

50% Lectures, 50% Projects/Discussion

Organization of Lectures:

Section I: Foundations of Population Dynamics

Section II: Empirical Dynamics (aka Nonlinear State Space Reconstruction)

Proposed Outline for Section I: Foundations of Population Dynamics:

1) Organization and Overview

Objectives:

- Provide an understanding of the foundations and origins of population models
- Survey of population dynamical behaviors in nature and the lab.
- Survey of population dynamical behaviors in simple models and field examples.
- Insights into nature gained from simple models.
- Multiple time scales as a source of richness in dynamical behavior.
- Critical review of assumptions underlying classical models
- Real time/out-of-sample prediction as a rigorous measure of scientific merit of models
- Evidence for the classical assumption of a stable balance of nature. Are real systems stable and linearly separable?
- Introducing Empirical Dynamics as a new paradigm with minimal assumptions.

(i) Empirical Examples From Nature and the Lab

- variety of different kinds of population dynamics in nature and the lab.

(ii) Foundations and Origins of Population Models

- historical reasons for interest in population regulation (pestilence).
- intellectual roots

(iii) Quantitative Population Biology and Dynamical Systems Theory

- fundamental problem: finding a sufficient dynamical description
- model complexity: measurement error vs detail (systematic) error

(iv) State Space and the Niche

- full knowledge state space
- fundamental nice, n-dimensional hypervolume (an intellectual cornerstone).
- How to reduce complexity?

(v) Understanding Assumptions Used to Reduce a Full Knowledge State Space to the Single Species Case

- Taylor's formula
- Ockum's Razor

- simplifying assumptions

- (vi) Unrestricted Growth: Geometric versus Exponential Growth

- discrete time vs. continuous time

- (vii) Introduction to Second Order Growth

2) Properties and Behaviours of Higher Order Systems: Part I

- (i) Reducing Dimensionality: Review

- (ii) Expanding r in the Laboratory: Algal Growth in a Chemostat

- (iii) Population Regulation Debate: Biotic versus $\square\square\square\square$ Climate School

- Historical Roots: a central debate with many names.

- biotic / climatic

- density dependent / density dependent

- equilibrium / nonequilibrium

- stability / instability

- biological / physical

- chaos / noise

- (iv) Testing for Density Dependence

- field examples (Tanner 1966)

- lab examples (Gause 1934)

- (v) Property I: Equilibrium N^*

- (vi) Property II: Attractor

- phase portraits

- omega limit set

- (vii) Property III: Stability

- local stability defined

- local linear stability analysis (theory and practice)

- Taylor approximation in the nbhd of an equilibrium point

- Lambda (slope of $F(N)$ with respect to N , at N^*).

- characteristic return time

- (viii) Property IV: Thresholds (Allee Effect)

- 3rd order

- separatrix

- phase portrait

- domains of attraction

-calculation of stability

3) Properties and Behaviours of Higher Order Systems: Part II

- (i) Review of Local Linear Stability Analysis
- (ii) Property V: Multiple Stable States
 - allee and model examples
- (iii) Property VI: Fold Catastrophe
 - fishing example
- (iv) Tychenoff Theorem and Center Manifold Theory for Analysing Systems Having Different Time Scales
 - the importance of characteristic return time
- (v) Fold Catastrophe: Models Meet Data
 - spruce budworm example
 - resource control vs. predator control
 - review of examples from nature (fisheries, corals, lakes, etc)
 - what constitutes sufficient evidence?

4) Properties and Behaviours of Higher Order Systems: Part III

- (i) Property VII: Smoothing and Tracking Environmental Variation
 - field examples (daphnia and algae etc)
- (ii) r and K Selection
 - Size and cycle: time scales and body size
- (iii) Property VIII: Intrinsic Oscillations with Time Lags in Regulatory Mechanisms (Continuous Time)
 - the relationship between characteristic return time and time delay in feedback
 - stable points and stable limit cycles
- (iv) Evidence and Insights:
 - Nicholson's sheep blowfly study
 - nature's 4-year cycle
 - storage product beetles
 - etc.

- (v) Property IX: Intrinsic Oscillations with Discrete-Time Models
 - derivation of discrete time logistic
- (vi) Analysis of The Discrete-Time Logistic
 - return map
 - equilibria
 - stability analysis (discrete time analogue to local linear nbhd method)

5) Properties and Behaviours of Higher Order Systems: Part IV

- (i) Analysis of The Discrete-Time Logistic
 - return map
 - equilibria
 - stability analysis (discrete time analogue to local linear nbhd method)
- (ii) Review of Destabilizing Factors
 - paradox of enrichment
- (iii) Property X: Chaos
 - implications
 - applications
- (iv) Property XI: Stability and Complexity from Models

Proposed Outline for Section II -Empirical Dynamics (aka. Nonlinear state space reconstruction)

- 1) Deducing Dynamics with Empirical Dynamics
 - Taken's Theorem
 - Lagged coordinate embeddings
 - Nonlinear Forecasting
 - Simplex Projection
 - S-maps
 - Measuring and understanding nonlinear state dependence
 - Distinguishing regime shifts from noise
 - larval reef fish example
- 2) Deducing Structure and Understanding Causality
 - distinguishing mirage correlation from causation
 - convergent cross mapping
 - identifying key drivers

- identifying functionally coupled species groups.
- ecosystem based management
- understanding variable interactions