Introduction to modelling techniques in ecology

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General objective

Numerical tools are essential to run biodiversity scenarios and rigorously formulate testable hypotheses in ecological research. The main purpose of this course is to get students familiar with the main techniques of ecological modelling. After this course, the student is expected to be able to formulate mathematically a simple ecological model, use standard analytical methods to study the equilibrium state and its stability, and run dynamic simulations. The main langage of the course is R, but the basic programming techniques that will be teached are easily transposable to other langages.

Specific objectives

At the end of the course, the student will:

- Formulate ordinary differential equations describing community dynamics of a given ecological system
- Analyze the equilibrium and the stability of systems of ordinary differential equations
- Aquire essential programming techniques for numerical analyses
- Develop functions to simulate ecological dynamics
- Understand, analyze and criticize usage of modelling techniques in ecology

Requirements

This intensive training session is principally intended for graduate students and postdocs in biology, ecology & evolution, forestry and marine sciences. For each theme, training sessions will be made of short lectures on the different techniques, followed by supervised exercises on R, and finally conducting a small research project in team in a workshop context. Programming skills in R and elementary notions of calculus are required.

Approach

Teaching will be highly dynamic and students are expected to participate actively. Emphasis will be given to exercises, programming and team work. Team projects will be established on the first day and the teams will present their results at the end of the week, with the objective of initiative collaborative studies and end up in scientific publications. Each day will follow rigorously the schedule:

08h00 - 09h45: Introductionary lecture & analysis of illustrative scripts
10h00 - 11h00: Supervised exercised
11h00 - 12h00: Analysis & reproduction of illustrative studies
13h00 - 14h00: Follow-up on the labs
14h00 - 16h00: Team project
16h00 - 17h00: Lecture by graduate students from the Theoretical Ecosystem Ecology Lab

Content

Day 1: Ordinary differential equations 1, analytical methods

- Discrete versus continuous time models
- Definition and formulation of ODEs
- Steady-state solutions
- Local stability analysis

Day 2: Ordinary differential equations 2, numerical methods

- Basic programming notions (loops, conditional statements, functions etc...)
- Euler & Runge-Kutta methods of integration
- Introduction to rootSolve and deSolve packages

Day 3: Stochastic models

- Discrete time stochastic models
- Analytical appoximations to stochastic models
- Probabilistic models
- Essential probability distributions & random number generators

Day 4: Spatial models

- Spatial models classification
- Cellular automaton
- Spatially explicit dispersal model
- Diffusion

Day 5: Ecological networks

- Network properties
- Network models (random, scale free, small world, cascade, niche)
- Null models

Required readings

The following readings are required for the course, with great attention. We will conduct specific exercise and discuss them in group.

- Tilman, D. (1994). Competition and Biodiversity in Spatially Structured Habitats. Ecology, 75, 2–16.
- Vandermeer, J. (2006). Oscillating Populations and Biodiversity Maintenance. BioScience, 56, 967–975.
- Hubbell, S.P. (1997). A unified theory of biogeography and relative species abundance and its application to tropical rain forests and coral reefs. Coral Reefs, 9–21.
- Malamud, B., Morein, G. & Turcotte, D. (1998). Forest fires: an example of self-organized critical behavior. Science, 1840, 1998–2001.
- Williams, R. & Martinez, N. (2000). Simple rules yield complex food webs. Nature, 404, 180–183.

Suggested readings

The following articles will not be specifically studied during the course, but students are strongly encourage to read them BEFORE the course to stimulate discussions.

- Chesson, P. (2000). Mechanisms of maintenance of species diversity. Annual review of Ecology and Systematics, 31, 343–366.
- Dunne, J.A. (2006). The Network Structure of Food Webs. In: Ecological networks: Linking structure and dynamics. Eds. M.Pascual & J. Dunne. pp. 27–86. Oxford University Press. Oxford.
- Evans, M.R., Grimm, V., Johst, K., Knuuttila, T., De Langhe, R., Lessells, C.M., et al. (2013). Do simple models lead to generality in ecology? Trends in ecology & evolution, 1–6.
- Fawcett, T.W. & Higginson, A.D. (2012). Heavy use of equations impedes communication among biologists. Proceedings of the National Academy of Sciences of the United States of America, 109, 11735–9.
- Gravel, D., Guichard, F. & Hochberg, M.E. (2011). Species coexistence in a variable world. Ecology letters, 14, 828–39.
- Gravel, D., Poisot, T. & Desjardins-Proulx, P. Using neutral theory to reveal the contribution of metacommunity processes to assembly in complex landscapes. In review in J. of Limnology.
- Strogatz, S. (2001). Exploring complex networks. Nature, 410, 268–276.
- Turchin, P. (2001). Does population ecology have general laws ? Oikos, 17–26.

Software

All of the teaching will be conducted on R. The following packages need to be installed prior to the course:

- cheddar
- rootSolve
- deSolve
- NetIndices
- vegan
- bipartite

- UNTB
- igraph

An introduction to the open source symbolic math toolbox *sage (http://www.sagemath.org/)* will be provided. This software allows to perform the most standard analysis of ordinary and partial differential equations such as solving for equilibrium, isolating variables, computing derivatives and integrals and computing eigen values. It runs on a common Python interface.

Housing & Food

Training will be given at the Domaine Valga (http://www.domainevalga.com/), located at Saint-Gabriel (approx. 30 km from Rimouski). Students are expected to arrive late afternoon on Sunday the 26th of August and the workshop will end at the end of the afternoon on Friday the 30th of August. Housing will be provided in two cottages located around the lake. **Sheets are not provided, bring your sleeping bag**. The course will be given at the main building of the Domaine Valga. Students are in charge of bringing food for breakfast and lunch, while dinners are included in the course fees. The cost of the summer school is of 287.44$ for students supervised by a member of the CREATE program in Forest Complexity Modelling (http://www.mcf.uqam.ca/) and of 356.42$ for other participants. The fees will have to be paid by check on site and a receipt will be provided.

References

1. Begon, M., C. R. Townsend, and J. L. Harper. 2006. Ecology. From Individuals to Ecosystems. Fourth Edition. Blackwell Publishing Ltd, Oxford.
2. Gotelli, N. J. 2008. A Primer of Ecology. 4th Edition. Sinauer Associates, Inc., Sunderland, MA.
3. Loreau, M. 2010. From Populations to Ecosystems: Theoretical Foundations for a New Ecological Synthesis. Princeton University Press, Princeton.
4. Soetaert, K., and P. M. J. Herman. 2009. A Practical Guide to Ecological Modelling. Using R as a Simulation Platform. Springer, New York.
5. Stevens, M. H. H. 2009. A Primer of Ecology with R. Springer, New York.
6. Wilson, W. 2000. Simulating Ecological and Evolutionary Systems in C. Cambridge University Press, Cambridge.