**模型假设**

1. 枯枝落叶和木质纤维等营养成分只会被真菌分解不会被生物消耗
2. 真菌群落的最大环境容纳量在一段时间内为常数，只与空间大小资源多少有关系
3. 一种真菌在竞争中被淘汰后，如果条件改变则该真菌有可能再次出现
4. 即使不同菌群并没有接触，不同真菌间也时刻都在竞争相互影响

**摘要**

为了分析真菌群落分解木质纤维作用，本文由相关理论入手推导了适用于多真菌群落间的竞争公式，将这一问题看作种群间以竞争为主的多种相互作用共存的问题，建立并优化种群关系，重点分析了模型的稳定，最终合理地模拟了真菌群落间的关系、多样性以及环境条件波动对真菌整体分解速率的影响，从理论上确定了系统存在稳定的条件。

In order to analyze the decomposition of woody fibers in fungal community, this paper deduces the competitive formula applicable to multi-fungal community from the relevant theory, and regards this problem as a problem of multi-interaction and coexistence between populations based on competition. We establish and optimize the relationship between populations, focus on analyzing the stability of the model, and finally simulate the relationship between fungal community, diversity and the influence of environmental condition fluctuation on the overall rate decomposition of fungi reasonably. The stable conditions of the system are determined theoretically.

对于问题一、二，我们利用线性拟合的方法，把最小二乘数作为拟合好坏的指标，将不同自变量对真菌分解速率的影响以函数的形式表现出来。对于Hyphal extension和moisture trade-off两个重要变量，通过相关研究图像进行线性和非线性拟合，利用分解速率相同得到两者间的关系，最后进行合并处理。

For problem 1 and 2, we use the linear fitting method, which takes the least two multipliers as the indicator of good fit, and show the effect of different arguments on the rate of fungal decomposition as a function. For the two most important variables, Hyphal extension and moisture trade-off. By researching the relevant images, we carry out linear and nonlinear fitting method, and obtain the relationship by the same decomposition rate, and finally merge them and process.

对于问题三，基于Lotka-Voltera模型进一步完善，通过微分方程组表达不同真菌之间的相互关系。求解奇点特征和类型，分析模型的稳定性和稳定条件，最后给出以两种真菌群落为例的分析，列出不同情况下的竞争结果。得出当双方只有竞争关系时两者最终会达到数量上的相对稳定，但是如果存在抑制关系则会出现一方胜出一方淘汰的情况。

For problem 3, we refine our model based on the Lotuka-Voltera model, and the relationship between different fungi is expressed through the different equations. To solve the singerum characteristics and types and analyze the stability and stable conditions of the model, we finally give an analysis of the two fungal community as examples and list the competitive results under different circumstances. It is concluded that when the two sides only have a competitive relationship, the two will eventually achieve relative stability in quantity. However, if there is a suppression relationship, there will be a situation in which one of the winning parties is eliminated.

对于问题四，在问题三模型的基础上，加入动态波动的影响来模拟干旱、半干旱、温带、乔木、热带雨林等不同环境下的短期变化。在存在动力干扰的情况下分析动力系统的稳定性，根据相关定义将每种真菌的结果分为“灭绝、非平衡持久、弱平衡持久、强平衡持久”四种情况，并进一步分析每种情况需要满足的条件

For problem 4, which based on the model of problem 3, the effects of dynamic fluctuations are added to simulate short-term changes in different environments such as drought, semi-arid, temperate, trees and tropical rainforests. We analyze the stability of the power system in the presence of dynamic interference, and divide the results of each fungus into four cases: “extinction”, “average persistent”, “weakly average persistent”, and “strongly average persistent” according to relevant definitions. Furthermore we analyze the each situation needs to meet the conditions.

对于问题五，为了模拟真菌多样性，包含竞争、抑制、促进三种相互关系同时存在的情况，以三种真菌共存为例进一步优化模型。利用矩阵进行对多样性系统分析的分析，使得求解更加简单，同时可以推广到任意数量真菌群落的情况。然后对优化的模型再次进行稳定性分析，以矩阵形式清晰地表达了存在全局渐进稳定的正平衡点的条件，描述了真菌多样性对生态系统稳定行和系统自我调节能力具有重要影响。最后结合问题一、二 的模型求出多样性真菌系统对木质纤维的整体分解速率。

For problem 5, in order to simulate fungal diversity, which includes competition, inhibition, promotion and the existence of three interrelations at the same time, we optimize the model further taking the three fungal coexistence as an example. We use the matrix to analyze the diversity system, and with analyzing the optimization model again, the conditions of the positive equilibrium point of global progressive stability are clearly expressed in matrix form, which describes the important influence of fungal diversity on ecosystem stability and system self-regulation ability. Finally, the overall decomposition rate of wood fibers of the diversity fungus system is solved by combining the models of problem 1 and 2.

**Conclusion:**

我们是2021 MCM contest的参赛团队，我们选择了”Fungi”问题。我们想要通过团队建立的模型和相关分析来讨论一下真菌在生态系统中的作用以及相关问题。

分解者在地球圈的碳循环中是必不可少的一部分，真菌是分解者的重要组成部分，真菌的重要作用在于可以分解枯枝落叶和木质纤维，因此研究真菌作用和保证木质纤维分解速率对维护碳循环的正常进行有重要意义。

通过我们的模型分析可以得出下列结论，不同的温度、湿度、天气气候、真菌种类以及不同种类真菌的物种组合都会对整体的木质纤维分解速率造成影响；环境变化对真菌分解速率有一定的影响，这种影响在不是很严重的时候会被真菌-环境系统抵抗或者消除恢复；真菌群落的多样性一定程度上决定了系统对于环境变化的抵抗能力和自我恢复能力，物种多样性越全面系统抵抗能力越强，在遭遇破坏时也就越容易恢复。

首先，通过上述分析，在维持真菌分解作用时，真菌的多样性起到了至关重要的作用，当环境发生局部变化或者短期变化时，真菌-环境系统不需要外力介入就可以通过系统内的自我调节来维持分解作用正常进行，这是一种可持续的环境系统。

其次，要防止火灾、洪水等严重的自然灾害和化学药剂泄露等物理化学重大破坏。这类事故会导致的巨大环境变化，这种变化超过了系统的自我调节能力，会破坏真菌多样性严重影响木质纤维的分解和区域内的碳循环进而威胁其他生物环境的正常活动。如果要进行灾后重建生态系统，在投放真菌时要注意真菌的种类搭配和投放规模，因为在模型中的初始条件决定了最终的模型稳定情况。同时，要防止外来真菌物种的入侵，真菌物种的增加不一定会增加物种多样性，只有当真菌间的相互作用关系满足系统稳定性要求才能够增加物种多样性。

最后，我们应该让更多的人意识到保护物种多样性的重要性。我们人类也是整个生态系统的成员之一，如果分解者遭到严重破坏我们也一定会受到严重影响，因此保护生物多样性是和我们每个人都是息息相关的。

Finally, we will be very glad if you can take time to read our paper and we hope our advice will be of help to you. If you have any questions, please feel free to ask us.