February 14, 2003

FW 662 Midterm Exam

This exam is a take-home, open-book exercise. There are 3 questions; you must answer all of them, including multiple parts. You may use any reference material (class notes, assigned reading, library material, etc.). Under NO circumstances are you to discuss this exam with classmates or any other individual. You are to work independently and you should not confer with others. If you need clarification on a question, please see the instructor, or send email with your question to gwhite@cnr.colostate.edu . This exam is to be turned in by 8:00 am Monday, 17 February, at the start of class. Turn in this sheet with your written answers and disks that hold the spreadsheet models on which your answers are based. All questions require a written answer. In addition, some questions also require you to provide a spreadsheet demonstrating how you obtained your answer. Typed, short, concise answers will be graded more generously than hand-written, long, rambling responses. Your **spreadsheets on the first diskette for questions 1 and 2, and on a second diskette for 3** will be used to verify that your answers were obtained in a logical fashion, and provide you with partial credit in cases where you got the wrong solution, but just made a simple mistake in the spreadsheet. **Please separate your answer sheets for questions 1 and 2 from question 3 so that they may be separated for grading. Identify your answer sheets and disks with your SSN only.** Only put your name (via your signature) on this sheet.

By my signature below, I certify that I have not collaborated with anyone concerning any material related to this examination.

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SSN Signature Date

1. Construct a population model for peregrine falcons (*Falco peregrinus anatum*) from the following estimates of survival and reproduction derived from banded birds (1973-2001) and monitored nests (1989-2001) in Colorado. Survival estimates for 0-1, 1-2, and 2+ year old birds are 0.544, 0.670, and 0.800, respectively, with standard errors of 0.0765, 0.0981, and 0.0544. Average young produced per pair is 1.660 (SE = 0.0443), but there is considerable variation across years (min = 1.388 in 1995; max = 2.122 in 2000). In 2001, the Colorado Division of Wildlife estimates there are approximately 100 pairs of birds nesting in the state.
   A. (10 pts) What is the expected annual rate of population change (λ) if females first reproduce at 2 years of age?
   B. (5 pts) What is the expected annual rate of population change (λ) if only half of the females first reproduce at 2 years of age, with the remainder first reproducing at 3 years of age?
   C. (15 pts) Falconers are requesting to remove young birds from nests to raise in captivity for falconry. Construct a graph of the expected population rate of change (λ) on the *y* axis and percent of young removed on the *x* axis. Plot 2 lines on the graph, one for the population first reproducing at 2 years of age, and one for the population first reproducing at 3 years of age.
   D. (10 pts) Assume that the annual variation in young produced per pair can be modeled as a normal distribution with mean 1.660 and standard deviation 0.18. What is the expected annual rate of population change (λ) with this variation incorporated into the model for the population with birds first reproducing at 2 years of age?
   E. (10 pts) The survival and reproductive parameters provided above include estimates of precision, i.e., SE are provided. Describe how these estimates of precision can be used in the models you constructed above to compute a SE on your estimates of expected annual rate of population change (λ). You don't need to build this spreadsheet, just describe the process of how you could go about producing a SE on λ that reflects the sampling variation of the input parameters.

2. The following data are the harvest, escapement (*S*) and returns (Recruits or *R*) for northern Southeast Alaska pink salmon (thousands of fish), 1960-1991.
   A. (10 pts) Compute the parameters of a Ricker curve that describe these data, and graph the Ricker curve and the observed values.
   B. (5 pts) Based on your model, what is the maximum yield that can be obtained from this population? Hint: use Solver to compute this value.
   C. (5 pts) What is your assesment of the amount of harvest of this population, based on the evidence provided in the data and the model you fitted to the data? That is, has the harvest generally been greater than or less than what you would consider optimal based on your analysis? Discuss the assumptions you made to make your assessment.

Year	Harvest	Escapement [S]	Return [R]
1958			2678
1959			10459
1960	1260	1418	2446
1961	7624	2835	14934
1962	489	1957	10031
1963	10901	4033	8050
1964	7281	2750	7884
1965	5159	2891	4430
1966	4786	3098	13086
1967	2429	2001	6051
1968	9871	3215	7801
1969	3608	2443	5846
1970	5240	2561	6101
1971	3012	2834	4175
1972	3242	2859	2541
1973	1880	2295	2194
1974	661	1880	1512
1975	615	1579	6704
1976	139	1373	5742
1977	2521	4183	8809
1978	2758	2984	4062
1979	3750	5059	9277
1980	1393	2669	15452
1981	5328	3949	10343
1982	11233	4219	8950
1983	6053	4290	30011
1984	4974	3976	3999
1985	21212	8799	9917
1986	1143	2856	4906
1987	5628	4289	18215
1988	2014	2892	9461
1989	13638	4577	23359
1990	5659	3802	
1991	18112	5247	

3. Field biologists have been studying a population of deer mice (*Peromyscus maniculatus*), in a small, isolated sky-island forest in Arizona. They would like you to build a population model for the species. The biologists will use this model to predict how many animals they can expect to have when they estimate populations in late April. You are given the following information:

   Mice rarely live past their second summer of life; thus, the maximum age of animals in the field is 2 years plus a few months, i.e., survival from year 2 to year 3 is 0. Survival from year 1 to year 2 appears to be highly dependent on rainfall, as rainfall has a large influence on food supplies (especially seeds). Annual survival from 1 to 2 years of age can be modeled as a ß-distributed random variable with a mean of 0.45 and a standard deviation of 0.1. Males and females have similar survival rates.

The vast majority of births occur in early May. On average, 1-year-old females give birth to 8 young per year, while 2-year-old females give birth to 4 young per year. These rates are expected to vary somewhat, but no variance on young per female is available. The sex ratio of animals at birth is approximately 1:1. Survival of these young appears to be density-dependent, probably due to a functional response of predators (more mice means more predators cueing in on this food source, and young mice are most vulnerable to predation). The survival of animals from birth to 1 year appears to follow the equation: $S(t + 1) = N(t) \times -0.001 + 0.45$ over the range of population sizes that have been observed in the field (approximately 150 - 300 mice).

A. (15 pts) Provide a model for this population. Include both males and females in the model. Either clearly on your spreadsheet, or on a separate piece of paper, sketch the projection matrix and vector that represent the model you built.

B. (5 pts) Estimate *K* (provide mean and SD) for this population over the next 50 years, assuming that no changes occur in the habitat over this time.

C. (10 pts) Will this model provide a reliable estimate of the population of deer mice in this area? Why or why not? If not, what additional information would be helpful in improving the model? Are their any potentially important sources of variation that have not been included in this model?

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1. A. λ = 1.080087 – check the spreadsheet for exactly how this was computed

   B. λ = 1.052835

   C. See the graph in the spreadsheet – I built this by repeatedly copying and pasting the value of lambda from the spreadsheet to create the table used to generate the graph. Note that the value of lambda for no reproduction is just the adult survival rate. The population will never decline at a faster rate than the adult survival rate.

   D. Mean λ equals about 1.08, using a NORMINV(1.66, 0.18) for the reproduction value each year. I've also included a spreadsheet with a bootstrap approach, where the annual reproduction rate is selected at random from the observed reproduction rates for the 13 years. This second spreadsheet is only an example, and you could not have built this model from the data presented.

   E. To compute the SE of λ from the SE of the input parameters, you need to repeatedly generate complete sets of the input parameters, and for each of these sets of values, compute the value of λ. That is, to compute an individual estimate of λ, you need to generate a set of the input parameters. Each parameter would be computed as a random normal with mean equal to its estimate, and standard deviation equal to the reported SE. From this single set of estimates, compute the value of λ, which would require running the model with these parameter values for multiple years to allow the model to stabilize. If this process is repeated for 1000 models, the mean and standard deviation of these 1000 estimates of λ would provide the mean and standard error of λ.

   You could also use analytical methods and apply the delta method, as described in the class notes, to compute the SE(λ) analytically from the standard errors of all the parameters.

   Note that I have assumed that all the parameters are independent, so that no covariances exist between them. If parameters are estimated from the same data in the same estimation model, covariances would have to be incorporated into the procedure.

2. A. Estimate of R_0 = 1.408947, K = 13750.88. I assumed normally distributed errors, but assuming lognormally distributed errors would also be appropriate.

   B. MSY = 7309.455. The easy way to compute this value is to use solver to maximize the equation

$$\text{MSY} = N_{t+1} - N_t \exp\left[R_0\left(1 - \frac{N_t}{K}\right)\right]$$

   given your parameter estimates from part A. Several of you had problems, and resorted to using the analytical solution from the logistic equation. Although approximately correct, this approach is not what was requested.

C. A whole list of assumptions have to be made:
1. Density dependence follows the Ricker equation
2. No sampling variance associated with the stock and recruitment values. Most people did not list this assumption, which is a major issue in actual problems of this sort.
3. No process variance, i.e., K and R_0 are fixed constants, and do not vary with time or space.
4. A single population exists, rather than a collection of many populations, each in their own stream. Also, fishing pressure and hence percent of the population harvested is assumed to be the same for each of these populations, an unlikely scenario.
5. No individual heterogeneity, although probably not a big issue given that spatial and temporal variation are more prevalent.
6. The range of the data used to compute the estimates does not cover the range over which the estimates will then be applied, i.e., a fair amount of extrapolation is required to actually implement the resulting estimates. You notice this when you look at the graph in the spreadsheet, and see that only one value is observed beyond the estimated MSY

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3. A. This is a pre-birth model with 4 age classes: just < 1-yr-old females, just < 2-yr-old males, just < 2-yr-old females, and just < 2-yr-old males. See spreadsheet for projection matrix.

B. K ˜ 245; SD ˜ 16.

C. I wanted some discussion of assumptions you made in order to build the model, and the relative strength of those assumptions. Some important ones include:
1. Process variation: there could be additional process variation on birth rates, as well as on the function relating survival to density.
2. Sampling variation (uncertainty): this is important; we assumed that everything we did know, we knew with certainty; this assumption clearly is not met with sample data.
3. Demographic variation: this could have influenced birth rates, survival rates, and sex ratio.
4. Spatial heterogeneity: we assumed no spatial heterogeneity in this population, and no migration, probably a reasonable assumption given that it exists in one isolated habitat patch.
5. Individual heterogeneity: this can be important over longer time scales (relative to life of an individual); (individual heterogeneity is the raw material of evolution by natural selection).
6. Constant K: we assumed that K would not change over time, but it is likely that directional changes in habitat (e.g., due to vegetation succession or disturbance) would change carrying capacity.