Regulatory Science: Mathematical vs. Statistical Models (Newsletter)*

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The term, regulatory science, is not frequently associated with environmental regulations, yet it should be. Understanding the science that should support regulation under the Clean Water Act, Endangered Species Act, National Environmental Policy Act, Superfund, and solid waste disposal sites, and related statutes leads to consistency and predictability for the regulated public and reduced risk of appeals and lawsuits by regulatory agencies.

One component of regulatory science is how natural ecosystems are modeled to characterize and classify them and to forecast future states under conditions of uncertainty. With climate change apparently accelerating, long term drought in the west, and societal desire for sustainability there is enough uncertainty to cause regulatory staff to rely on what has been done before rather than to seek more appropriate methods.

When environmental statutes in the US were created or updated in the early 1960s-1970s the most common tools for analyzing complex systems such as natural ecosystems was the mathematical model.

Mathematical models are equations that represent how a system changes from one state to the next (differential equations) and/or how one variable depends on the value or state of other variables (state equations) These models can also be either numerical or analytical. Often, these complex models require very large input data sets which are costly or not possible to acquire; it is common to estimate or assume values for rates and constants. Mathematical models require the data be fit to the established model.

Now abundant computing power is widely available and statistical models appropriate to the analysis of environmental data are available at no cost so there is no reason not to apply them to support environmental decisions.

Statistical models quantify the characteristics of environmental data, forecast future behavior of a natural ecosystem based on past behavior, and explain cause-and-effect relationships of variables for which operators and regulators want objective insights to help them make correct decisions.

Three reasons why numerical models should not be used to set environmental policy or regulation are:

1) The equations define ecosystem dynamics and the data must be fit to the fixed model. Statistical models are selected to fit the existing data because the data define ecosystem dynamics and the models objectively quantify those dynamics.

2) Mathematical models require several dozen input variables, for many of which the modeler needs to make assumptions or estimates that are open to challenge in the values used. The statistical model appropriate for both the available data and the question to be answered avoid assumptions or estimates. When missing values need to be filled by imputation there are statistical models to do this objectively.

3) Mathematical models do not incorporate the multiple scales of variability (daily, seasonal, annual) commonly reflected in environmental data. Statistical models focus on the variability and can distinguish natural from anthropogenic changes.

A white paper providing more specific details is available from <www[dot] appl-ecosys[dot]com/publications/regulatory-science-models.pdf>.

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