Lecture 01 – Analysis of Animal Populations: Theory and Scientific Process

Motivation

1. Review the basic theory of animal population dynamics
2. Lay the foundation for the analysis of animal populations
3. Place in context of good scientific process

What is a population?

Theory of population dynamics

1. Population state (size and distribution) is driven by four vital rates:
    a. Births
    b. Deaths
    c. Immigration
    d. Emigration

    The analysis of animal populations concerns estimating the state(s) or the vital rates of a population and the factors that influence them.

Vital rates & fitness

1. Rates – population level contributions of the four basic population processes
2. Fitness – probability of individual contributions to population
3. Subtle differences
4. Estimated in similar ways

Why do we care?

1. Conservation & management
    a. Sustaining small populations
    b. Controlling large populations
    c. Managing harvestable surplus
2. Contribution to science
    a. Understanding life history & ecology
    b. Population theory

    Either should be employ good scientific process!

Population Analysis and Good Science

1. Are we answering the questions we think we're asking?
2. Are we asking the right questions?
3. Are we measuring what we think we're measuring?
4. How do we know?

Scientific method

1. Theory
2. Hypotheses
3. Prediction
4. Observation (data collection)
5. Comparison of predictions to data (analysis)
6. Start over

Causation and Science

1. Causes – explanations for patterns we observe
   i.e., what is "truth?"
2. Science – attempts to use logic to establish cause

Causation

1. Necessary causation – inductive logic
2. Sufficient causation – deductive logic

Causal relationship

1. Science – attempts to use logic to establish cause
2. Hypothetical statement: $A \rightarrow B$
   a. Read: If A then B
   b. Antecendent – premise
   c. Consequent – conclusion

Logic of Causality: $A \rightarrow B$

1. Affirmation of premise A implies affirmation of conclusion B
2. Assymetrical – affirmation of B does not affirm A
3. Example:
   a. If my dog is here (A), then slobber will be on the floor (B) ($A \rightarrow B$)
   b. If there is slobber on the floor (B), then my dog is here (A)? (not $B \rightarrow A$)
4. Causation established scientifically by identifying cause (**C**) and effect (**E**) as either premise (**A**) or conclusion (**B**).

Necessary causation (inductive)

1. Sets effect (E) as premise (A), and cause (C) as conclusion (B), $E \rightarrow C$
2. Observing effect means you can conclude cause was present.
3. If cause is present, effect may or may not be present.
4. Examples:
   a. photosynthesis (E) → light (C)
   b. forest fire (E) → fuel loads (C)
5. Equivalent: $\sim C \rightarrow \sim E$ ("~" = "not")
   Absence of the effect follows from absence of the cause

Sufficient causation (deductive)

1. Sets cause (C) as premise (A), and effect (E) as conclusion (B), $(C \rightarrow E)$
2. Observing cause means you can conclude the effect must be present.
3. If effect is present, cause may or may not be present.
4. Examples:
   a. Heat causes fluid dynamics
   b. Drought causes physiological stress in plants

Logical Rigor

1. Sufficient causation logically stronger than necessary causation:
   a. Necessary: C is one condition (possibly among many) that must be present for E
   b. Sufficient: C alone ensures E
   c. Example:
      1) Heat source = necessary cause of fire
         Fire → Heat Source
      2) Heat + fuel + O_2 = sufficient cause of fire
         Heat + fuel + O_2 → Fire

... and in Science

1. Attain sufficient causation through manipulation
2. Control (~C) and treatment (C)
3. If effect is observed in treatment but not in control, C is sufficient cause of E
4. If no control used, observed effect in treatment at best indicates C is **necessary** cause of E
5. Use of a control in **research = rigor**!

Strength of inference (rigor)

1. Experimental manipulation
    a. Using appropriate controls, replication & randomization
    b. Impact studies (before and after)
2. Observational studies (most studies in ecological literature)
    a. Based on *a priori* hypotheses
    b. Based on *a posteriori* description (just good story telling)

Hypothesis Development

1. *a priori* Hypotheses = {T} + H
    a. Adds to theory
2. With experimentation
    a. Leads to sufficient causation & scientific rigor
3. With observation
    a. Leads to necessary causation
4. *a posteriori* description

Models

1. "All models are wrong; some are useful." (G. Box 1979)
2. Approximations of reality.
3. Mathematical → Conceptual
4. A statistical model is a mathematical expression that help us predict a response (dependent) variable from an hypothesis as a function of explanatory (independent) variables based on a set of assumptions that allow the model not to fit exactly.

Modeling

1. One-to-one correspondence with hypotheses
2. Allows prediction
3. Determines what data is collected
4. Used to identify parameters of interest
5. Used to confront predictions with data
6. Determine strength of evidence

Modeling example 1

1. Observation: Large numbers of dead waterfowl with ingested lead shot in gizzard
2. Theory: Lead is toxic in many vertebrates
3. Hypothesis: Ingested lead shot (C) is causing waterfowl mortality (E)
4. Treatment (C) – mallard fed lead shot
5. Control (~C) – mallard fed seeds
6. Model: $S_{\sim C} = S_C + E$
7. Prediction: $S_{\sim C} > S_C$
8. Observation: $S_{\sim C} > S_C$
9. Causation?
    a. Necessary (E→C)
    b. Sufficient (C→E)

Modeling example 2

1. Theory
    a. Daily survival rates (DSR) of nests increases with nest age because vulnerable nests are found by predators first
    b. DSR also varies each year because of function and numerical responses of predators

Hypothesis	Model
DSR varies by nest age	DSR = f(age)
DSR varies annually and by nest age and the effect of age is similar each year	DSR = f(year + age)
DSR varies annually and by nest age and the effect of age is different each year	DSR = f(year x age)

2. Causation?
    a. Necessary (E→C)
    b. Sufficient (C→E)

Modeling & truth

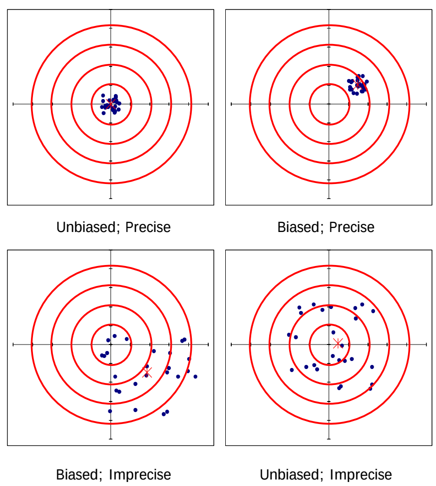
1. Do models represent truth?

2. Models are approximations of reality
3. Searching for the best approximating model
4. How do we do that?
   a. Confront the model with data
   b. Examine the strength of evidence

Parsimony

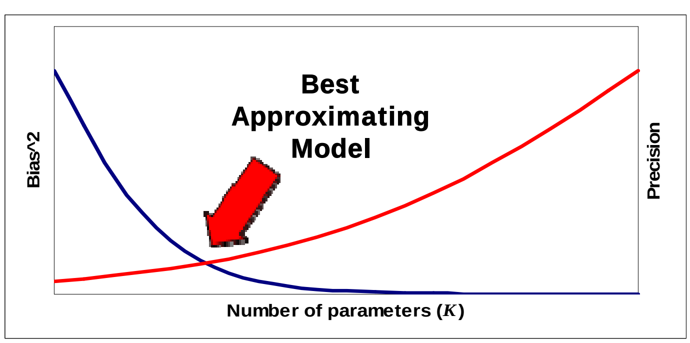
1. Defined - Economy in the use of means to an end.
2. …[using] the smallest number of parameters possible for adequate representation of the data." Box and Jenkins (1970:17)
3. In the context of our analyses, we strive to be economical in the use of parameters to explain the variation in data.

Precision versus bias



Trade-off between precision and bias.

As_*K*, the number of parameters increases, bias decreases (blue line) and variance inccreases (blue line). Thus, over-fitting (too many parameters) results in high precision and low bias, while under-fitting results in low precision and high bias.



Information Theoretic Methods

1. Kullback-Leibler (Kullback and Liebler 1951) “distance," or “information" seeks to quantify the information contained in a model (i.e., distance from “truth”)
2. Information Theoretic Methods use measures of information for data-based model selection.