MCM 2021 (Madison's Workspace/ Writing)

1 Environmental Impacts

1.1 Environmental Influence on Hyphal Tip Extension (ν)

Environmental impacts are introduced to the decomposition model through ν, the hyphal tip elongation rate. This elongation occurs at tip of the hyphae via vesicles known as Spitzenkorper, but the mechanism of this extension remains unknown [**?**]. As described in Gervais et al. 1999, "cell turgor pressure corresponds to an overpressure which allows the cell morphology, elongation, division and hence the biomass evolution" [**?**]. In fungi, cell turgor itself is respondent to water potential gradients rather than to active transport within the cell, making it very environmentally dependent [**?**]. Thus, we have reason to examine environmental impacts on fungal decomposition rates by varying ν outside of baselines for given species in set locations.

This brings us to the issue of determining ν based on environmental factors. Experimental data from Maynard et al. 2019 shows the relationship between ν and the environmental parameters of water potential (ψ) and temperature (T) [**?**]. Water potential as a parameter will take into account both moisture content to fungi as well as the availability of that moisture as dictated by the soil composition.

1.2 Estimating ν For Various Environments

When considering a sampling of decomposition rates in various environment types, we must determine how to estimate temperate and water potentials that ground fungi would experience. In the case of determining ν, this requires finding projected temperature and water potential.

Amongst existing biome classification models, Whitaker's scheme [**?**] is perhaps the simplest, being particularly trait-based. Whitaker's scheme provides a layout of biomes based on mean annual temperature and mean annual precipitation. However, modern classification of biomes has drifted away from using these traits as definitive biome identifiers [**?**]. These traits alone do not define all features of concern to fungal growth, such as soil composition for example. In addition, by Whitaker's scheme, we find that a given biome can have a wide range of average annual temperatures (such as arid desserts ranging from about -10 to 30 $°C$) [**?**]. Thus, we can sample a range of temperature and moisture values to output various ν and then select certain regions to profile in order to gauge potential environments where fungi can decompose and interact.

The following are the specific environments selected to represent various biomes:

Biome	Specific Environment Selected
Dessert (Arid)	Sonoran Desert, USA
Grasslands/shrublands	(Semi-Arid), central Argentina
Temperate Forest	Sal Forests, central Himalayas
Boreal Forest (Arboreal)	Pine Forests, central Himalayas
Tropical Rain Forest	Tropical Forests, Barro Colorado Island, Panama

The following are the average annual temperatures of these biomes. Note that if ranges were given, the average of the maximum and minimum is the selected value.

Biome/ Environment	Regional Average Annual Temperature [$^{\circ}C$]	Selected Value [$^{\circ}C$]
Dessert (Arid)	10 to 20 [**?**]	15
Grasslands/shrublands (Semi-Arid)	15.3 [**?**]	15.3
Temperate Forest	-1.42 to 26.39 [**?**]	12.49
Boreal Forest (Arboreal)	-1.42 to 26.39 [**?**]	12.49
Tropical Rain Forest	23 to 32 [**?**]	27.5

Although water potentials can be approximated based on predictive models, the measure is best found experimentally from soil samples [**?**]. Ranges for moisture potential of these environments have been found experimentally from a variety of studies is shown in the following table. Note that single water potentials are selected for sampling, as we are aiming to compare discrete environmental conditions rather than create a complete span of environmental conditions. These values are the average of the ranges or seasonal values given.

Biome/ Environment	Water Potential Range [MPa]	Selected Value [MPa]
Dessert (Arid)	-4.0 to -5.0 MPa [**?**]	-4.5 MPa
Grasslands/shrublands (Semi-Arid)	-1.4 to -5.0 [1] [**?**]	-3.2 MPa
Temperate Forest	-0.44 (Fall), -1.19 (Winter), -0.58 (Spring), -1.42 (Early Summer), -1.81 (Summer) [**?**]	-1.09 MPa
Boreal Forest (Arboreal)	-0.83 (Fall), -1.20 (Winter), -0.55 (Spring), -1.61 (Early Summer), -3.36 (Summer) [**?**]	-1.51 MPa
Tropical Rain Forest	1.57 MPa to 0.00 MPa [**?**]	-0.79

Given these estimates, we can have a probable example combination of temperature and moisture potential in various environments. Note that these are not wholly representative configurations, but rather examples to provide insight into how fungal species with specific traits may respond in discrete and distinct conditions likely to exist.

We can then find ν using experimental data from Maynard et al 2019. **** (talk about continuous data technique thingy in the extra methods info sheet)

[1] Measurements taken November through January at 100 cm soil depth.

1.3 Other Responses to Temperature and Water Potential

Our growth model takes into account temperature (T) and water potential (ψ) in two more parameters: the soil temperature coefficient (S_T) and the soil temperature coefficient (S_M). Moorhead et al. (1991) provides a simple relationship between S_T and T using the rate of increase (Q):

$$\log_{10}(S_T) = \frac{T-25}{10}\log_{10}(Q) \tag{1}$$

Although this equation does not take into account specific fungal response to temperature change, more recent evidence supports that this relationship is not direct, with most of the direct impact coming from moisture [**?**]. As the ratio of rates of decomposition given a temperature change however, Q will represent the effective output of various mechanisms influenced by temperature rather than focusing on specific mechanisms.

Water potential also relates to a constant, S_M, in a simple equation described in Moorhead et al. (1991) using α_2 and λ:

$$S_M = \alpha_2 - \lambda\log_{10}(-\psi) \tag{2}$$

These two parameters help calculate the maximum growth rate by the relationship:

$$\beta = S_T S_M r \tag{3}$$

where r is the enzyme biomass ratio.

1.4 Responses to Other Environmental Parameters

****this whole part is chaos*** only if we have space/ time :(

The mean soil profile distributions by percentage is [**?**] [2]:

Biome/ Environment	Sand [%]	Silt[%]	Clay[%]
Dessert (Arid)	43.21	33.67	23.05
Grasslands/shrublands (Semi-Arid)	45.14	34.71	20.15
Temperate Forest	45.42	34.97	19.59
Boreal Forest (Arboreal)	50.01	32.77	17.22
Tropical Rain Forest	42.42	27.05	30.53

To define soil characteristics of various sample biomes within Whitaker's scheme, we can refer to the sampling documented in , which describes soil properties found in the top 30 cm.

Thus, we will use the two aforementioned schemes to provide us with a more focused selection of the following environments, whose properties will be expanded upon:

[2] Note that here we neglect uncertainties for these percentages, as we need only a general estimate of the biome.

2 Model Parameters

Here are the model parameters for the coupled decomposition and growth model for Armillaria gallica located at 30.465247 degrees latitude and -89.040298 degree longitude secreting cellobiohydrolase (Cel7A) to decompose hardwood holocellulose [**?**] [**?**]:

Parameter	Symbol	Value	Units	Source and Specification
Half-Saturation constant [3]	K_e	7	$\frac{g_{enzyme}}{L_{litter}}$	[**?**] Enzyme
Holocellulose carbon [4]	$1 - LCI^5$	0.709	N/A	[**?**]
Hyphal tip elongation rate	ν	0.250	$\frac{mm}{day}$	[**?**] Species, ψ, T
Temperature	T	25	$^\circ C$	[**?**] Specie's habitat
Water potential	ψ	-0.5	MPa	[**?**]
Enzyme biomass ratio [6]	r	0.437	$\frac{g}{g}$	[**?**] Species
Hyphal death rate	γ_1	0.15	day^{-1}	[**?**]
Anastomosis coefficent	μ	0.3	$\frac{mm}{day}$	[**?**]
Branching rate	α_1	1.2372	day^{-1}	[**?**]
Intercept of S_M function [7]	α_2	0.311	N/A	[**?**]
Slope of S_M function	λ	0.345	N/A	[**?**]
Soil moisture coefficient	S_M	0.4149	N/A	[**?**] ψ
Soil temperature coefficient	S_T	1	N/A	[**?**] T
Rate of Increase	Q	??	$^\circ C$	[**?**] T
Rate constant [8]	G	10	$g * mm^{-1} * day{-}1$	[**?**][9]

[3] Also called Michaelis Constant.
[4] We assume that all carbon compounds excluding lignin are holocellulose.
[5] Where LCI is the lignocellulose index.
[6] Proportion of specific enzyme biomass to total enzyme biomass.
[7] The intercept of soil moisture effect on decay rate.
[8] Proportionality constant between maximum rate of decomposition and enzyme biomass.
[9] Emprically derived.