Statistical Ecology
Stat 555

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EXPERIMENTAL DESIGN

**How can I design an experiment that will be able to detect meaningful changes with a reasonable amount of effort?**

**PROBLEM**: most experiments suffer from poor design and have limited statistical power to detect meaningful changes

Typical problems:

- Poor understanding of problem = poor design
- Non-random sampling
- Lack of proper replication and/or confounding
- Lack statistical power to detect changes (low sample size relative to variability)

A. Design: be able to address the following basic questions (partially after Green, 1979)

1. Be able to concisely state to someone else the question you are asking. Your results will only be as coherent and comprehensible as your initial conception of the problem.

2. Based on your questions develop specific testable hypotheses. List the assumptions for each hypothesis and test these whenever possible.

3. Based on your goals and hypotheses decide on the type of sampling method to be used in the study (see Eberhardt and Thomas, 1991)

4. Conduct a preliminary study if at all possible. Those that skip this step because they do not have enough time usually end up losing time.

5. Use the preliminary study to guide the next steps.

6. Clearly define the statistical population to sample. Define the statistical population precisely on the scale of inference.

7. Clearly define the variable(s) to sample. Be sure they are appropriate, measurable and reasonable. Determine if factors are *fixed* or *random*.

8. Space: decide where to select a sample: consider the costs and benefits of random, systematic, and stratified sampling methods. Consider *blocks* and *nested* factors to minimize know or suspected variation, respectively.

9. Time: decide how often to collect samples: the frequency of sampling will vary in proportion to how fast the system changes. Consider the time scales relevant to your questions and how they should be measured. Replicate sample repeatedly in short time intervals to document temporal patterns. Consider if a repeated measure design is appropriate.

10. Take independent, replicate samples within treatments for each combination of time, location, and any other controlled variable. (remember: lack of independence = pseudoreplication = confounding in space/time)

11. Design experimental controls, if needed: to test whether a condition has an effect, collect samples both where the condition is present and where the condition is absent but where all else is the same. An effect can only be demonstrated by comparison to a control. Also consider *procedural controls*. Controls should have temporal concordance with treatments.

12. If some factors are uncontrolled consider using analysis of covariance.

13. Based on knowledge of the system consider possible experimental designs. Start with a factorial experiment and eliminate known interactions, if possible, to reduce effort. All else being equal the simplest design is always best.

14. Based on the design construct a linear statistical model of the design. This step includes calculating degrees of freedom and sum of squares for each factor (see Underwood, 1997).

15. Calculate appropriate sample size based on power analysis. Consider the consequences of type I and II errors and set $\alpha$ and $\beta$ accordingly. Consider using a weighing procedure (such as Mapstone, 1996).

16. From the design describe the statistical test(s) that will be used to test the hypotheses in step 2.

17. Based on satisfaction with step 14 either proceed or redesign the study from steps 3-14.

B. Execution: Minimize errors within data collection method:

1. Write clearly and legibly; use numbers or scratch marks but not both; review data sheet after recording and make sure it's complete and readable

2. If several people are involved either standardize how the data are taken or control for their effect by design (e.g., protocols).

3. Eliminate systematic measurement error by using the same equipment compared to a standard.

4. If repeatedly sampling same site affix permanent markers to accurately locate study areas (i.e., minimize between survey habitat variability).

5. Minimize temporal/spatial variation: conduct surveys in short period of time and close together spatially

C. Data Management: considerations after the survey

1. If working with multiple data collectors have a data manager. Assign one person to collect and hold data (Nightmare scenario: lose data!!!)

2. Review data sheet after recording and make sure it is complete and readable! (all header information must be filled out!!!).

3. Always make copies of data after field work.

4. Design data sheets to collect data for easy entry into the computer.

5. Use a relational database (such as MS Access) to manage medium- to large-datasets. Use a shared online database if there are multiple users.

6. Verify entered data against raw data.

7. Make back-up copies of computer data files; leave copies in several different locations.