**Apêndice: ODD protocol**

1. Objetivo

O modelo tem o propósito de investigar o efeito da plasticidade comportamental dos indivíduos na resiliência da população e da comunidade do sistema.

2. Entidades, Variáveis de estado e Escalas

Há treze entidades no modelo: quatro espécies produtores primários (plantas), quatro espécies consumidores primários (ovelhas), quatro espécies de consumidores secundários (lobos) e a perturbação.

Plantas: as plantas tem **quatro** variáveis de estado:

* ID: each spider has its own individual identifier
* Location: represents the spider’s position in the XY plane
* personality: A proxy for risk-seeking behaviour. Bolder spiders tend to move to a patch with higher risk, with probability equal to its personality score. Varies between 0 and 1
* mutation-prob: represents the probability of offspring personality score mutations. It is equal for all spiders
* mutation-rate: represents the amount of change in an offspring personality mutation. The change can be positive or negative (an increase or a decrease in personality value), and the direction is selected randomly, with equal probability. It is equal for all spiders
* mating-radius: This represents, in abstract units of space, how far the spider looks to find a mate.
* Age: How old the spider is. When a spider reaches age 5, it dies

Consumidores primários:

Consumidores secundários:

Perturbação:

*Spatial units (e.g., grid cells)*.

* *Web*:the simulations happens within the web. The web is represented as a rectangular plane of 10 by 40 units of space, called *patches.* Each patch has a given amount of protection, determined by de distribution of danger in the environment. Time and space are arbitrary units
* *Environment*:
* The only important trait of the environment is the *danger level*, which represents the attack probability for any given spider
* *Collectives*:
* The are no collectives in the model

3. Visão geral e agendamento de processos

Time passes in discrete steps, and each simulation lasts a hundred rounds. Agents act in a randomised order, and their internal state is updated, at the beginning of their turn, with information from the current state of the world. This simulates an asynchronous update process (Caron-Lormier et al. 2008). The model runs according to the following pseudo-code:

1. Simulation starts, the *danger level* of the patches is updated according to the chosen distribution, agents are created and distributed randomly throughout the web
2. Start of time-step, agent order is randomised by the NetLogo Observer agent
3. On its turn, each agent does the following, in order:
   1. Move: the agents draws a random number between 0 and 1 and compares it to its personality score. If the random number is lower, the spider moves to one of the neighbouring patches with a danger level higher than the one it is currently in, otherwise, it moves in a random direction, as in brownian motion.
   2. Test survival: the agent tests if it suffers a predation event, with probability equal to that patch’s danger level
      1. If attacked, the spider has a survival probability equal to its *personality*, which represents an attempt to evade predation. If preyed upon, the agent dies, if not, it proceeds to the reproduction event
   3. Reproduce: the spider tests against its mating probability. If successful, if there are any other spiders in its *mating radius*, the spider picks one at random and they reproduce. Each mating event produces one offspring. The offspring’s *personality* is the average of its parents’ *personality*
      1. Mutation: if a mutation event happens, the offspring’s *personality* is altered by an amount equal to its *mutation rate*, randomly determined to be an increase or a decrease
      2. The offspring is randomly placed somewhere in the web
   4. Ageing and death: the agent’s *age* is updated by one. If the age is greater than 5, the agent dies
4. End of turn: the simulation time-step counter is updated. If the set limit is reached, the simulation stops.

4. Design conceitual

* *Basic principles.* The spiders’ *personality* is a proxy for risk-seeking behaviour: bolder spiders tend to seek danger more often than shyer ones. The danger level represents the protection afforded by the web’s structures, with danger increasing from the centre of the web to its borders. Different web structures are represented as different distributions of danger level.

Danger can increase linearly, as found for instance in planar webs, or it can vary highly, presenting a secluded, protected area, with an exposed outer rim, as in the complex webs of *Anelosimus* sp.. We model this exposure to danger as the web patches` danger level (see equation 1 in submodels)

* *Emergence*.We also expect that a mixed bold-shy population will emerge from a pure bold population, due to the protection given by the web
* *Adaptation*.The agents have noadaptive traits, as they do not make choices based on the environment or presence of other agents.
* *Objectives*. Agents do not have stated objectives
* *Learning.* Agents do not learn
* *Prediction*.Agents make no predictions
* *Sensing*. The agents sense the number of neighbours when they reproduce, and sense the danger level of the web patch they are in and its immediate neighbourhood
* *Interaction*. The only interaction is reproduction
* *Stochasticity*.Almost all processes are stochastic. Movement is randomly decided. At every turn there is a 30% chance that each spider will reproduce. Death can happen by age, or by predation events. The probability of a predation event is the danger level of each patch
* *Collectives*. There are no collectives
* *Observation*.At the end of the simulation, the position and personality of each agent is collected, and appropriate statistics are calculated outside the model

5.Inicialização

At time zero, the danger level of each patch is assigned, according to the chosen distribution, and 100 spiders are randomly generated, each with a personality drawn from a given distribution between 0 and 1. Each replicate has a different random seed. Parameters "degree of refuge protection" and “refuge size” x (see submodels) are varied in different combinations in the ranges given in *submodels*

6. Dados de entrada

O dado de entrada utilizado foi à perturbação (fragmentação) gerada em arquivo no formato (.txt). O arquivo foi gerado no Gradientland, pois este é um programa especializado em geração de paisagens com propriedades fractais e impactos de tamanho diferentes, com evoluções graduais a partir das propriedades do formato anterior.

7. Submodelos

The danger level (y) of each web patch is determined by its position (x) from the centre of the web and the danger distribution of the given simulation, according to the following equation, where *"degree of refuge protection"* varies between -15 and 0, and "refuge size"varies from 0.1 to 1



where "refuge size" corresponds to proportion of the web inside the refuge, and "degree of refuge protection" corresponds to the size of the concavity in the sigmoid danger function. In biological terms, a larger "refuge size" imply a larger, central protected area in the web; a larger "degree of refuge protection" corresponds to a more stepped, more abrupt danger increase from the centre to the periphery of the web.

Grimm, V., Berger, U., DeAngelis, D. L., Polhill, J. G., Giske, J., & Railsback, S. F. (2010). The ODD protocol: A review and first update. *Ecological Modelling*, *221*(23), 2760–2768. https://doi.org/10.1016/j.ecolmodel.2010.08.019