy to perform, as it only requires the grower to separate the stem from the rest of the mushroom, while making sure to preserve the rhizomorph structures that connect to the underground mycelium. Many saprophytic mushrooms can regrow pretty quickly from their stem butts, once those are placed within an appropriate growth substrate such as cardboard or wood chips (Stamets, 2005). However, the grower will need to harvest naturally for the mushroom species they wish to cultivate, as many commercial varieties have had their stems removed in preparation for cooking, and not all species can regenerate from stem butts (Andrews, 2009). An easier method for inoculation is to purchase pre-made pure culture spawn from known cultivators. This spawn usually consists in mycelium amalgamated with woody materials favorable for growth such as sawdust, grain or wood plugs/dowels (Chang and Miles, 2004). Some advantages to using pure culture spawns are that most common cultivated species such as the ones presented above have been associated with many companies which have produced successful spawns, and there is less risk of contamination of the growth medium with other fungi or organisms, as these spawns are usually produced in sterilized laboratory conditions (Marshall and Nair, 2009). A disadvantage to using cultured spawns is that the laboratory grown mycelium is not exposed to the natural microorganisms present in the habitat in which it will be inoculated, which means that it will have more difficulty initially in overcoming potential natural competitors. One way to decrease this pressure is by introducing, prior to inoculation, a small amount of the growth substrate onto the spawn, thus allowing the mycelium to familiarize itself with its future habitat (Stamets, 2005). The recommended method of inoculation for the GCA mushroom project to maximize fruiting success is therefore to use commercially available plug spawn for each of the desired species. The following paragraphs below are adapted from Stamets, 2000, Aloha Medicinals, 2017 and Tipton-Fox, 2016 and will present the required material as well as the steps in which log inoculation and harvesting of a mushroom garden should occur.

Material needed:

- a drill & drill bit
- a hammer/thumb inoculator
- plug spawn
- wax
- a paint brush or a piece of sponge.
- a pot;
- a heat source
- logs

Step 1. Selecting the wood substrate.

There are advantages and disadvantages when choosing between hardwood and softwood species. Research has shown that species grown on softwood will grow faster, but their overall productivity will be lower, when compared to hardwood species, where mycelium growth is slower, but the overall production will be greater. It is recommended not to grow mushrooms on conifers because tannins and resins present in the bark can inhibit mycelium development, however more resilient species such as the Oyster mushroom (*Pleurotus ostreaus*) can grow on firs and conifers without much trouble. Recommended wood substrates are usually in the hardwood category, such as alders, maples and oaks.

Another important thing to keep in mind is the time of the felling. Inoculation of the logs should happen right after felling, as that is when the logs will have the highest amounts of nutrients and water. If one wishes to use logs which have been previously cut, then they must be soaked with water three to four days prior to inoculation in order to ensure high enough moisture levels. Average dimensions for cut logs are between three to four feet in length and four to eight inches in diameter, however one can use bigger sizes as well, as long as they are able to maneuver around them and carry them.

Step 2: Drilling holes

Once the substrate has been selected and the logs have been cut, it is time to drill the holes in which the spawn will be inoculated (Figure 7). Holes should be approximately two inches deep, six to eight inches apart and there should be two to four inches between each row of holes. An average sized log (dimensions mentioned above) should yield approximately 40 to 50 holes.

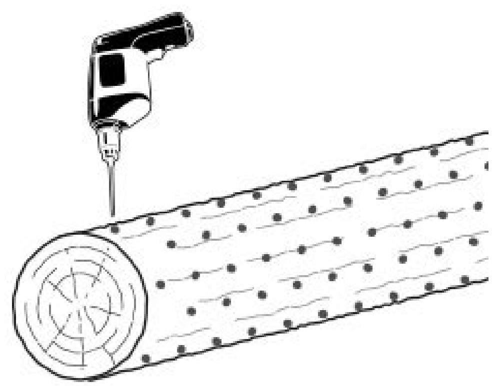


Figure 3. Log inoculation with drill.
Image source: Fungi Perfecti, 2015

Step 3: Inoculation

Log inoculation can occur at any time during the year, but as fruiting of the mushrooms usually occurs between six to twelve months after inoculation, it is recommended to be performed in the fall, consistent with BC climate. This way, the logs will be naturally kept moist during the winter and fruit in the spring or summer. Once proper pure culture plug spawn is acquired, simply introduce one plug in each hole by using a hammer or thumb inoculator. A thin layer of wax then needs to melted and applied over each hole, in order to seal it from potential contaminants.

Step 4: Log placement

Once the logs have been inoculated, they are to be stacked and put away from direct sunlight, in a shaded and moist area. The location as presented in Figure 4 is a good candidate, as the cedar grove will provide the necessary shade and moisture required for the mycelium to grow and fructify. Logs can be stacked in different styles, with the three most common styles being:

- Low stack: logs are simply left on the ground. This is not recommended however, as ground fungi can invade and contaminate the logs
- Crib stack: logs are placed perpendicular one on top of each other in horizontal layers (Figure 8)
- Lean-to: logs are leaned against fencing, wire or any nearby structure.

Figure 4. Crib stack log placement after inoculation.
Image source: Tipton-Fox, 2016

From the structures/conditions currently available at the proposed site, it is recommended that inoculated logs be crib stacked. Until pinning induction occurs, logs must be visited every two to three days in order to make sure they are receiving adequate amounts of moisture.

Step 5: Pinning induction

Pinning induction simply means stimulating the formation of the mushroom fruit. If the wood substrate used was softwood, then pinning induction will usually occur six to nine months after inoculation, and if it was hardwood, then fruiting is expected 12 to 14 months after inoculation. This time period is an average at which point logs will start to give fruits naturally, as the mycelium has had enough time to grow and develop enough nutrient in order to be able to support the formation of the mushrooms. However, pinning induction can also be enhanced by cold-shock or soaking the logs into water: this will “stress out” the mycelium and accelerate the production of the mushrooms. It will take four to eight days for mushrooms to grow large enough for harvest after the shock.

Step 6: Harvest & storage

After pinning induction, logs must be kept very moist and it is recommended that they be sprayed two-three times/day. After the first harvest, a second harvest usually occurs two to three weeks later, as most logs will produce at least two crops per year. Once harvest is completed, the logs are to be stacked and stored in the same area they were placed in prior to pinning induction. The same log can produce mushrooms between one to four years in a row, depending on the species and the storage/climatic conditions.

6. BUDGET

The following table presents estimated costs for the proposed mushroom garden, for the first 3-4 years of operation (i.e.an average production cycle per log), assuming log and spawn quantities as presented in the plan in section 4.4. Subsequent years will be less costly, as the required materials for the cultivation and inoculation will already have been purchased.

Table 3. Budget for proposed GCA mushroom garden project

	1st time/year costs ($)	per year costs($)	4th year costs($)	**Source/Notes**
Drill & Drill bits	115	N/A	N/A	DeWALT drill + drill bits, from Home Depot. Can also be sourced from GCA equipment shed, if they already possess.
Spawn *Lentimula edodes* *Pleurotus ostreaus* *Ganoderma lucidum* *Grifola frondosa* *Hericium erinaceus* *Strophara rugoso-annulata* *Laetiporus sulphurous*	 45 45 45 45 45 50 120	Only requires monitoring/watering of the logs by employees/volunteers	 45 45 45 45 45 50 120	On average, one log will hold 50 spawns. As there are 20 logs/species, each will require 1000 plugs. Source: Fungi perfecti.com (owned & operated by Paul Stamets) & Everythingmushrooms.com. All are plug spawns except for *Strophara rugoso-annulata*, which grows best spread on wood chips/mulch and is available as sawdust spawn. 25$/3lbs bag of sawdust spawn.
Hammer	7	N/A	N/A	Home Depot
Wax	96	N/A	96	Price per pound is 8$ and is good on average for 10 logs. Total logs to be inoculated: 120. Total required wax: 12lbs Source: Everythingmushrooms.com/
Heat source (camp stove) & pot	47	N/A	N/A	Basic Primus camp stove/gas (32$) and pot (15$) from MEC. Can most likely also be sourced from the GCA, as they already have various camping equipment available.
Paint brush	8$	N/A	N/A	Amazon.ca
Logs (20/species grown, except wine cap)	N/A	N/A	N/A	Logs are to be acquired from the property. Perhaps part of the fuelwood forest. As there are 6 species to be inoculated, 120 logs will be required (20x6).
Total	**668**		**491**	

7. MYCORESTORATION

In addition to their nutritional and medicinal properties, many mushroom species also possess the ability to bio-accumulate and degrade many metals and toxic pollutants (Chen et al. 2015). Due to their unique relationship with soil and the plants that thrive on it, macrofungi are able to secrete particular chemical compounds which can help to restore or decontaminate a previously polluted site. Indeed, studies have shown that species such as *Lentinula edodes*, *Ganoderma lucidum* and *Pleurotus ostreatus* possess specialized enzymes such as laccase, which allows them to efficiently degrade polycyclic aromatic hydrocarbons (PAHs) and heavy metals such as cadmium and mercury (Ghorai et al. 2009, Adenipekun and Lawal, 2012, Chen et al. 2015). Mushroom species can also be used in the treatment of contaminated water sources. Taylor and al., 2015, determined that wood chips infused with Wine cap mushrooms (*Strophara rugoso-annulata*) were 20% more efficient at removing *E.coli* pathogens from stormwater than control filters. Lastly, some species of macrofungi are also able to break down crude oil spills, as long as they are provided with additional woody substrates (sawdust, mulch, straw) on which they can develop (Rhodes, 2014).

This process of applying mushroom species onto substrates which have been harmed either by humans or natural catastrophes in order to restore them to healthy and functional states is known as mycorestoration (Adenipekun and Lawal, 2012). According to Stamets, 2005, mycorestoration actions can be grouped into four different categories: mycofiltration (using fungi to filter water-based substances), mycoforestry (using fungi to enact sustainable ecoforestry practices), mycoremediation (fungi are applied in order to degrade toxic contaminants) and mycopesticides (fungi as natural control agents of insect pests). In the case of the Galiano Conservancy Association and the Learning Centre site, it can be said that a mushroom garden could be used to fulfill all of these different restorative functions. For example, they could be utilized in the fuelwood forest as a non timber forest product, which could help to enhance the resilience and increase the biodiversity of that particular site. Their location near the forest garden also places them at a good position to defend against potential pests that may prey on the food crops. Although not recommended as a unique source of water treatment, an interesting option would be to use the cultivated mushrooms as an integrated element of the water filtering system at the main classroom facility. Finally, the fungi can also be applied onto the mill restoration site in order to increase the quality and fertility of the soil and degrade any possible contaminants that might still be present from the previous milling operation. Overall, there are many benefits to using the products of the mushroom garden as tools for ecological restoration in many areas of the Learning Centre property.

8. MUSHROOMS AS INVASIVE SPECIES: A POTENTIAL CAUTIONARY NOTE

Although not commonly considered as invasive species, non-native mushrooms have the potential, under the right conditions, to spread and take over habitat from native fungi species. Currently, research has focused primarily on parasitic mushrooms and plant pathogenic fungi, with very few studies actually looking at the potential spread of other types of fungi (Pringle and Vellinga, 2006, Vizzini et al. 2009). This may be due to the fact that other types of relationships between mushrooms and hosts are overall beneficial for the environment. Nonetheless, a non-native fungi has been brought to attention recently due to its risk for mushroom poisoning. It is the case of the Death cap mushroom (*Amanita phallaoides*), a mycorrhizal fungi who has been linked with three recorded cases of poisonings in the last 20 years in BC, including one recent death of a child in 2016 in Victoria (Berch et al. 2017). Death cap mushrooms have been introduced from Europe, and it was recently discovered that they had started to form mycorrhizal relationships with native tree species such as the Garry oak (*Quercus garryana*) (Berch et al. 2017). Their spread into native habitat and particularly into residential areas could potentially modify the structure and function of those ecosystems, as well as cause serious health issues to residents and mushroom harvesters.

When establishing the mushroom garden site at the GCA, it is therefore important to consider potential implications of the culture, such as an unwanted spread of species unto adjacent sites. It is also important to take into account factors which can facilitate introductions and spread, such as moving debris on the forest floor or simply having an increase in the numbers of visitors at a site (Pilz and Morena, 2002). These factors can however be minimized by implementing best practices and educating the public on the topic. Furthermore, the choice of log inoculation with plug spawn also diminishes the risk of spreading due to the nature of the localized cultivation, meant to be contained within the logs. Simple management approaches could help here in minimizing the risk of spreading and contamination.

9. CONCLUSION

Mycoculture can provide many benefits to local, community-based organizations such as the Galiano Conservancy Association and to any grower that decides to embark on such a project. Not only do mushrooms contain a variety of essential nutritional and medicinal properties, but they can also be used as substrate for the remediation of contaminated sites and can enrich soils and be used as compost in order to increase the fertility and stability at garden sites. Additional benefits include their commercial viability as well as their educational potential, as mushroom gardens can provide learning opportunities on sustainable agriculture and eco-forestry practices to children and adults of all ages.

In terms of inoculation, methods can vary greatly in function of the chosen species and the commercial availability of the spawn, however this report recommends that log inoculation be attempted, as it is the method with the highest success rate for the proposed species.

It is the hope of the author that this report provided sufficient information on the topic so that this project is incorporated by the GCA as part of their land management objectives and becomes a successful component of the forest garden project within upcoming years.

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