SCIENCE AND POLICY IN MARINE RESOURCE MANAGEMENT

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ABSTRACT

This note discuses the problem of handling uncertainty in the management of marine resources. In one approach, "science first," scientific questions of fact are addressed first. Once it is concluded that there is a high probability that there is a problem, the analysis preceeds to value questions, where the costs and benefits of possible remedies are weighed. In the alternative "policy first" approach, value questions are addressed at the beginning. The note suggests that both approaches are needed and can be fitted together using a framework of statistical decision theory.

We know little about the effects of toxic chemicals, and little about the importance for toxics of wastewater and sludge disposal in coastal waters relative to other transport mechanisms such as air pollution and groundwater contamination. There are large gaps in our knowledge of the more traditional materials as well -- the natural organics, nutrients, and metals. We can measure changes in worm populations where sludge is discharged, but we know very little of the long term implications of such disturbances.

The nature of uncertainty varies from one management problem to another, from toxics to pathogens to other materials. For some problems, such as toxics, uncertainty is very great and for other problems the appropriate alternatives are more clearcut, because in spite of the remaining uncertainties the alternatives are few and simple, and the weight of evidence leans strongly to one side.

The purpose of this note is to discuss how uncertainty can be taken into account in the formation of policy and decision. The starting point is the realization that because of existing uncertainty, the policy maker is condemned to make decisions under uncertainty. A decision to postpone some action until more is learned is a decision under uncertainty, just as much as is a decision to take a precautionary action in the meantime. A decision to promote further research, and what type of research, is still a decision under uncertainty.

Yet decisions are made "in the meantime." We have built ocean outfalls and treatment plants, and we have existing policies concerning the level of treatment, pretreatment, disposal and source control. This note discusses a framework for such policies.

The natural place to begin a policy analysis is with questions of resource commitment. These are the practical questions which legislatures and agencies deal with. But besides the fact that questions of resource commitment are the bottom line questions for government bodies, there is an other reason for starting here.

Starting with questions of resource commitment helps structure scientific information and research for decision purposes. By itself, scientific inquiry is an open-ended process, with investigation of each interesting question leading to several more interesting questions. To structure information for decision purposes, it is useful to start with a list of policy questions which have to be decided at the current time, one way or another, by default if not be active choice. Such questions might include the following (list A):

A1. How much regional variation should there be in the treatment of wastewater and sludge?

A2. How advanced should be the treatment?

A3. What should be the balance between ocean disposal and disposal into other media?

A4. What should be the balance between treatment at the sewage plant and pre-treatment by industrial firms before disposal into the municipal sewage system?

A5. How much source control should there be?

A6. What research and monitoring should be sponsored by government agencies?

While these and similar questions help organize analysis, it is not possible to answer them directly. They depend in large measure on judgments as to the seriousness of the effects of wastewater and sludge disposal. The main questions of effects can be briefly summarized in list B:

B1. How bad is the toxics problem? How severe is the problem of metals?

B2. How bad is the problem with pathogens and communicable diseases?

B3. How much damage is there to recreational use of coastal water?

B4. How severe is the stress to marine polulations?

These questions in turn depend on interpreting the existing scientific information.

The decision maker (or policy analyst) and the scientist tend to work in opposite directions. To organize and focus his inquiry, the decision maker begins with the practical, bottom line questions of decision (list A) and works back to the questions of effects (list B) and what is known about marine transport and chemical and biological systems. The scientist tends to work forward, beginning with the physical inputs to coastal waters, to model the causal flows as they move forward in time. As another difference, to put it crudely, scientists are more interested in truth while policy makers are more interested in cost. It may not matter very much to a policy maker whether a particular species is flourishing, he is more interested in what the flourishing, or non-flourishing, means for treatment requirments. For a scientist it may matter intrinsically.

When scientists and policy makers do not recognize these differences in direction and style, they talk past each other. In my view, for managing marine problems, neither approach by itself is the right one. Both are needed, and both need to be done at the same time. The trick is to structure the two approaches so that each contributes to the other.

The way they fit together is sketched in Figure 1. The science-first approach begins in the upper left corner and works down toward the lower right corner. Actual systems (the top row) cannot be understood directly, but scientists try to make their models correspond to the actual systems as closely as possible -- knowledge for its own sake. Much attention is devoted to tightening the correspondence (a) and developing detailed submodels.

The policy-first approach begins in the lower right corner of Figure 1 and works back toward the phenomena of the upper left. Policy analysis, especially in the form of cost-benefit analysis focused of the evaluation of effects and costs of control (b).

Given the complexity of marine systems and the enormous uncertainty involved, it is fair to ask what might be gained from a policy approach that attempts to work back from potential decisions in the lower right corner of Figure 1 toward the phenomena of the upper left. There are three types of benefits.

First, in a few cases the analysis may be clearcut, with effects and control possibilities well enough understood so that the expected net benefits of various decision alternatives can be estimated quantitatively, and a single course of action selected as offering the highest net benefits.

Second, in many cases the uncertainties are sufficiently pervasive so that explicit calculation of expected net benefits from alternative possible decisions is not very helpful. Nonetheless, "islands of relative certainty" rise above the sea of uncertainty. These islands are not built upon underwater mountains of evidence, like normal islands, but on broad understanding of what appear to be the largest and most important effects, in their qualitative evaluation of costs and benefits. In such cases the existing evidence is not conclusive in a scientific sense, but accumulates in favor of the relative certainty, and suggests that further resolution of uncertainty will strengthen the evidence. For example, concern with toxic chemical discharge into ocean water existed a decade ago (Brooks [1971]). Research in the intervening period has strengehened our concern, and it appears likely that future research will further strengthen it.

Third, and perhaps most important, the approach which starts with policy first, even when not yielding specific decicions, may offer some guidance as to the process of policy formation.

To an audience of scientists the importance of the science-first approach needs no lengthy discussion. I will merely note that the bottom line questions that the policy maker starts with typically come from scientists' informal identifications of the important questions. And of course the information needed to address list B comes from scientists, most of whom are following a science-first approach.

We need a flexible framework which is broad enough to encompass both approaches and tie them together. In my view, statistical decision theory provides at least part of that framework. A narrow version of cost-benefit analysis accepts the predicted effects (it tends to use point estimates) and concentrates on the problem of evaluation. Applied a little more broadly, statistical decision theory focuses more on the interpretation of uncertainty in the scientists' judgments. Applied still more broadly, statistical decision theory attempts to minimize the expected costs over the decision process taken as a whole.

At each period of the decision process there are two types of decisions that need to be made. The first is a decision, on the basis of the current state of information, concerning the appropriate interim level of action. To address the first question is to ask "what do we do in the meantime, before all the important uncertainties are resolved?" Since the current state of information is often fragmentary, the appropriate acton may be a hedging strategy, or an interim precautionary action. It is important to realize that the <u>meantime</u> can be a long time, for problems of marine management where many important uncertainties are unlikely to be resolved in the near future. The second is a decision, also on the basis of the current state of information, as to what information to gather for the next period of the decision process. This is the question of research priority.

At the next period the two same two questions are addressed again, but from the perspective of a new state of information and a new situation. The state of information is different because of the research undertaken in the last period, and the situation is different because of the interim action taken in the last period (and of course there additional sources of information and changes that were not specifically planned).

In going from this general framework to the identification of the best interim action, for this period, we need several ingredients. We need a specification of the main hypotheses related to the decision alternatives, an assessment of the likelihoods of the hypotheses, an assessment of the costs and benefits associated with the decision alternatives, an assessment of the costs of the possible wrong decisions which are not completely avoidable because of the uncertainty, and an assessment of the likelihoods of wrong decisions as functions of the various possible decisions.

In going from the general framework to the identification of the most important research to undertake, the same ingredients are needed, plus one more. We also need to assess the possible impacts of alternative information gathering activities on the probabilities of wrong decisions. Such assessment goes under the name "value of information" (see DeGroot [1971]).

It is sometimes suggested that the work of policy analysts and decision makers be kept separate from the work of the scientists, lest the questions of evaluation taint the science. A division of labor is a good idea, but only insofar as the divided labors fit together in a common framework.

The framework offered here is that of minimizing the expected cost of the decision process taken as a whole. While it is possible to adopt this framework and keep the roles of decision makers and scientists separate, to make the framework successful communication between the scientists and decision makers must be considerably improved.

The framework is admittedly not a complete one -- it does not deal with questions of equity and rights. These latter questions can and should be addressed. But even in its limited form of expected cost minimization, the framework is probably an improvement over what we are doing now. By addressing questions of equity and rights we may be able to improve the proess of management still further.

REFERENCES

Brooks, Norman H. (1971). "Statement." Public Hearing regarding Proposed General Principles and Provisions for Discharge to Ocean Waters, California Water Resources Control Board, San Diego, Dec. 2, 1971.

DeGroot, Morris H. (1971). <u>Optimal Statistical Decisions</u>. McGraw-Hill Book Co.: New York.

FIGURE 1