MATRIX POPULATION MODELS 5-15 May 2008
Universidade de São Paulo, São Paulo, SP, Brasil

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Description: The aim of the course is to give the students the conceptual, mathematical and computer tools necessary for determining population growth rates of structured populations and to analyze which components of the life history have the largest effect on population growth rate. Structured populations refers to populations in which survival, growth and reproduction probabilities are not uniform for all members of a population, but rather depend upon subdividing a population into classes, such as age, or stage. Understanding what influences population growth rate is significant for ecological issues such as conservation of endangered species, control of exotic species and persistence of species in certain habitats. It is also crucial for such evolutionary ecological issues such as life-history evolution and plant animal interactions.

Course philosophy: The only way to learn math is to do it. Each student should keep a notebook that reflects the learning process. The homework exercises and the student presentations of them on the following day are the most important activities of the course. Each student should be sincerely engaged in attempting to do the exercises. Misunderstanding and mistakes will be part of the process and these should also be reflected in the presentations of the exercises. If a student could not get all the way through a problem, she/he should be prepared to say where the block occurred. The student presentation sessions should be viewed as a workshop session rather than a showcase. Background and previous experiences will surely vary among the students and it is expected that students will share their knowledge and skills with one another. It is hoped that each student will progress with respect to her/his own starting point.

Pre-requisites: Introduction to ecology or population biology.

Course Outline:

Monday, May 5, 2008

Lecture 1. Representing the dynamics of structured populations by a matrix or by a life cycle graph.

Computer Lab.

Introduction to MATLAB.
Matrix projection. (mat1project)
Invent your organism (this creature will stay with you for 2 weeks).

Tuesday, May 6, 2008

Lecture 2. Population growth rate, stable stage distribution, and reproductive values: Eigenvalues and eigenvectors.
Student presentations of homework

Computer Lab.

Eigenvalues, eigenvectors and the projection equation (mat2valvecs).
Powers of real and complex eigenvalues.
Transient vs. asymptotic dynamics.
Apply analytical techniques to your invented organism.

Wednesday, May 7, 2008

Lecture 3. What influences population growth rate? Sensitivity (prospective), elasticity (prospective) and the product of sensitivity with variability (retrospective) (LTRE's).
Student presentations of homework

Computer Lab.

Proportional vs. linear perturbation (mat3prosretr).
Perturbation "experiments" within single environments.
Sensitivity and elasticity matrices for single environments.
Retrospective analysis across several environmental states.
Gradient analysis and regression designs
Invent variants (habitats, plots or treatments) for your invented organism.

Thursday, May 8, 2008

Lecture 4. Stochastic environments: probability distributions
Student presentations of homework

Computer Lab.
Stochastic environmental variation: uniform probability distribution. (sev1uni)
Stochastic environmental variation: normal probability distribution (sev2norm)
Stochastic environmental variation: discrete probability distribution (sev3disc).
Stochastic environmental variation: Markov probability distribution (sev4markov).

Friday, May 9, 2008

Lecture 5. Disturbance mosaics: space, time and population growth in variable environments.
Student presentations of homework

Computer Lab.
Kronecker products and the Megamatrix (mat4mega)
Megamatrix population growth rate and what influences it.
Invent a disturbance mosaic for your invented organism.

Saturday and Sunday May 10, 11 2008

To be arranged. Possible activities: field trip, field techniques, workshop on going from field data to matrix model

Monday, May, 12, 2008

Lecture 6: Stochastic demography: New sensitivities: means, variances and environment-specific rates
Lecture 7. (Seminar) "Hurricanes, seed-predators and habitat-stage elasticity: global patterns with local consequences"
Student presentations of homework.

Computer Lab.
Stochastic sequence and sample paths (mat5stochseq)
Stochastic population growth rate and what influences it.
Investigate changing a biological or environmental feature of your invented organism in its invented disturbance mosaic.

Tuesday, May 13, 2008

Lecture 8. Introduction to spatial ecology of structured populations.

Lecture 9. (Seminar) Rate of spread of a population: sensitivity of wave speed to different reproductive modes in an ant-dispersed plant:

Student presentations of homework.

Computer Lab.

Combining demography and dispersal.(mat6wavespeed)

Invent a dispersal kernel for your invented organism and analyze its movement across space.

Wednesday, May 14, 2008.

Lecture 10. Integral projection models: introduction and construction

Student presentations of homework.

Computer Lab. (using R).

Construction: Growth, survival and fertility statistical models.

Analysis: growth rate, stable stage distribution, reproductive value, sensitivity, elasticity and more…

Thursday, May 15, 2008.

Lecture 11. Integral projection models: numerical analysis

Student presentations of homework.

Final projects and presentations.

NOTE: Code will be available to be downloaded from a website.

Main text:

Caswell, H. 2001. *Matrix population models. Second Edition.* Sinauer Associates, Inc. Sunderland, Massachusetts. 722 pages.

Additional references:

Morris, W.F. and D.F. Doak. 2002. Quantitative Conservation Biology: Theory and practice of population viability analysis. Sinauaer Associates, Inc. Sunderland, Massachusetts. 480 pages.

Roughgarden, J.1998, *Primer of ecological theory*. Prentice-Hall.

Tuljapurkar, S. and H. Caswell. 1996 .*Structured population models in marine, terrestrial and freshwater systems*. Chapman and Hall.

Vandermeer, J. 1981, *Elementary mathematical ecology*

Some of my relevant papers:

Calvo, R.N. and C.C. Horvitz. 1990. Pollinator limitation, cost of reproduction, and fitness in orchids: a transition matrix demographic model . *American Naturalist* 136:499-516.

Horvitz, C.C. 1991. Light environments, stage structure and dispersal syndromes of Costa Rican Marantaceae. *Ant-Plant Interactions,* ed. C.R. Huxley and D.F. Cutler, pp.463-485. Oxford University Press. New York.

Horvitz, C.C. and D.W. Schemske. 1986. Seed dispersal and environmental heterogeneity in a neotropical herb: A model of population and patch dynamics. In *Symposium on frugivores and seed dipsersal* . (A. Estrada and T.H. Fleming, eds.) Dr. W. Junk Publishers, Dordrecht, Netherlands. pp. 169-186.

Horvitz, C.C. and D.W. Schemske. 1995. Spatiotemporal variation in demographic parameters of a tropical understoty herb: projection matrix analysis. *Ecological Monographs 65*: 155-192.

Horvitz, C.C., D. W. Schemske, and H. Caswell. 1996. The relative "importance" of life-history stages to population growth: prospective and retrospective analyses. Chapter 7. In. S. Tuljapurkar and H. Caswell (eds.).*Structured population models in marine, terrestrial and freshwater systems*. Chapman and Hall.

Pascarella, J.B. and C.C. Horvitz. 1998. Hurricane disturbance and the population dynamics of a tropical understory shrub: megamatrix elasticity analysis*: Ecology 79*: 547-563.

Tuljapurkar, S., Horvitz, C.C. and J. Pascarella, 2003. The many growth rates and elasticities of populations in random environments. *American Naturalist.* 162: 489-502.

Kwit, C., C. C. Horvitz, and W.J. Platt, 2004. Conserving Slow-growing, Long-lived Tree Species: Input from the Demography of a Rare Understory Conifer (Taxus floridana). *Conservation Biology* 18: 432-443.

Horvitz, C.C., S. Tuljapurkar, J.B. Pascarella. 2005. Plant-animal interactions in random environments: habitat-stage elasticity, seed-predators and hurricanes. *Ecology* 86: 3312-3322.

Koop, Anthony and C.C. Horvitz. 2005. Projection matrix analysis of the demography of an invasive, non-native shrub (*Ardisia elliptica*). *Ecology* 86:2661-2672.

LeCorff, J. and C.C. Horvitz. 2005. The contrasting roles of chasmogamous and cleistogamous reproduction in population growth and population spread in an ant-dispersed neotropical herb, *Calathea micans* (Marantaceae). *Ecological Modelling* 188: 41-51.

Johnson, D.M. and C.C. Horvitz. 2005. Estimating natal dispersal: tracking the unseen dispersers. *Ecology* 86: 1185-1190.

Morris, W.F., S. Tuljapurkar, C.V. Haridas, E.S. Menges, C.C. Horvitz, and C.A. Pfister, 2006. Sensitivity of the population growth rate to demographic variability within and between phases of the disturbance cycle. *Ecology Letters* 9:1331-1341.

Tuljapurkar, S. and C.C. Horvitz. 2006. From stage to age in variable environments: life expectancy and survivorship. *Ecology.* 87: 1497-1509

Boyce, M.S., C.V. Haridas, C.T. Lee and the NCEAS Stochastic Demography Working Group. 2006 Demography in an increasingly variable world. *TRENDS in Ecology and Evolution.* 21: 141-148.