Analysis of the Scientific Basis for Policy and Regulation: Is this "Best Available Science"?

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Defining good science is a bit like defining good art. It takes a trained eye and a trained intellect to distinguish the pretenders from the genuine. In fact, it is much easier to know what is bad science than it is to know what is good science. We should be cautious not to simply equate good science with truth nor bad science with error. Much truly great science has been later proven wrong or, more properly, incomplete. Occasionally, poor scientific work has hit upon an explanation by serendipity or some other fortunate accident. Nor should we equate science only with method, technique or data. Scientists have often employed the "scientific method" or scientific practice impeccably, only to fail by the weight of poor assumptions or inconsistent interpretation. Much science is highly theoretical, awaiting experimental techniques with which to test its predictions. Its value lies in the explanatory power and *elegance* of the theory, characteristics combining diverse observations with simplicity.

Good science begins with a conceptual framework based on cogent observation (these are often quite inseparable. Observations are necessary to the development of theory and our observations are guided--often unconsciously--by our theory), proceeds with well-defined questions and clearly stated assumptions, good experimental design and analysis, and rests on honest evaluation [of the results] that tests our theory and world-view. The conclusions may later be proven wrong by a shift in framework--a change in understanding--or by developments of more rigorous analytical techniques, but the science remains good. Newton's work on the universe remains great science to this day despite the replacement of much of the gravitational theory by Einstein's work on relativity. Good science will stand up to rigorous re-evaluation by independent investigators; the best science will stand up to time.

All such observations and conclusions that by weight of evidence and time are generally accepted in the scientific community contribute to the foundation and application of new knowledge. Time-tested theories may ultimately become scientific "laws"--rules for the workings of nature--that can be relied upon to guide further scientific inquiry and management. Newton's Laws of Motion are such a set of observations and conclusions; Einstein's rule of mass/energy equivalency is another; Darwin's theory of evolution by natural selection is yet another.

In most work that seeks to link science with policy, the questions posed to scientists tend to be less about scientific knowledge per se, and more about the application of scientific information to a particular management issue. Often, the issue is poorly defined or ambiguous and may lack a clear management objective. Thus, the scientific questions or scientific issues cannot be properly framed; particular data or information to address the management issue is sought as the outcome of the scientific process. The task of the scientist becomes one of responding to a specific need; context is overlooked and the information obtained lacks theoretical clarity. Data and information can only be interpreted and evaluated within a proper scientific framework that recognizes the theoretical context of the observations. That is, data from one experiment cannot simply be transferred to the solution of a different--even related--question without examining the assumptions and conditions under which it was collected and under which it will be used. Thus, even when questions have been properly framed, the assumptions and applicability--the *appropriateness*--of the knowledge to the management issue at hand are rarely evaluated thoroughly prior to application.

The common approach is generally to ask of scientists: "what should we do?" and assemble the opinions via a survey or poll, then choose the consensus position or the most heavily favored one. This approach does not reveal knowledge or uncertainty; instead, it reveals the values and opinions of scientists about management or policy issues, areas of skill and knowledge where most scientists hold no particular expertise. Even though the scientists proffering their opinions may be the best and brightest in their fields, this approach is not verifiable and should not be counted on to be "best available science" since we did not frame the question as an explicitly scientific one. From a scientific perspective, such processes are inappropriate as a basis for conservation decisions. The only data integral to the process are the opinions of the participating scientists, data that are not reproducible or testable. The collective opinion of the group becomes a surrogate for science-based understanding even though no scientific information has been brought to bear on the problem or issue. This process might be relatively benign if the expert opinions reflected the state of knowledge--if uncertainty of knowledge was made explicit in conclusions--but it mainly reflects the perspectives of the panelists and individual degrees of understanding.

A more useful approach, and one used in crafting the conservation program for Lynx in the United States, has been called the *Inductive Approach* by Ruggiero et al (2000). In this approach, it is acknowledged that our ecological information is provisional and local; that is, we will never have perfect knowledge or the ability to easily extrapolate information collected under specific circumstances to other circumstances. A strict scientific interpretation limits the scope of inference to the specific study site, the specific population studied, and the timeframe of the study. The accumulation of scientific information gathered in this way leads to more robust generalizations and finally to the formation or modification of scientific paradigms. If we wish to apply this limited knowledge to our circumstances and to the solution of large-scale problems, we must employ subjective, judgmental methods. This is the most difficult (but most important) part of the scientific process--the interpretation of our findings within the context of "what is known" or what is predicted. The critical component of this approach is to limit interpretations to scientifically defensible inferences based on the empirical evidence and acceptable theory as judged by peer review.

The qualified insights developed in this way are thus separated from even the most qualified insights derived from opinion-based approaches. In taking such an inductive approach, judgement is acknowledged to be an integral part of the scientific process but it must be based on empirical data and theory, and it must be specific, its limitations and assumptions readily apparent. *It is the specificity of the linkage among theory, data and inference that differentiates this approach from opinion-based approaches.* We can employ this inductive approach in the analysis of the scientific foundations of any policy or regulation by examining the inferences used to craft the policy or regulation, evaluating the adherence to the principles discussed above. That said, how should we go about using science in policy or ordinance formulation? There are some logical steps to assure the integrity of scientific inclusion and the use of the best and most appropriate scientific methods and information in this endeavor.

Steps to Determine the "Best Available Science" for Policy Development.

1. The problem or issue to which scientific information and analysis will be applied must be stated clearly;
2. Assumptions that constrain the problem must be stated thoroughly and clearly;
3. Questions of value must be kept separate from scientific questions;
4. Identify the scientific aspects of the problem or issue; be careful to keep other aspects of the problem--legal, social, institutional, political--separate.
5. Develop the scientific questions required to address the problem. These should be stated simply and clearly.
6. Identify the *appropriate* scientific framework (body of theory) to address the problem or issue. List the assumptions of the framework;
7. Using the assumptions of the framework as a guide, gather and review the scientific literature appropriate to the questions. This may include literature that is largely theoretical and literature that is largely empirical. Both should be reviewed according to the assumptions of the overall framework and the applicability to the question(s);
8. Interview appropriate scientific experts to gather the most recent theoretical and empirical perspectives on the scientific information (do not ask questions about appropriate policy, ask only "what is known or what do we understand? How confident are we in that understanding?");
9. Evaluate the gathered literature for clarity (and agreement) of assumptions and scientific logic, appropriateness of methods, and robustness of analysis;
10. The subset of literature selected from the winnowing in steps 7, 8 and 9 is the appropriate and best available science for use in addressing the problem or issue.

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