

Biodiversity Question 3b – Young Growth Habitat: Fungi

Goals and Objectives: Manage young growth to improve habitat for wildlife and for commercial timber products. Review standards and guidelines for applicability to young growth stands. Maintain habitat capability sufficient to produce wildlife populations that support the use of wildlife resources for sport, subsistence, and recreational activities. Include a young growth management program to maintain, prolong, and/or improve understory forage production, and to improve habitat distribution, including future old-growth timber stands for wildlife (e.g., deer, moose, black bear, and other species) on both suitable and unsuitable lands.

Background

The following information is to provide an overview about terrestrial fungi and their functions in forested ecosystems. The richness and diversity of fungi contribute directly to biodiversity and can change as forests age, thus they may be useful in providing answers to Forest Plan biodiversity questions.

Overview of Terrestrial Fungi

Fungi are essential components of all ecosystems. They contribute to the function of healthy forest ecosystems by forming mutualistic, symbiotic associations with plants, decomposing organic matter, contributing to nutrient cycling, providing food for animals, and creating habitat diversity for many forest organisms (Castellano et al. 1999). There are two broadly defined growth forms of fungi that contribute to the health of forested ecosystem: macrofungi and microfungi. Microfungi are the molds, yeasts, lichen symbionts, endophytes, endomycorrhizae, and plant pathogens (Castellano et al. 1999). These are found throughout the forest, from deep within the soil to up in the canopy. Those in this growth form are more difficult to survey for due to their diminutive nature compared to macro fungi. Therefore micro fungi will not be addressed in the biodiversity question.

Macrofungi come in a myriad of colors, forms, and interact with hundreds of forest organisms. This group includes mushroom, sequestrate, shelf, coral, teeth, club and cup fungi forms. They are commonly called the “fleshy fungi.” Two taxonomic classes are distinguished: Basidiomycetes and Ascomycetes. The Basidiomycetes include mushrooms, puffballs, coral, teeth and shelf fungi while the Ascomycetes include cup fungi and morels. The sequestrate fungi (truffle and truffle-like) can be in either group. The broad definition of a truffle is applied to fungi that have evolved a belowground fruiting habit, but “sequestrate” may better define the group (Kendrick 1992, Smith 1995). The sequestrate term has been adopted to describe the aboveground and belowground fungal sporocarps (or fruiting bodies) that have an enclosed fruiting habit in which spores are retained in the sporocarp until it decays or is eaten by an animal (Kendrick 1992). These fungi depend fully on animals for spore dispersal. As they mature, they produce an odor that attracts mammals. These mammals excavate and eat the sporocarps and the spores eventually pass through the digestive tract unharmed into the soil (Maser and Maser 1988). The spores are washed into the soil and make contact with the roots of their future host trees. It is the macro fungi group of fungi with which this biodiversity question will be addressed.

Southeast Alaskan forests are dominated by trees associated with macrofungi, with a large proportion of the mushrooms and sequestrate fungi being mycorrhizal. Mycorrhiza, which literally translates as “fungus root,” refers to a common and mutually beneficial association between plants and specific fungi (Smith and Read 1997). The mycorrhizal fungi associated with Southeast Alaska’s *Picea sitchensis* (Sitka spruce), *Tsuga heterophylla* (western hemlock), and *T. mertensiana* (mountain hemlock) root systems are the dominant organs of nutrient uptake for these tree species. Mycorrhizal fungi greatly extend the nutrient absorbing surface area of the roots and are more effective in nutrient and water absorption than roots themselves. Soil nutrients essential to plant growth, such as phosphorus and nitrogen, are absorbed

by the mycorrhizal fungus and transported to the root for use by the plant. In return, the plant provides sugars produced in photosynthesis to fuel activities of the mycorrhizal fungus. Without mycorrhizal fungi, the forest would not exist.

Mushrooms and sequestrate fungi are also important for wildlife food and are consumed by numerous animals such as deer, small mammals including flying squirrels, birds, gastropods and insects (Carey 1991; Fogel and Trappe 1978; Maser et al. 1978; Flaherty et al. 2010). Fungi provide essential nutrients to these animals, some of which are only available from fungi. Therefore, fungi are very near the bottom of the food chain in forest ecosystems.

Equally important, the saprotrophic (decomposer) fungi play critical roles in forest nutrient cycling by making nutrients available through the breakdown of dead plant material. Wood-decaying fungi soften interiors of snags and logs, allowing birds and other animals to burrow into them and create homes (Harmon et al. 1986). The saprotrophic fungi include cup, shelf, earth tongue, mushroom and toothed forms. All saprotrophic macrofungi growth forms, except those on standing snags, will be addressed in the biodiversity question.

Many mycorrhizal and saprotrophic macrofungi form large fleshy structures (variously referred to as sporocarps, carpophores, or mushrooms) as part of their sexual reproductive cycle and the presence of these fungi can be confirmed when their mushrooms are present. Although surveys, collection, and identification of mushrooms cannot furnish a complete picture of the fungus community of a forest, they can provide a valuable first step in understanding the various fungal microbes in certain soil types on the Tongass National Forest.

Understanding soil microbial tolerance to levels and thresholds of disturbance severity is critical to long term forest productivity (Marshall 2000). Disturbances such as harvesting can impact the abundance, activity, and composition of soil microbial communities (Smith et al. 2005; Smith et al. 2008), thereby contributing to changes in nutrient cycling, organic matter decomposition rates, and ecosystem C accrual (Pietikiinen and Fritze 1995; Neary et al. 1999).

Mitkof Island Pilot Project 2010

The species of macrofungi that occur with the five main tree species in SE Alaska (*Picea sitchensis*, *Tsuga heterophylla*, *T. mertensiana*, *Thuja plicata*, and *Callitropsis nootkatensis*) have not been thoroughly catalogued on the Tongass National Forest. It is also unknown whether the old growth associated macrofungi communities remain after timber harvest and are available to provide nutrients to the young growth forest and the animals dependent on them as a food source. To help begin filling this information gap, the Tongass National Forest initiated data collection on fungi from Mitkof Island. The purpose was to compare fungus communities within the same soil type but under different management, old-growth and young growth. On Mitkof Island, it is difficult to find accessible locations that are paired (i.e. two sites with the same soil type but different management) as most of the accessible, productive soil types have been harvested and therefore limited old-growth sites are available for comparison, or the remaining forests are on soil types that are less productive and therefore have not been harvested due to lower site quality. Three sites were finally chosen on the basis of road accessibility, soil type (Kupreanof and Maybeso series) and pre-surveys by local mushroom hunters who noted high fungal diversity.

In 2010, Pacific Northwest mycologist Dr. Steve Trudell, to begin surveys in three predetermined areas during one week in both July and September. The three sites are: 1) Twin Creek area (56°43'N, 132°54'W), old-growth forest classified as *Tsuga heterophylla*, *Callitropsis nootkatensis*, *Vaccinium sp.*, *Lysichiton americanum* within Maybeso and Kupreanof series soils, 2) Falls Creek area (56°42'N, 132°54'W) young growth forest (mainly *Picea sitchensis*) with Kupreanof series soils, and 3) Green's Camp area (56°32'N, 132°41'W) in old-growth, beach fringe forest with some thinning, primarily of *Picea sitchensis*, *Tsuga heterophylla*, and *Alnus rubra*. The soils developed were primarily of marine sediments (Blashke or Salt Chuck series in the dry areas and Karheen in the wet areas). No young growth

comparison was found for the Green’s Camp site. It was mainly included to be a collecting site to document species in this forest habitat, as many mushroom hunters note that beach fringe forests are important for edible mushroom collecting.

Surveys during the week in July also included Dr. Mike Castellano of the Pacific Northwest Research Station in Corvallis. He focused on the sequestrate fungi, and accompanied Dr. Trudell to the three sites for two days. Two Tongass NF scientists, Dennis Landwehr, Soil Scientist, and Karen Dillman, Ecologist, also accompanied the mycologists for a few days in July. Dennis dug soil pits to confirm the soil types in the study areas. Volunteers from Petersburg also helped Dr. Trudell survey for mushrooms for a few days each time period, as having additional people helps cover more ground.

In total, 452 fungal collections and observations were made by Dr. Trudell: 185 in July and 267 in September. Two hundred thirty-two collections were dried and retained, pending designation and herbarium-accessioning of voucher collections. All but four of the collections and observations were identified at least to genus. One hundred fifty-eight species were identified in 2010. In 2009 several independent mushroom collecting forays conducted by Dr. Trudell added an additional twelve species not found again in 2010. Therefore, the grand total for Mitkof Island is 170 macrofungi species identified from these three areas.

Sixty species were collected from Twin Creek old growth, seventy-four from Falls Creek young growth, and eighty-six at Green’s Camp beach fringe. Twin Creek and Falls Creek had twenty-four species in common, Falls Creek and Green’s Camp twenty-six in common, and Green’s Camp and Twin Creek only fifteen species in common. Only ten species were found from all three areas. With this limited overlap in the species of the different areas, pair-wise coefficients of similarity are relatively low (table 1) (Trudell 2011). However, the collecting effort to date has been insufficient to determine whether the fungus communities of these forested areas differ markedly from one another.

Biodiversity 3b Table 1. Similarity coefficients for macrofungus species collected or observed at the Twin Creek, Falls Creek, and Green’s Camp study areas. Values to the right of the diagonal calculated with Jaccard’s formula; those to the left with Sørensen’s formula. Scales for both range from 0 = no species in common, to 1 = all species in common.

	Twin Creek	Falls Creek	Green’s Camp
Twin Creek	---	0.22	0.11
Falls Creek	0.36	---	0.19
Green’s Camp	0.21	0.33	---

Of the 170 species, fifty-three percent are mycorrhizal, forty-one percent saprotrophic (sixteen percent on wood, ten percent on needles and other fine litter, and fifteen percent terrestrial with substrate not obvious), two percent plant parasitic, one percent mycoparasitic, one percent lichenized, and two percent trophic status uncertain (Trudell 2011).

The Mitkof Island fungi show similarity to the fungi from two areas in nearby British Columbia (BC) : Clayoquot Sound on the west side of Vancouver Island (Roberts et al. 2004), and Haida Gwaii (Queen Charlotte Islands, Kroeger et al. 2008, 2010), with sixty-four percent and seventy-four percent of the Mitkof Island species occurring in those two areas, respectively. Both those areas in BC were surveyed much more intensively than was possible in the pilot project (i.e. several times each year over five year periods) and more than 550 and 660 species, respectively, were recorded. Thus, it is surprising that thirty-

six percent and twenty-six percent of the Mitkof Island species were not recorded in the BC studies, indicating an element of uniqueness in Southeast Alaska fungal communities compared to BC realized during just one survey year.

In both BC studies, the proportions of mycorrhizal and saprotrophic species were similar to those at Mitkof Island: forty-nine percent mycorrhizal and forty-eight percent saprotrophic at Clayoquot Sound, and forty-eight percent mycorrhizal and forty-seven percent saprotrophic at Haida Gwaii. Jaccard similarity coefficients calculated by Roberts et al. (2004) for old-growth, second-growth, and spruce fringe habitats at Clayoquot Sound (comparable to the Twin Creek, Falls Creek, and Green's Camp habitats in this study) were 0.28 (old-growth/second-growth), 0.25 (second-growth/fringe), and 0.31 (fringe/old-growth), somewhat higher than the analogous values in this study (table 1), but still relatively low. This suggests that the fungus communities of all the Mitkof Island sites are both highly diverse and highly heterogeneous.

Most likely, more than 1,000 species of macrofungi occur on Mitkof Island alone, and more collecting is required to provide at least a basic assessment of the general character of the fungal communities on the Tongass National Forest in a particular soil type (Trudell 2011). More effort will be required before sufficient information is available to address management questions such as whether old-growth and young growth forests differ in their fungus communities, and whether the makeup of the fungus community at a young growth site can be used to assess soil productivity or old growth conditions. Nonetheless, the information generated in this pilot project does allow some preliminary comparisons to be made with other data sets. Despite the general similarity of the Mitkof Island fungi to those of British Columbia, there is a significant distinctive element in the fungi recorded on Mitkof Island. Whether this represents a true difference in the fungus communities, or merely artifacts of the vagaries of fungal fruiting patterns, insufficient collecting effort, or collecting at different times under different weather conditions, and can only be assessed by longer-term collecting.

Biodiversity Question 3b: Are young growth treatments improving other key habitat components for old-growth associated species?

Evaluation Criteria

Fungal inventories in both young growth and old-growth forests can help determine the utility of using fungi to identify key old-growth species present in young growth stands under certain soil conditions. Presently, presence may be one method of determining that, but also the *relative abundance* of a species in the unit surveyed can help determine if the old growth associated fungi are found in young growth forests under certain soil conditions. Presence and relative high abundance in young growth of certain functional groups may indicate that the fungi species important to the health and productivity of forests are not disturbed in young growth after management actions remove the overstory.

Sampling/Reporting Period

Sampling period: 2012 (annual); reporting and evaluation period: every five years

Monitoring Results

A contract was prepared in 2012 to initiate fungal surveys on Prince of Wales Island (POW) in selected young growth and old-growth forests. Data collection, planned to begin in 2013, aims to address the

question of whether terrestrial fungi can be used to determine if key habitat components, such as old-growth associated species, exist in young growth treatments areas. The selected sites contain similar soil type so that comparisons can be made on a broad scale as to the functional groups found in the young growth and old growth stands. This will identify the possibility of fungi being used to determine if old-growth forest associated species are present in young growth stands.

The goals of the 2013 project on POW are twofold. One goal is to obtain baseline information about the presence and abundance of terrestrial fungi critical to soil productivity and other ecosystem functions (i.e. wildlife habitat and nutrient availability for vegetation) on selected areas of similar soil types on Prince of Wales Island (POW). The second goal is to determine the utility of applying acquired information about the fungi to augment young growth management plans and other restoration efforts focusing on improvements to soil productivity and other ecosystem functions within certain areas on POW (and possibly to other locations on the Tongass National Forest that are relevant).

The objectives of this 2013 project are to:

- 1) Utilize the information from fungal inventories on Mitkof Island in 2010 and implement a similar project on POW in selected old-growth and young growth forests where concurrent soil inventories are planned or have been completed.
- 2) Report fungal inventory results on POW with specific recommendations for using the acquired information in restoration projects, soil productivity and wildlife habitat enhancement projects, or young growth thinning treatments for enhancing terrestrial fungi communities that may be critical to young growth forests and the animals that use them.
- 3) Relate fungal information needs to the next Forest Plan revision goals and objectives under biodiversity, plants, or wildlife habitat.
- 4) Begin accumulating relevant information concerning the functional groups of fungi that are responsible for important nutrient cycling in forested ecosystems for help in understanding their roles in soil productivity, yellow-cedar decline and a variety of other ecosystem functions that could be at risk due to the 100 year harvesting cycles and predicted climate change scenarios.

Evaluation of Results

The baseline information acquired during this project concerning terrestrial fungi will enhance Forest Service capabilities to successfully plan for improvements to soil productivity and overall forest ecosystem health and function as the agency transitions fully into young growth management.

Action Plan

Fungi should be surveyed for over several years to gather enough information about the species present and their relative abundance in a particular habitat. An individual fungal body can live for many years in one location in the soil, yet produce mushrooms very infrequently. This somewhat cryptic nature poses problems in locating specimens. Therefore, a site must be repeatedly surveyed over several years and at least two times during one year (two to five times) to detect or monitor species of interest (Castellano et al. 1999).

Molecular tools can be combined with field surveys to help determine species presence of an area and help tease out temporal dynamics and soil microbe identity more effectively. One method measures biomarkers of the phospholipid fatty acids (PLFA) in soil microbes. PLFAs are essential components of every living cell and are useful biomarkers because of their wide range of structural diversity (Zelles 1997). PLFAs are considered to be representative of the viable microbial community because they are not

found in storage products or in dead cells. Upon death, the phosphate group is quickly hydrolyzed (Zelles 1999). The relative proportions of these groups of PLFA biomarkers provide a fingerprint of the microbial community. This fingerprint can then be used to infer the overall response of the microbial community to a particular treatment. PLFA profiling was used to determine the impact of harvest on soil microbial communities (SMC) structure and function at the Wind River Canopy Crane Research Forest in Oregon (Moore-Kucera and Dick 2008). Their data show that SMC recovered between eight and twenty-five years post-harvest. However, they did find that community shifts in fungal biomass occurred as well as fungal biomass reduction with clear-cutting. Seasonal changes were also very pronounced, likely linked to availability of nutrients and water throughout the year (Moore-Kucera and Dick 2008).

Another method used to characterize soil microbes is T-RFLP profiling (Terminal Fragment Length Polymorphism). T-RFLP analysis is a technique used to study complex microbial communities based on variation in the 16S rRNA gene (1). This analysis can be used to examine microbial community structure and community dynamics in response to changes in different environmental parameters or to study bacterial populations in natural habitats. Researchers on the Desoto National Forest in Mississippi used this technique to detect shifts of fungal and bacterial communities in wood treated with sublethal concentrations of different chemicals (Kirker and Diehl 2010). T-RFLP takes into account all species of a taxonomic group and creates a community profile, also known as fingerprint, where each peak in the profile represents a unique species. Both chemicals appeared to change the patterns of bacterial succession completely, so that beginning and ending communities were significantly different in regard to species composition. Fungal species community structure was initially changed, but became more similar to untreated controls over time, presumably as the preservatives were depleted from samples (Kirker and Diehl 2010). However these techniques do not show the identities of the community members. Therefore, clone libraries are also constructed to help identify the dominant community members of the fungal and bacterial communities and to potentially determine which organisms were associated with indicator fragments from the community analysis.

The Pacific Northwest Region (R6) is the center for forest fungus research, mainly due to FEMAT (Forest Ecosystem Management Assessment Team) formed to develop management alternatives to balance forest conservation with the economic and social needs of the people under President Clinton (FEMAT 1993). In their lengthy analysis, 527 fungal species were found to be strongly associated with old-growth forests or their legacy (i.e. coarse woody debris) and 234 species required some level of attention under the survey and manage strategies of the plan (FSEIS: USDA and USDI 1994a). Twenty of those species were found during the Mitkof Island Pilot Project in one season (Trudell 2011).

Even though increased funding provided the opportunity to include the survey and management of lesser known species, R6 scientists have only recently begun to understand the biodiversity of fungi in forested ecosystems. Some of the key findings are that rarely detected fungal species are more likely to occur in old-growth stands than younger managed stands, although all age classes of forest are important for maintaining biodiversity of fungi and the organisms they support (Smith et al. 2002). Logs provide suitable habitat for the conservation of a variety of fungal species, in both old-growth and young growth managed stands (Molina et al. 2001). For the persistence of some species of mycorrhizal fungi, down, coarse wood, including logs and stumps, is very important in the forest (Smith et al. 2000).

Therefore, the assessment of the macrofungi at selected sites on POW will be useful to help answer the biodiversity question if subsequent surveys or molecular techniques are employed. Answering this question with information on macrofungi proposes to improve soil productivity interpretations through a better understanding of fungal occurrence in different soil types, vegetation, and successional stages across the Forest. Understanding the factors influencing fungal occurrence will inform soil restoration efforts and young growth productivity dynamics.

Citations

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