10 simple rules for experimental design in ecology

This article contains proposed guidelines for ensuring proper experimental design in ecology. In a sequential fashion, it is important to begin with stating a hypothesis, followed by clearly defining terms and choosing appropriate samples and parameters. Following the tips and guidelines in order will help guide the researchers thought process when designing an ecological experiment. Consult the listed citations for in-depth explanations when required. The rules may be generalized to other fields of science.

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Neha Saini

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1. **Begin by identifying a hypothesis for the topic you are interested in.** Testable predictions generated will allow you to formulate a hypothesis. The hypothesis is an explanation of how you think a system works based on observation. The hypothesis will be either accepted or rejected based on the data collected.

2. **Define parameters for the experiment by being clear and concise in your wording.** By clearly defining terms, you can focus in on experimental methods and avoid ambiguity. This ensures that the results will be more accurate and there will be less flexibility in the experimental design, again increasing accuracy (Hurlbert, 1984).

3. **Decide if you would like to perform a mensurative or manipulative experiment.** A mensurative experiment involves making measurements at different times or in different areas. A manipulative experiment involves physically altering a treatment group, and thus always has two or more treatments (Hurlbert, 1984).

4. **Choose an appropriate sample size that is fitting for the results you wish to obtain**. Generally, a smaller sample size produces results that are inaccurate for generalization. A smaller sample size will also produce a smaller effect size measure, which is the efficacy of the treatment, and thus should be avoided (Ionnidis, 2005).

5. **Introduce a control group.** In biology, systems tend to exhibit temporal change, which could be an influencing third variable. In order to isolate any changes to the experimental treatment alone, a control is necessary.

6. **Randomize assignment.** By randomizing sample units to different treatment groups, experimenter bias is avoided. Randomization is a critical facet of the experimental design as it intersperses the samples being tested (Hurlbert, 1984).

7. **Replicate!** The number of replicates necessary will vary with design, however it ensures precision in experiments (Oksanen, 2001).

8. **Ensure samples are dispersed in space or time to avoid pseudoreplication.** This ensures replicates are statistically independent. Often, experimenters will make inferences based on the data collected and quantify samples from the same unit as independent, however in reality the samples come from the same unit, thus it is not a genuine replication (Oksanen, 2001).

9. **Use linear regression based analysis first, before introducing analysis of variance** (ANOVA). Linear regression is more powerful to analyze obtained data, and indicates how dependent variables change with the independent variable. (Cottingham, 2005).

10. **Refrain from deducing results based on P value alone.** The p value is indicative of confidence interval in statistics, however it fails to indicate how a system actually changes. Effect size measures are more meaningful in ecology, and thus should be given more weight in findngs (Stern and Smith, 2001).

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