

Uncertainty and the relevance of ecology

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Ecology is about figuring out how nature works. A large part of ecology, as of any science, is involved with reducing uncertainty, with deriving ever more secure, robust, rigorous, and certain answers to questions about nature. As ecologists, we do this by following the recipe that has been so successful in other sciences: gathering observations, posing questions, conducting experiments, using models, and developing theory. All of these approaches involve simplifications of reality, stripping away extraneous sources of variation and uncertainty to isolate the variables and relationships of interest. We filter out the background noise so we may hear the symphony of nature, understanding and appreciating the interplays among the instruments and the resulting harmonies.

Yet as we have learned more about nature, more and more of its complexities have emerged, compounding uncertainties. Feedbacks, indirect effects, nonequilibrium dynamics, nonlinearities, and scale dependencies have made ecology a more exciting but less certain science. Attempts at further simplification in the face of this complexity are likely to reduce the symphony to a solo part, shorn of any accompaniment and lacking the beauty that comes with variety.

This is not a new or novel insight, of course. Books and papers have been written about uncertainty and the methods for dealing with it. Marc Mangel addressed some technical and analytical aspects in the most recent issue of the *BES Bulletin*. I'd like instead to consider a different aspect of uncertainty: namely, how much uncertainty can be tolerated when making decisions or formulating policies about the environment – what is “good enough”?

In ecology there are well-established standards for answering this question. The statistical threshold of $P < 0.05$ still holds sway in much ecological work. This level of uncertainty may be adjusted to reduce Type II errors, or Bayesian nonparametric methods may be used to assess probability distributions (as Marc suggested), but the urge to minimize uncertainty remains overpoweringly strong. At its worst, this quest to reduce uncertainty constrains us to ask questions and design studies that can meet such high standards, often at the cost of even greater simplification. Questions about messy systems (so-called “wicked problems”; see <http://www.swemorph.com/wp.html>) lead to answers riddled with uncertainties. Because the answers don't measure up to the criteria for publication in most scientific journals, the questions may go unasked. Yet these are the very questions that are often most critical and relevant to those charged with managing natural resources or conserving nature. The complexities of nature are the reality they must manage.

There is a tension, then, between the desire of scientists to conduct more research (to reduce uncertainty to acceptable levels) and the imperative of managers to take action (“just do it”). Figure 1 illustrates the challenge. Scientists typically strive to achieve a level of certainty that is sufficient to reduce the probability of making errors while satisfying the rigors of peer review. Of course, managers and conservationists would like that same degree of certainty, but they are often unable (or unwilling) to spend the additional time and money to achieve it; they must be satisfied with answers that are less certain but “good enough.” What is “good enough” lies somewhere between attaining a desired level of statistical confidence and having an

unacceptable probability of making mistakes because of incomplete knowledge; in other words, doing something stupid.

The location of this tradeoff threshold on the knowledge-uncertainty curve will depend on the costs of making the wrong decisions. Consider, for example, the decision to declare a threatened species extinct. An incorrect decision may be costly, for the removal of legal protection may expose previously protected habitat to exploitation. If the species is later found to be not quite so extinct after all, the habitat critical to its continuing survival may have disappeared in the interim, sealing its fate. Such a situation demands a low level of uncertainty.

There is, of course, a danger in advocating the use of some ill-defined “good enough” standard as a basis for management or policy decisions. Science has extraordinary standing in such decisions because of its credibility. Scientists have the expectation that they can in fact achieve a high degree of certainty, and the public has the expectation that science will deliver such certainty. Relaxing the standards runs the risk of eroding that hard-won credibility. More importantly, it may open the door to pseudoscience, beliefs, faith, or advocacy masquerading as science, further eroding the credibility of science.

As the pressure on managers and conservationists to address complex environmental problems becomes more immediate and more intense, the need to work with greater levels of uncertainty escalates. How can ecologists ensure their relevance – how can we navigate between the rigor and certainty we demand of science and the need for action, which will often entail living with levels of uncertainty (“good enough”) that make scientists uncomfortable (and that don’t generate scientific publications)? There is no easy answer. We should recognize, however, that clinging tenaciously to rigid standards of certainty may marginalize science in situations where decisions must be made quickly. Instead, rigor must be tempered with realism. We must recognize that reality is really complex, and that the certainty achieved by simplifying it is illusory and potentially misleading. We must change the perception of the public and decision makers (and scientists) about what uncertainty in science really means. And we should find out how to balance what is “good enough” with the costs of being wrong.

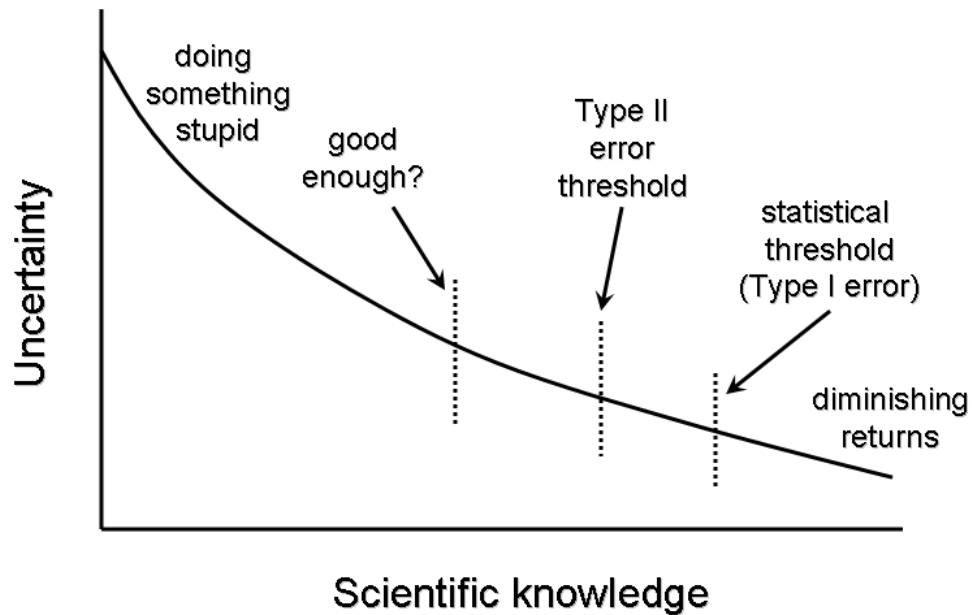


Figure 1. Uncertainty decreases as some function of increasing scientific knowledge. The statistical thresholds that define Type I errors (the likelihood of incorrectly inferring a relationship between variables when none exists) and Type II errors (the likelihood of incorrectly concluding no relationship when in fact one exists) are generally well established. The location of the “good enough” threshold is more nebulous, and shifts toward the right as the costs of making a mistake become greater.