50% Lectures, 50% Projects/Discussion

Organization of Lectures:

Introductory lecture on empirical dynamics to set the stage
Section I: Foundations of Population Dynamics
Section II: Empirical Dynamics (aka Nonlinear State Space Reconstruction)

Class Plan:
Introduce Empirical Dynamics (EDM) as a new paradigm with minimal assumptions.
Introduce foundations of classical population dynamics models

- Acquire literacy in rEDM tools (required for student projects)
- rEDM package on CRAN: https://cran.r-project.org/web/packages/rEDM/index.html
- Student project presentations

Proposed Outline for Section I: Foundations of Population Dynamics:

1) 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.
- The conflict between classical stable dynamics and the actual empirical evidence.
- The implications of constant-linear versus unstable nonlinear systems for understanding nature and doing experiments.

(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 hyper-volume (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 Behaviors 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 Climate School
- Historical Roots: a central debate with many names.
  - -biotic / climatic
  - -density dependent / density dependent
  - -equilibrium / non-equilibrium
  - -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) Reveiw 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 Behaviors 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 beatles
- 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