Ecological Problem Solving

FW 364

Predator Prey Lab

**Due: December 3**

**Learning objectives**: In this lab, we examine predator-prey interactions with Stella. In particular, we compare scramble and contest predators and their effects on prey dynamics. Stella is a powerful modeling software tool that is based on the ecosystem concept of **stocks** and **flows** (Labs 1 and 2).

**Review of contest and scramble predators, and “ceilings” for contest predators**

In this exercise, we will compare the effect of two types of predator (the consumer) on the abundance and dynamics of a prey population (the resource). Scramble predators are oblivious to the presence of other individuals of the same species; scramble predators do not defend territories (or the resources territories contain) or act aggressively toward potential competitors at any population density. Many herbivores, especially those that travel and feed in herds, tend to be scramble predators with respect to their prey (plants). In contrast, territorial (contest) predators may interact directly with individuals of the same species, depending on population density. At low densities, individual predators may not encounter each other enough to interact. At high densities, contest predators may exclude other predators from their territory and the resources within it. As a result, territorial behavior may set a limit to the abundance of a predator population (a “contest ceiling”) that is below what could be sustained based on the availability of prey. In this case, the predator is said to be “self-limiting”. Many birds and carnivorous mammals defend territories, and so can at times be self-limiting. These predators tend to be most aggressive toward individuals of their own species.

**Creating the Stella model to be used in this lab (in-lab together)**

At the beginning of this laboratory we will explore modeling in Stella and develop the models needed for this assignment together as a class. We will make (and save) a series of models (with increasing complexity), and the last one, PredModel4 (which can be modified for scramble and contest predation), will be the model you use for this lab. There is a handout with general instructions for modeling in Stella (Stella Modeling Notes.pdf) on the course website.

**Part A: How prey and predator steady state abundance changes with prey carrying capacity (Excel)**

Before running any simulations with PredModel4, solve the models below for the steady-state abundances of the prey (V\*) and predator (P\*). In other words, you will develop general equations (will symbols) that can be used to calculate the abundance of prey and predators at steady state (i.e., the prey and predator equilibrium abundances, V\* and P\*, respectively).

$$^{dV}/\_{dt}=b\_{max}\left(1-\frac{V}{K}\right)V-d\_{v}V-aVP$$

$$^{dP}/\_{dt}=acVP-d\_{p}P$$

Note that these equations are from PredModel3 which we will build together in lab. PredModel3 does not contain a predator ceiling; we **cannot** solve for equilibrium with the complicated ceiling included. The prey model includes a density-dependence term $b\_{max}\left(1-\frac{V}{K}\right)$, and assumes that each predator removes a constant fraction of the prey population (the attack rate, *a*, is constant).

*Instructions for how to* ***solve*** *the predator-prey equations for steady state*

At steady state, the growth rate is 0, so dV/dt = 0, and dP/dt = 0.

You can get V\* (prey abundance at equilibrium, i.e., steady state) by doing some algebra on the predator equation and solving for V\*:

 $0=acV^{\*}P^{\*}-d\_{p}P^{\*}$

You can get P\* (predator abundance at equilibrium, i.e., steady state) by solving for P\* in the prey equation:

$$0=b\_{max}\left(1-\frac{V^{\*}}{K}\right)V^{\*}-d\_{v}V^{\*}-aV^{\*}P^{\*}$$

Note that when you solve the prey equation for P\*, you will have V\* in the solution!

Once you have equations for V\* and P\*, find V\* and P\* (i.e., find the prey and predator steady state abundances) for a series of values of prey carrying capacity, K (use the series: 20, 40, 60, 80, 100, 120, 140, 160, and 180), using the parameter values in Table 1 (note: see the excel file for this information). Provide a table of results in your lab report and describe (and contrast) how V\* and P\* change as the prey’s carrying capacity (assumed to be a measure of habitat productivity) increases. Remember that these steady state abundances are in the absence of a contest ceiling for the predator.

Based on what you just learned about how P\* changes as a function of prey K, at what value of K would you expect a territorial predator to begin showing self-limitation if there is a “ceiling” of 5 predators? That is, at what value of K would increasing K (habitat productivity) not lead to more predators if the system’s limit is 5 predators?

**Part B: Effect of predator density dependence (contest vs. scramble) on prey (Stella)**

Using **PredModel4** (that we built together in class), run Stella simulations for the two types of predators (contest vs. scramble) using the parameter values (Table 1) and the series of prey carrying capacities (20 through 180) used above (total of 18 simulations). Record the equilibrium abundance of prey (V\*) and predators (P\*) for each simulation and be sure to also pay attention to the dynamics of predators and prey (e.g., do they cycle, overshoot, or have a steady approach to equilibrium?). The **scramble** predator can be simulated using a high ceiling, i.e., a **ceiling equal to 100** (this value is so high that the ceiling is never reached). For the **territorial** (i.e., contest) predator, use a **ceiling of 5**. In addition to the simulations with predators, complete simulations without a predator (to do this you can set initial predator abundance to 0; this adds 9 more simulations, for a grand total of 27 simulations for Part B). For the simulations without predators, record prey abundance at equilibrium (V\*) and pay attention to prey dynamics. **Make sure the duration of each simulation is long enough that steady-state is reached!** (See excel file for recommendations). Note that you can change the simulation duration in the Run Specs window; the 100 time steps we used during class may not be sufficient for some simulations. For runs where there are cycles (no steady-state), you can calculate steady-state abundance as the average of the maximum and minimum abundance of the cycle. You can use the “Table” output feature to get accurate abundance estimates, and the “Graph” output feature to examine dynamics.

In your excel file, discuss your results, including answering the following questions:

* Did the simulations support your prediction from Part A about an increase in prey carrying capacity and predator self-limitation?
* How do the prey dynamics (e.g., cycles, overshoot of equilibrium, vs. gradual approach to equilibrium) differ between the 3 scenarios (i.e., scramble predator, territorial predator, vs. no predator scenarios)?
* How does the response of prey abundance to an increase in prey carrying capacity differ for the two types of predators?
* Given your answer to the question above, which type of predator is better able to control prey abundance?

**Table 1.** Parameter values used in this lab exercise.

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Symbol** | **Value** |
| Initial predator abundance | P | 2 |
| Initial prey abundance | V | 4 |
| Prey maximum birth rate | *bmax* | 0.80 |
| Prey death rate (non-predatory) | *dv* | 0.05 |
| Attack rate | *a* | 0.10 |
| Fraction of killed prey converted into new predators | *c* | 0.60 |
| Predator death rate | *dp* | 0.60 |
| Prey carrying capacity | *K* | 20 – 180 |