Field Biology Techniques - Biology 378

Biological Field Techniques – an overview

Biologists – particularly ecologists and field botanists and zoologists – need to measure and understand both the physical world and the organisms that live in it. To do this, there are specific tools and techniques that are applied, just as we have instruments and techniques that are used in the laboratory. The purpose of this introduction is to give an overview of the issues, the types of measurements we need to make, and the techniques used.

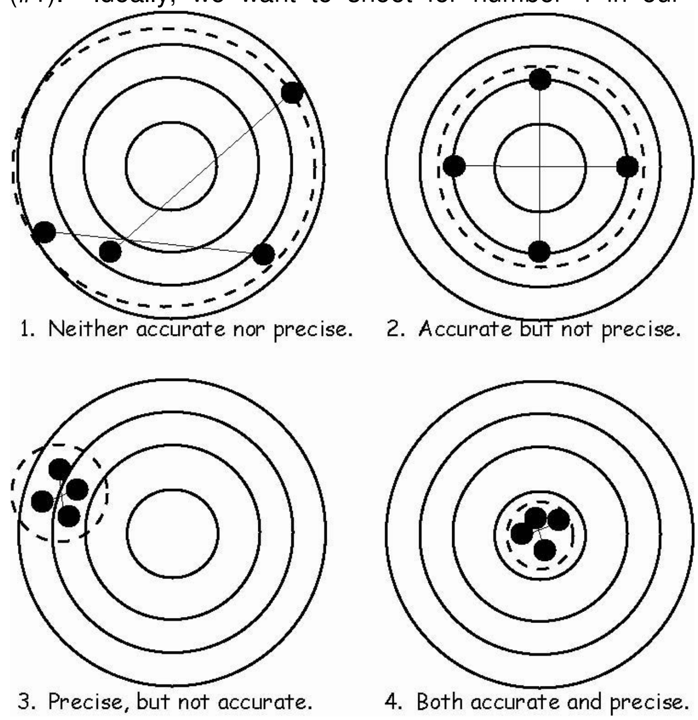
1. **The world vs. a population (sample):** Ideally, we'd like to know everything about everything. The sum total of possible measurements might be described as the **world**. We can't measure the world. We can't physically do it, and we if we could we couldn't store and process all of the data. Even if we are only considering a small portion of the world – say a forest – we can't measure everything. This leads us to the concept of a **sample** (when talking about organisms we often use the term **population** or **subpopulation** instead of sample). Ideally, a sample is an unbiased **subsample** of the world, and its characteristics are very similar to those of the real world, so we can make accurate assumptions about what the world would be like if we could measure everything. *Example*: We want to know how tall trees are in a forest. We can't measure them all, so we measure a sampling of them. Hopefully, we don't bias our sample by choosing our sample in such a way that we get more of the tall trees, or more of the short trees, or any other distortion of the trees out there.

2. **The role of statistics:** As soon as we take samples, we have to relate them to the real world through the use of **mathematical models**, or **statistics**. Statistics give us useful measurements and allow us to make comparisons. Example: How tall are those trees? One is 100 meters, another is 50 meters, another is 75 meters. We can come up with a single measurement, the **mean** (average) to describe the height of the trees in our sample (75 meters in this case). Ideally, this mean is the same as the overall mean of all the trees in the world (and it will be close, if we've done our sampling well). We can also use statistics to determine if such measurements as the mean differ between two parts of the world, answering such questions as "are the trees in forest A the same height as forest B?"

3. **Sampling designs:** To get an **unbiased** sample, one in which any measurements we take can be reliably used to predict what the real world is like, we need to have methods that allow us to select places (or organisms) to measure in such a way that every possible sample we could take has a equal chance of actually being sampled. Usually, this requires using **random** sampling techniques, although in some cases highly **structured** sampling can work as well, and many techniques are combinations of structure and random elements. For instance, if we wanted to measure how much birds weigh, we could catch them at bird feeders, but that would introduce a **bias** – birds near feeders might well be expected to weigh more than birds which do not frequent feeders. Plants are easier to sample than highly mobile animals like birds, but if we sample only along trails, for instance, we might also bias our samples. To offset this, we might use a **transect** technique whereby we sample along a straight line drawn through the forest at a random angle. Also, instead of sampling every tree, we might sample at random **intervals** along the line, thus allowing us to cover more area and avoid bias that would come from confining all of our samples to a small locality. In other situations, we might use a **plot** technique, where we set up plots at random locations and measure every organism of interest within that plot.

4. **The balancing act:** We always want to take larger samples; all things being equal a larger sample will be closer to the real world than a smaller one (at least large samples will be closer to the real world more often than small samples will be). On the other hand, taking samples is expensive in terms of actual cost and, more importantly in most cases, time. We have to strike a balance between accuracy and cost. If sampling is destructive; ecological considerations may also play an important role.

5. **Accuracy vs. precision:** These terms require definition; knowing the distinction is one of the marks of someone who understands science. **Accuracy** refers to how close the central tendency (such as the mean) or other measurement is to the comparable "real world" measurement. **Precision** refers to how close subsequent readings are to each other, that is, how repeatable the measurements are. The traditional way of visualizing this is the so-called "target analogy". Imagine you are shooting at a target. The closer you are to the "bull's eye" at the center the more accurate you are. The closer the bullet holes are to each other the more precise they are. Ideally you want both. Look at the illustration below: The dashed circles encircling all the bullet holes (black dots) represent the precision; the smaller the dashed circle, the more precise the measurements. Accuracy is determined by where the center of the points is found; this can be approximated by drawing lines between opposite points. As you can see from the figure, you can be both accurate and precise (#4, the ideal); precise but not accurate (#3), accurate but not precise (#2), and neither accurate nor precise (#1). Ideally, we want to shoot for number 4 in our measurements, but with good statistical procedures we can often live with number 2 or number 3. Precision is controlled by two factors – real world **variability** (often the subject of our study) and/or **error** in measurement. We need to reduce the latter as much as possible; doing so will allow us to draw better conclusions with fewer samples. Error in measurement is in turn controlled by two factors, the precision of the instrument we are using and the skill (or care) of the operator. Statistically, error measurements (standard error, variation, confidence intervals, etc.) tell us about that aspect of precision, once error is accounted for whatever variation is left is "real". In terms of accuracy, in physics and chemistry we often have known **standards** (such as the boiling point of water, or the speed of light) to tell us if we are accurate; in biology and ecology we often do not know what the "real world" values are so we have to infer accuracy based on multiple studies. In general, more samples lead to grater accuracy, although precision may suffer.



6. **Experimental design:** The real trick, then, is to figure out how, when and where to measure, and to do this in advance so that we can take our "real" measurements as smoothly as possible. This is **experimental design**. Often it involves doing a **preliminary survey** to determine how precise and accurate our measurements are. We then need to compare this to how accurate and precise we need our measurements to be in order to reach our conclusions with reasonable certainty, or in order to make a decision. ***THIS IS THE WAY REAL SCIENCE IS DONE*** – in an undergraduate setting, because of time constraints; we often omit the preliminary study, even in things like capstone projects. Too often, we just take the measurements; with some nod to the need for replication (let's do this experiment with 10 mice in the control and 10 in the experimental group…). In the real world, a study is done to determine how many replications are needed to be able to conclude, with 95% (or 90%, or 80% or whatever) **confidence** that there is a difference between the mice that got antibiotics and the ones that didn't. It might be that the effect is so strong that the conclusion could be reached with only 5 mice in each group – or the effect might be so subtle (or the precision so low) that thousands of mice might be needed. In this class, we will use our results both to draw conclusions and to estimate the sampling regime we would need for "real" studies.

7. **Equipment and Instruments:** To actually take measurements of obtain specimens to measure, we need **equipment**. Sometimes these are **instruments** like a GPS receiver or a thermometer; instruments take **measurements** of the real world. The accuracy and precision of an instrument are functions of its design and the skill of the operator using it. Often, accuracy and precision in taking measurements are sacrificed for other attributes such as convenience, portability, and, most importantly, cost. Note that a convenient instrument which is not particularly precise or accurate may still end up taking better measurements than a "better" instrument which is more precise and accurate but hard to use, and thus vulnerable to user error. Field instruments in general are often less accurate or precise than their lab-based counterparts, so good user technique is important. Other equipment is used to actually obtain samples (or even just to get to the study site). Proper use of this equipment is needed if you are to obtain unbiased samples, particularly of animals. If you can only catch the slowest animals, your measurements will hardly be unbiased. Likewise, if you can't SCUBA dive you will have a harder time making measurements on a coral reef. **Safety** – for yourself, your colleagues, and the organisms you are collecting – is a key criterion as well.

8. **Qualitative/Quantitative:** Most of this discussion has focused on **quantitative** measurements; these measurements are taken and ultimately recorded in a **numerical format**: 35 degrees C, 15 grams, 2 meters, 14 walleye per hectare, etc. Often field studies are concerned with **qualitative** data; these data do not have numbers associated with them. Flora and fauna studies, for instance, are mostly concerned with determining which species are present in a given area, not necessarily how many of each are present. Often such studies are easier to conduct, but sometimes they still may require the use of specialized equipment.

9. **Identification**: Field studies done with organisms often require that the organisms be identified if any meaningful conclusions are to be drawn. Lab experimenters often (but not always) have this part easy, since they may be working with an organism ordered by name from a catalog, and presumably supplied by people who know a mouse from a guinea pig. In the field, there may be dozens of organisms which all look very similar, and one of the first tasks is learning to identify them so that any measurements can be taken from (or recorded for) the right species. Often this requires the use of **taxonomic keys**, developed by specialists in the various groups of organisms. These keys range from simple **picture keys** to more complicated **binomial keys**, where identification is determined by answering a series of **binary** (true- false, yes/no) type questions. Further, even if identification is achieved in the field, it is often necessary (and prudent) to obtain a number of **voucher** specimens, to be preserved in case there are questions about the identifications later (or in case the taxonomy changes, as it frequently does).

10. **Observation**: I left it for last here, but this is the most important and most basic skill. It is the beginning and the heart of the scientific method. Without the ability to see (hear, feel, smell) the world around you, you have no basis on which to formulate questions, design experiments, gather results, etc. You may hear of a dichotomy in science between observational and experimental techniques, but this is largely a false dichotomy. Experimental techniques are a powerful tool to get to answers by making observations under highly controlled conditions, conditions in which there are very few differences, so that any differences in the measurements are thus likely due to the differences in the conditions. Often, these conditions are purposely manipulated (say by applying fertilizer to one plot but not another – the only difference is the fertilizer, and any differences in plant growth are thus presumably due to the effects of the fertilizer). In field work it is often impossible/illegal/unethical to alter the environment for experimental purposes, and in those cases we must rely on natural or coincidental treatments. Thus, it may not be practical to put huge lights over a forest to see the effects of longer day length, but we could study forests at different latitudes (hoping to find forest with similar temperature, precipitation and soil types despite the difference in latitude). It might not be legal to burn part of a forest to study the effects of fire, but we could locate two study sites otherwise similar except that one was affected by a naturally started fire.