

Homework Assignment #3: Matrix Models: The Tragopan

Due: Monday, September 30

1. The following text is taken from *Gillman and Hails: An Introduction to Ecological Modelling*:

**4.3 Three-stage model of Cabot's tragopan**

Cabot's tragopan *Tragopan caboti* is endemic to the lower montane zone of south-eastern China, where it inhabits evergreen deciduous forest and mixed deciduous-coniferous forest at an altitude of 800–1400 m (Collar & Andrew 1988).

Cabot's tragopan breeds once a year, starting in late March or early April and ending in May or June. The following details are from Wuyanling (and Philip McGowan *pers. comm.*, Zhang Ding Chang-qing and Zheng, 1990), where the sex ratio of adult male to females is approximately 1 : 1.

Nesting failure is very high. During 1984–1993, 33 nests were found in the wild and only five (i.e. about 15%) of them hatched successfully. The reason for nest loss was attributed to various factors such as predation by jays and egg-collection by local people. Completed clutches contain two to six eggs, with an average of 3.5. Because of the bad winter weather (snow and heavy rain) and the predators, the survival rate of chicks is generally not more than 50%. The ratio of adults to one-year-old birds is 4.6:1. In the wild the bird starts breeding in the third year. Life expectancy in the wild is unknown; in captivity the longest recorded is 8 years.

- (a) Read the above carefully. From the information provided, construct an *age-structured* (matrix) model for the evolution of the population density of this bird. How many stages will you consider (look at the title!)? Use the information to estimate fecundity and survival rates. Clearly show how you arrive at these numbers.
- (b) Write your model down, mathematically, in the following form:

$$\mathbf{X}_{i+1} = \mathbf{A}\mathbf{X}_i$$

What does the discrete time unit,  $i \rightarrow i + 1$  represent in reality? What are the entries in the matrix  $\mathbf{A}$ ?

- (c) Write a MatLab script to numerically determine the time evolution of the Tragopan population. Start from some initial condition, say: No eggs, no juveniles, 10 adults. Plot the evolution, in time, of each segment of the population. Does the population grow?

- (d) Use Matlab to plot the number of eggs/adult and number of juveniles/adult as a function of time. DO this for several different initial populations. Do these ratios converge to constants? Do the constant values depend upon the initial conditions?
  - (e) Use MatLab to find the eigenvalues and eigenvectors of the Matrix  $\mathbf{A}$ . What do these objects say about the population? In particular, compare the structure of the eigenvector associated with the largest eigenvalue to what your model shows for the population structure (ie: number of eggs/adult, number of juveniles/adult.)
  - (f) Use your model to assess what the effect of increased egg gathering by a growing population of encroaching humans will do the Tragopan population. How would you incorporate 'egg gathering' into the simple model? Determine what the minimum value of egg survivorship must be to insure that the bird population does not decay to zero.
2. Read the paper *A Stage-Based Population Model for Loggerhead Sea Turtles and Implications for Conservation* by Deborah T. Crouse, Larry B. Crowder and Hal Caswell. (You can download this from:

<http://www.math.csi.cuny.edu/~poje/Teach/LoggerHeadTurtles.pdf>

- (a) You should be familiar enough now with matrix population models to understand what these folks are trying to do. What is their model? Write down the matrix model they study. How many age classes do they use? Why did they pick these? How did they estimate parameters?
- (b) Write a MatLab script to compute the evolution of the modeled logger head turtle population. In other words, use MatLab to solve

$$\mathbf{X}_{i+1} = \mathbf{A}\mathbf{X}_i$$

where  $\mathbf{A}$  is given in *Crouse, Crowder and Caswell*. Plot the time evolution of the population and the evolution of the age structure of the population (ie: number of eggs/mature breeder, number of novice breeders/mature breeder, etc).

- (c) Use MatLab to find the eigenvalues and eigenvectors of the matrix. Relate these to what you found in the simulations.