# Anthropological Sciences 155: Human Population Biology

Instructor: James Holland Jones

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## 1 Course Description

This course will explore problems in demography and theoretical population biology applied to human systems. The emphasis will be on establishing relationships between models in theoretical population biology and empirical demographic methodology. Topics include philosophy of models and model building, population dynamics, stable population theory, species interactions in human ecology, models of infectious diseases and their control.

You will learn how to interpret standard demographic terms such as "life expectancy at birth," "stable population," "intrinsic rate of increase," and "generation" as well as understand the theory behind them. You will also learn how to interpret terms from theoretical population biology such as "carrying capacity," "reproductive value," "exponential growth," "epidemic," and "herd immunity." This course is simultaneously theoretical and methodological. It is about acquiring and applying tools and understanding the theory that motivates them. Because of this, we have little time to discuss substantive issues in detail. However, it is helpful to always remember what types of questions motivate the theoretical and methodological development that is the subject matter of this course.

- How long until the world population doubles in size?
- What is the probability that a child age 10 will have a living mother? How will this change under a generalized HIV/AIDS epidemic?
- How will the age structure of a population change if mortality is improved?
- What has the greater effect on the population growth rate: a decrease in childhood infectious disease or a decrease in cancer mortality of adults?
- How can we measure mortality in a country without vital registration?
- Can we eliminate an infectious disease by only vaccinating a fraction of the population? What is that fraction?
- Which is a more effective strategy for malaria eradication: vaccination or vector control?
- What is the optimal age-profile for vaccination for an infectious disease?

## 2 Expectations

This course uses mathematics to describe processes relevant to the study of human biology and social behavior. It is not, however, a course in mathematics. You will not be expected to do mathematical proofs or derive complex formulae. You will be expected to understand the demographic, social, and biological theory contained in the mathematics as described in class lectures and in the readings.

A large segment of this course involves developing computational skills to aid your analysis of population phenomena. We will be using the free computer package R, a variant of the S statistical programming language (which underlies the commercial software S-Plus).

R is, at first glance, not terribly user-friendly, in part because of its command-line interface. However, you will soon discover that this interface is one of the great strengths of R as a teaching tool. The text-based command-line interface will allow you to re-create the examples I show in class and in the course notes *exactly* and then tinker as the need arises.

## 3 Grading

The breakdown of grading for this class will be as follows:

**50%** Weekly problem sets designed to reinforce lectures and readings and build confidence in your analytic skills. Problem sets will be due on Monday at the beginning of class each week. Late work will lose a third of a grade per day past due.

**15%** Take-Home Midterm Exam. This exam must reflect your own work.

**25%** Final Exam. Before the exam you will receive a list of possible questions from which the actual questions on the exam will be taken. You are encouraged to work in teams to prepare for the exam, but the exam itself must reflect your own work.

**10%** Class Participation. This is a small class. If you have questions, ask them in class. Show me that you are actually working to understand the material.

## 4 Prerequisites

I expect that you have taken one year of calculus. Good preparation for this class is HUMBIO 137.

## 5 Readings

There are two required texts for this class.

**Hastings (1997)** This is a brief and accessible textbook on theoretical population biology and will serve as the primary methodological source for the class.

**Preston et al. (2001)** This is the current textbook on formal demographic methods.

There will be weekly readings from the primary and historical literature in demography and population biology. Many of these readings are available in electronic format, and I have provided links to these wherever possible.

The course website can be found at the following address:

http://anthsci155.stanford.edu

In addition to the textbooks and primary readings, I have prepared fairly extensive course notes. These notes include discussion of theory, derivation of key results, pointers to the research literature, and examples of computations carried out in R.

## 6 Course Outline (Subject to Change)

Week 1 Preliminaries and Philosophy

1. Population problems in the human ecology and the anthropological sciences
2. Why make models?
3. Model trade-offs
4. Continuous time vs. Discrete time
5. Introduction to R

**Readings**: Levins (1966), Hilborn and Mangel (1997, chap. 1), Keyfitz (1975), Kareiva (1989)

**Assignment**: Introduction to R

Week 2 Population Biology I: Population Growth in Unstructured Populations and Density-Independent Growth

1. Continuous- vs. discrete-time formulations
2. Exponential and geometric growth
3. Multiple sub-populations
4. Equilibria and stability

**Readings**: course notes, Hastings (1997, chap 1)

**Assignment**: Exponential Population Growth and Doubling Time

Week 3 Population Biology II: Population Growth in Unstructured Populations and Density-Dependent Growth

1. Continuous- vs. discrete-time formulations
2. Equilibria and stability

**Readings**: course notes, Hastings (1997), von Foerster et al. (1960), Cohen (1995)

**Assignment**: Fun with Density-Dependence

Week 4 Population Biology III: Population Growth in Structured Populations

1. Leslie matrices
2. Reproductive Value
3. Matrix perturbations

**Readings**: course notes, Hastings (1997), Fisher (1958, pp. 25-30), Caswell (1997)

**Assignment**: Population Projection and Sensitivity Analysis

Week 5 Formal Demography I

1. Life table analysis
2. Fertility

**Readings**: Preston et al. (2001, ch. 2-3), Lexis (1875)

**Assignment**: Life Table Problems

Week 6 Formal Demography II: Stable Population Theory

1. The renewal equation of Lotka
2. Demographic relations under stability

**Readings**: course notes, Lotka (1907), Sharpe and Lotka (1911), Lotka (1922), Coale (1957)

**Assignment**: Problems in Stable Population Theory

Week 7 Formal Demography III: Applications of Stable Population Theory

1. Estimating growth from a single census
2. Model life tables
3. Population momentum*
4. Counting kin

**Readings**: Goodman et al. (1974), Howell (1979, ch.2 & 4), Brass and Coale (1968, pp. 127-132)

**Assignment**: Applying Stable Theory: Model Life Tables

Week 8 Infectious Diseases I: The SIR Model and Variants

1. SI, SIR, SIS models
2. Eradication and control

3. Childhood diseases, TB, influenza

**Readings**: course notes, Getz and Pickering (1983), Anderson (1991), Blower et al. (2000), Mclean and Blower (1993)

**Assignment**: Epidemic Models: Modeling Control Measures

Week 9 Infectious Diseases II: Vector-Borne and Parasitic Diseases

1. Indirect transmission
2. Malaria, Chagas disease, onchocerciasis

**Readings**: Koella and Antia (2003), McKenzie (2000), Cohen and Gürtler (2001)

**Assignment**: Malaria Eradication: Chemotherapy or Vector Control?

Week 10 Infectious Diseases III: Structured Models of Epidemics

1. Age structure
2. Structured mixing
3. Childhood disease redux, HIV/AIDS, STDs

**Readings**: Morris (1991), Morris (1995), Sattenspiel (1990), Heesterbeek (2002)

**Assignment**: Age-Schedules of Vaccination

## References


Anderson, R. M. (1991). The Kermack-Mckendrick epidemic threshold theorem - discussion. *Bulletin of Mathematical Biology 53*(1-2), 3–32.

Blower, S. M., H. B. Gershengorn, and R. M. Grant (2000). A tale of two futures: HIV and antiretroviral therapy in San Francisco. *Science 287*(5453), 650–654.

Brass, W. and A. Coale (1968). Methods of analysis and estimation. In *et al.*. Brass, W (Ed.), *The demography of tropical Africa*. Princeton: Princeton University Press. Reprinted in D. Smith and N. Keyfitz (1977) *Mathematical Demography: Selected Papers*. pp. 307-314. Berlin: Springer-Verlag.

Caswell, H. (1997). Matrix methods for population analysis. In S. Tuljapurkar and H. Caswell (Eds.), *Structured-population models in marine, terrestrial, and freshwater systems*, pp. 19–58. New York: Chapman & Hall.

Coale, A. (1957). How the age distribution of a human population is determined. *Cold Spring Harbor Symposia on Quantitative Biology 22*, 83–88. Reprinted in D. Smith and N. Keyfitz (1977) *Mathematical Demography: Selected Papers*. pp. 167-172. Berlin: Springer-Verlag.

Cohen, J. E. (1995). Population Growth and Earth's Human Carrying Capacity. *Science 269*(5222), 341–346.

Cohen, J. E. and R. E. Gürtler (2001). Modeling household transmission of American trypanosomiasis. *Science 293*(5530), 694 –698. Make sure to read the Supplemental Material.

Fisher, R. (1958). *The genetical theory of natural selection*. New York: Dover. Reprinted in D. Smith and N. Keyfitz (1977) *Mathematical Demography: Selected Papers*. pp.161-166 Berlin: Springer-Verlag.

Getz, W. and J. Pickering (1983). Epidemic models: Thresholds and population regulation. *American Naturalist 121*(6), 892–898.

Goodman, L. A., N. Keyfitz, and T. W. Pullum (1974). Family formation and the frequency of various kinship relationships. *Theoretical Population Biology 5*, 1–27.

Hastings, A. (1997). *Population biology: models and concepts*. New York: Springer.

Heesterbeek, J. A. P. (2002). A brief history of $R_0$ and a recipe for its calculation. *Acta Biotheoretica 50*(3), 189–204.

Hilborn, R. and M. Mangel (1997). *The ecological detective: Confronting models with data*, Volume 28. Princeton: Princeton University Press.

Howell, N. (1979). *The demography of the Dobe !Kung*. New York: Academic Press.

Kareiva, P. (1989). Renewing the dialogue between theory and experiments in population ecology. In J. Roughgarden, R. May, and S. Levin (Eds.), *Perspectives in ecological theory*. Princeton: Princeton University Press.

Keyfitz, N. (1975). How Do We Know the Facts of Demography? *Population and Development Review 1*, 267–288.

Koella, J. C. and R. Antia (2003). Epidemiological models for the spread of anti-malarial resistance. *Malaria Journal 2*, 3.

Levins, R. (1966). Strategy of model buildung in poulation biology. *American Scientist 54*, 421–431.

Lexis, W. (1875). *Einleitung in die Theorie der Bevölkerungs-Statistik*. Strasbourg: Trubner. Translated by N. Keyfitz and Reprinted in D. Smith and N. Keyfitz (1977) *Mathematical Demography: Selected Papers*. pp. 39-41. Berlin: Springer-Verlag.

Lotka, A. (1907). Relation between birth rates and death rates. *Science 26*, 21–22. Reprinted in D. Smith and N. Keyfitz (1977) *Mathematical Demography: Selected Papers*. pp. 93-96. Berlin: Springer-Verlag.

Lotka, A. (1922). The stability of the normal age distribution. *Proceedings of the National Academy of Sciences 8*, 339–345. Reprinted in D. Smith and N. Keyfitz (1977) *Mathematical Demography: Selected Papers*. pp. 101-108. Berlin: Springer-Verlag.

McKenzie, F. E. (2000). Why model malaria? *Parasitology Today 16*(12), 511 – 516.

Mclean, A. R. and S. M. Blower (1993). Imperfect vaccines and herd-immunity to HIV. *Proceedings of the Royal Society of London series B-Biological Sciences 253*(1336), 9 – 13.

Morris, M. (1991). A log-linear modeling framework for selective mixing. *Mathematical Biosciences 107*(2), 349–377.

Morris, M. (1995). Data driven network models for the spread of disease. In D. Mollison (Ed.), *Epidemic Models: their structure and relation to data.*, pp. 302–322. Cambridge: Cambridge University Press.

Preston, S., P. Heuveline, and M. Guillot (2001). *Demography: Measuring and modeling population processes.* Oxford: Blackwell.

Sattenspiel, L. (1990). Modeling the spread of infectious-disease in human-populations. *Yearbook of Physical Anthropology 33*, 245 – 276.

Sharpe, F. and A. Lotka (1911). A problem in age-distribution. *Philosophical Magazine 21*, 435–438. Reprinted in D. Smith and N. Keyfitz (1977) *Mathematical Demography: Selected Papers*. pp. 97-100. Berlin: Springer-Verlag.

von Foerster, H., P. M. Mora, and L. W. Amiot (1960). Doomsday: Friday, 13 November, A.D. 2026. *Science 132*, 1291–1295.