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Bio 417: Theoretical Population Biology
Syllabus Spring 2019

Instructor: Erol Akçay – eakcay@sas.upenn.edu, Lynch 204E
Office hours by appointment

Meeting time/location: M-W 2-3:30pm, Goddard 100

Scope: The purpose of this class is to get you acquainted and proficient in fundamental concepts and tools in the mathematical theory of ecology and evolution. The course will have two parts: the first part will consist of lectures that will survey basic models and techniques used in theory of population biology. The second section will be in a seminar format, where we will discuss parts of the primary literature.

Theoretical population biology is a big field, and we will not attempt to cover all areas, but the material you will learn in this class will help you deal with a large class of problems, and also prepare you for learning other mathematical techniques and theories you might need later on.

Reference resources: There is no required textbook for the class. For most of the lectures, there will be lecture notes, and jupyter notebooks for some to do computations. All material will be posted on Canvas. In addition to the lecture notes, there are several books that you may wish to consult for different parts of the course, as described below.

Otto, S. P., and T. Day. 2007. A biologist's guide to mathematical modeling in ecology and evolution. Princeton University Press
Highly recommended as a gentle and readable introduction to many of the techniques we use in the class, and also to the practice of constructing models.

Caswell, H. 2001. Matrix Population Models. Sinauer Associates, Sunderland MA
Must have reference book if your life includes matrix population models. Don't lend your copy to anyone.

Rice, S. H. 2004. Evolutionary theory: mathematical and conceptual foundations. Sinauer Associates Sunderland
Concise and well-presented; covers a good selection of topics, including the Price equation and evolutionary game theory.

Roughgarden, J. 1979. Theory of population genetics and evolutionary ecology: an introduction. Macmillan New York NY United States 1979
Older book but a great exposition for the classical theory of population genetics and evolutionary ecology

Kot, M. 2001. Elements of mathematical ecology. Cambridge University Press
Good and accessible introduction to mathematical techniques used in ecology, focusing on models of a single population, including spatial models.

Bodine, E. N., S. Lenhart, and L. J. Gross. 2014. Mathematics for the Life Sciences. Princeton University Press
Excellent math textbook for biologists textbook covering linear algebra, probability theory, calculus among others.

Required work and grading: For the lecture part of the class, there will be homework assignments. These assignments will in total provide 25pts. The homework will consist of mathematical and coding exercises. There will be five homework assignments, 5 pts each.

For the seminar part, doing the readings and participating in class discussions will be evaluated. Additionally, each student will lead a class discussion. These discussions will be on a research paper from the primary literature mutually agreed upon between you and me. The paper needs to be on the topic of the term paper (see below), and present a new theoretical approach or be an application of a modeling approach we have discussed in the class. **Reading suggestions are due March 13th, but you are advised to talk to me about possible topics earlier than that. Participation throughout the class and leading the paper discussion will be 25 points total.**

You will also write a 10-15 page (1.5 spaced length) paper about a topic in theory of population biology. The paper can either be a substantive review of a body of theory (e.g., a review of stochastic community dynamics) or report on a modeling project. You are free and advised to choose the topic that most excites you among topics discussed in class, or related issues in population biology (provided there is a theoretical component to it). **A first draft of the paper is due by April 10th**, which I will return comments on. **The final paper is due in class on May 1st (last day of the course), and will be worth 50 points.**

Points Summary:

Homework assignments:	25 pts
Participation and paper discussion:	25 pts
Final paper:	50 pts

Schedule: Below is the currently planned schedule of lectures. The references in bold are readings assigned for the class. The last part of the class is allocated to discussions of contemporary papers related to your class paper.

Monday	Wednesday
Jan 14th **1**	16th **2** First meeting: organizational/introductory
21st **3** Martin Luther King Day/No classes	23rd **4** Why theory? **Levins (1966); Servedio et al. (2014)**
28th **5** Single population dynamics: continuous time	30th **6** Single population dynamics: discrete time
Feb 4th **7** Age-structured populations and demography	6th **8** Stage-structured populations, matrix models
11th **9** Stochastic population dynamics: birth-death process	13th **10** Stochastic population dynamics: branching processes
18th **11** Two population models 1	20th **12** Two population models 2
25th **13** Short-term evolution: Population Genetics	27th **14** Long-term evolution: Optimality models **Charnov (1976); Parker and Maynard Smith (1990)**
Mar 4th **15** Spring Break	6th **16** Spring Break
11th **17** Evolutionary game theory Guest lecture by Dr. Andrew Tilman	13th **18** The Price equation **Rice (2004, Ch 6)** Reading suggestions due
18th **19** Inclusive fitness and Hamilton's rule **Hamilton (1964); Akçay and Van Cleve (2016); Lehmann et al. (2016)**	20th **20** Multilevel selection **Rice (2004, Ch 10)**

Monday		Wednesday	
25th Adaptive dynamics Guest lecture by Alexandra Brown **McGill and Brown (2007)**	**21**	27th Spatially explicit models Guest lecture by Dr. Bryce Morsky **Durrett and Levin (1994)**	**22**
Apr 1st Paper discussion	**23**	3rd Paper discussion	**24**
8th Paper discussion	**25**	10th Paper discussion First drafts due	**26**
15th Paper discussion	**27**	17th Paper discussion	**28**
22nd Paper discussion	**29**	24th Paper discussion	**30**
29th Paper discussion	**31**	May 1st Paper discussion Final papers due	**32**

References

Akçay, E., and J. Van Cleve. 2016. There is no fitness but fitness, and the lineage is its bearer. Phil. Trans. R. Soc. B 371:20150085.

Bodine, E. N., S. Lenhart, and L. J. Gross. 2014. Mathematics for the Life Sciences. Princeton University Press.

Caswell, H. 2001. Matrix Population Models. Sinauer Associates, Sunderland MA.

Charnov, E. L. 1976. Optimal foraging, the marginal value theorem. Theoretical population biology 9:129–136.

Durrett, R., and S. Levin. 1994. The importance of being discrete (and spatial). Theoretical population biology 46:363–394.

Hamilton, W. D. 1964. The genetical evolution of social behaviour. II. Journal of theoretical biology 7:17–52.

Kot, M. 2001. Elements of mathematical ecology. Cambridge University Press.

Lehmann, L., C. Mullon, E. Akcay, and J. Van Cleve. 2016. Invasion fitness, inclusive fitness, and reproductive numbers in heterogeneous populations. Evolution doi: 10.1111/evo.12980.

Levins, R. 1966. The strategy of model building in population biology. American scientist pages 421–431.

McGill, B. J., and J. S. Brown. 2007. Evolutionary game theory and adaptive dynamics of continuous traits. Annual Review of Ecology, Evolution, and Systematics pages 403–435.

Otto, S. P., and T. Day. 2007. A biologist's guide to mathematical modeling in ecology and evolution. Princeton University Press.

Parker, G. A., and J. Maynard Smith. 1990. Optimality theory in evolutionary biology. Nature 348:27–33.

Rice, S. H. 2004. Evolutionary theory: mathematical and conceptual foundations. Sinauer Associates Sunderland.

Roughgarden, J. 1979. Theory of population genetics and evolutionary ecology: an introduction. Macmillan New York NY United States 1979.

Servedio, M. R., Y. Brandvain, S. Dhole, C. L. Fitzpatrick, E. E. Goldberg, C. A. Stern, J. Van Cleve, and D. J. Yeh. 2014. Not just a theory—the utility of mathematical models in evolutionary biology. PLoS biology 12:e1002017.