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 greatest effect on the population growth rate: a change in childhood survivorship, adult survivorship, or fertility?
- 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:

40% 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.

20% Midterm exam.

40% 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.

4 Prerequisites

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

5 Readings

There will be one required text for this class as well as two recommended texts. These are:

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

Recommended: (Cohen 1995a). This semi-popular work will help you to make the link between models, the theory they encapsulate, and applied population problems in the world.
Recommended: (Preston et al. 2001). This is a textbook on formal demographic methods. We will be reading a couple chapters. I *highly* recommend this book for anyone planning to do future work on population issues.

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

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 Tentative Course Outline

**Week 1** Preliminaries and Philosophy

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


**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), Cohen (1995a)

**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

**Assignment:** Fun with Density-Dependence

Week 4  Population Biology III: Population Growth in Structured Populations

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


**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


Assignment: Epidemic Models: Modeling Control Measures

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

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


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


Assignment: Age-Schedules of Vaccination

References


