Ecological Risk Analysis

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CHAPTER I.6

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SUMMARY

Risk assessment has been suggested as a tool to help manage ecological problems. Ecological risk assessment is usually defined as the process that evaluates the likelihood that adverse ecological effects are occurring, or may occur, as a result of exposure to one or more stressors. The basic concept, while straightforward, is difficult to apply to any but the simplest ecological problems. Strong reactions, both positive and negative, are often evoked by proposals to use ecological risk assessment. Risk assessment applied to relatively simple ecological problems (chemical toxicity being the most common) is popular; there are many vigorous supporters, particularly among scientists, administrators, and politicians. Yet critics are equally vocal. The intellectual history of the risk assessment paradigm as applied to ecological problems does not follow a neat, linear evolution. A formidable problem in many risk assessments, and especially for complex questions such as addressing the challenge of ecological sustainability, is selecting *what* ecological component or system is to be considered at risk. This selection is entirely social and political, but estimating the actual risk is technical and scientific. The question of what is at risk must be answered within the political decision-making framework or the results of the risk assessment will be of limited utility. ***Performing credible risk assessments for complex ecological problems is difficult unless the boundaries of the assessment problem are highly constrained. However, narrowly defining ecological***

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problems produces risk assessments that are of limited relevance in resolving public policy questions.

Key Words: ecological risk assessment, risk assessment, risk management, environmental protection, decision analysis, expert opinion, conservation, ethics, modeling, multiple-use management, sustainability, bioassays, environmental impact assessment, ecological health, biological diversity

1. INTRODUCTION

Increasingly, there are calls for the use of risk assessment to help solve complex ecological problems (examples are Pacific salmon decline in the Pacific Northwest and the decrease in biological diversity). The basic concept underlying risk assessment is relatively straightforward. Risk is something that can be estimated (i.e., risk *assessment*). In turn, that estimate can be used to manage the risk (i.e., risk *management*). Ecological risk assessment is usually defined as "the process that evaluates the likelihood that adverse ecological effects are occurring, or may occur, as a result of exposure to one or more stressors" (U.S. EPA 1992). Analyses of the options and procedures for conducting risk assessment for human health issues are available in Chapters I.1, I.2, II.1, and II.2.

The basic concepts of risk assessment may be simple, but the jargon and details are not. Risk assessment (and similar analytical tools) is a concept that has evoked strong reactions whenever it has been used. At the extreme, some have even concluded that use of risk assessment in human health decision making is "premeditated murder" (Merrell and Van Strumm 1990). A number of philosophical and moral reasons for such strong reactions exist, but they are usually based on either (1) concerns that the analysis (risk assessment) and decisions (risk management) accept the premise that people will die to achieve the desired net benefits or (2) a belief that the process of risk assessment places too much power with technocrats.

Reaction to ecological risk assessment may be less harsh than reaction to risk assessment applied to human health problems, but even with ecological issues, both strong positive and negative responses occur. Several bills (e.g., Environmental Risk Reduction Act) have been introduced in the U.S. Congress mandating that federal agencies use risk assessment to set priorities and budgets. Several panels of prestigious scientists have made similar recommendations. Popular and influential publications argue for a risk assessment approach. On the other hand, some conclude that risk assessment is a disastrous approach, one that is "scientifically indefensible, ethically repugnant, and practically inefficient" (O'brien 1992).

Still, risk assessment has been used extensively to link environmental stressors and their ecological consequences. The risks associated with chemical exposure are the typical concern. Quantifying the risk of various chemicals to human health is a logical outgrowth of risk assessment as applied in the insurance industry and other fields. Over the past 20 years, a body of procedures and tools has been used for environmental risk assessment for human health. Risk assessment applied to ecological problems is more recent, but has also focused primarily on chemicals, with animals used as surrogates for "ecological health."

Adapting the risk paradigm from assessing insurance risks to assessing human health risks to assessing ecological risks has not been simple (Lackey 1994). Some view ecological risk assessment merely as using new labels for old ideas. It is still unclear whether ecological risk assessment will actually improve decision making and ultimately protect ecological resources.

2. RISK ASSESSMENT IN PRACTICE

In spite of the difficulties of defining problems in complex ecological policy questions, the use of risk assessment to help solve ecological problems is widely supported. Legislation recently debated in Congress would mandate the use of risk assessment by federal agencies for many problems. Clearly, many people think that risk assessment is a valuable tool and should be used extensively in solving ecological problems.

There is, however, a vocal group of critics of the use of risk assessment for ecological problems. They argue that risk assessment (and risk management) is essentially triage — deciding which ecological components will be "saved" and which will be "destroyed." The theme of "biospheric egalitarianism" is a mindset that makes risk assessment a real anathema. Many risk assessment critics have a strong sense of technophobia and often view mainstream environmental organizations as co-opted by industrial or technocratic interests.

Risk assessment is also challenged from a different, more utilitarian perspective. The assertion is that, while the concept of risk assessment is sound, the *process* of risk assessment is often controlled by scientists and others who have political agendas different from the majority. Critics contend that "risk assessors" use science to support their position under the guise of formal, value-free risk analysis. Risk assessment as thus viewed has the trappings of impartiality, but is really nothing more than thinly disguised environmentalism (or utilitarianism). The apparent lack of credibility and impartiality of the science (and risk assessment) underlying the policy debates over acid rain, stratospheric ozone depletion, global climate change, and loss of biological diversity are often offered as examples of how science has allegedly been misused by scientists and others to advocate political positions.

Risk assessment has historically been separated from management. Such separation requires that scientists play clearly defined roles as technical experts, not policy advocates; these distinctions are blurred when scientists advocate political positions. Further, some critics charge that scientists who use their positions to advocate personal views are abusing their public trust. The counterargument is that scientists, and all individuals for that matter, have a right to argue for their views and, as technical experts, should not be excluded simply because of their expertise. Others conclude that the execution of the scientific enterprise is value laden and therefore partially a political activity. Rather than attempting to be solely "scientifically objective," a scientist should also be an advocate. Either way, the role of the analyst must be clear to everyone using the results.

3. HISTORY OF THE PARADIGM

Neither risk assessment nor any other commonly used management tool is completely new, but draws on earlier tools and shares some of the core principles. For example, both assessment and management are based on the fundamental premise that all benefits are accruable to man. This is a utilitarian approach and a necessary assumption in all the models or paradigms that follow. "All benefits are accruable to man" encompasses the fact that society might choose to protect wilderness areas that few visit, preserve species that have no known value to man, or preserve natural resources for their scenic beauty. Benefits may be either tangible (fish yield, tree harvest, camping days, etc.) or intangible (pristine ecosystems, species preservation. visual beauty, etc.). It is easy to jump past the fundamental premise of a utilitarian assumption, but much of the political debate revolves around the issue of whether a person operates with a utilitarian worldview or ecocentric (or other, usually religiously based) worldview. It is not a trivial difference. In practice, however, the split between those with utilitarian and ecocentric (or other) worldviews is not complete; most of us manifest features of both (Herzog 1993).

The multiple-use model of managing natural resources has been the basic paradigm in North America during this century. Popularized by Gifford Pinchot and others, it has been used extensively and widely in fisheries, forestry, and wildlife. The idea is simple: there are many benefits that come from ecological resources (commodity yields, recreational fishing and hunting experiences, outdoor recreational activities. ecosystem services such as water purification, etc.) and that the mix of outputs needs to be managed to produce the greatest good for the greatest number over a sustained period of time (Callicott 1991). The concept is straightforward and works well if there is a high degree of shared values among the public.

A number of variations in the multiple-use model arose over the middle years of this century: maximum sustainable yield, maximum equilibrium yield, and optimum sustained yield. Widely used in teaching and management, these concepts have dominated mainstream professional thought and practice through current times. As with all natural resource management paradigms and goals, none of these evolved in a linear manner. The basic idea is that commodity yields (fish, trees, wildlife) could be produced annually from "surplus" production and could be continued in perpetuity with sound management. All these models suffered from the problem of a heterogeneous public with competing demands and with demands that change over time. Even today, there is still a struggle to control fishing, hunting, and logging levels in politically acceptable and managerially efficient ways.

Scientific management is a related management paradigm that includes operations research, management by objectives, optimization, linear programming, artificial intelligence, and other mathematical procedures (Lackey 1979). There are many outputs from ecosystems, both commodity and noncommodity, and these can (must) be measured, and the aggregate output optimized. The outputs are selected by experts, who then use mathematical tools to quantify and evaluate various combinations of outputs. ***Input from the public is not considered particularly important because there is a "correct" optimal set of decisions to maximize output. The***

natural resource "professional" is dominant in the process. The view that "if politicians and the public will just stay out of the process, we professionals will manage natural resources just fine" is characteristic of scientific management. There are many examples of the collapse of natural resources based on following this general management approach.

Ecosystem management, including variants such as watershed management, has become popular in the past decade. Both ecosystem and watershed management have ambiguous definitions, illustrated by the popular wall poster for ecosystem management: "Considering All Things." Usually other concepts, such as biological diversity, are embedded in ecosystem management, although biological diversity is an ill-defined concept in its own right. For example, in our quest to restore salmon stocks, should we eradicate squawfish (predators) and walleye (competitors), or do we restore ecosystems (habitat) to some desired state and let nature take its course? Does ecosystem management mean we "optimize" this mix of species? These and a myriad of others are policy questions and must be explicitly answered regardless of what management approach is used. They must be answered as policy questions, not scientific ones. Advocates of ecosystem management often see it as a fundamental shift in management and assessment thinking; skeptics see it as a "warmed-over" version of multiple-use management or, more pejoratively, as "policy by slogan."

A different approach is embodied in chaos theory and adaptive management; these approaches recognize the high degree of uncertainty in ecosystems. The basic idea is that ecosystems are unfathomably complex and react to unpredictable (chaotic) events; thus, it is pointless to develop sophisticated ecosystem models for decision making based on equilibrium conditions. There is also constant feedback between man's decisions and adjustments of the ecosystem to those decisions. Uncertainty is so great that it is not feasible to create useful predictive models. Also, for alternatives that preclude future options, adaptive environmental assessment and management will not work well (for example, construction of dams on the main stem of the Columbia River has had major ecological consequences for salmon, and each major project was an irrevocable decision). In general, the manager or analyst will make a series of "small" decisions, evaluate the results, and then make revised decisions. To make a "big" decision requires strong public support and acceptable ways to compensate the losers.

Total quality management (TQM) is a concept that became popular in business and government in the 1980s and 1990s. The widespread efforts to "reinvent government" have their basis in TQM. The core idea is that the customer comes first, and, in turn, management should be measured by what customers want. In natural resource management and environmental protection, the "customer" is often defined as the "public." Hence, TQM presupposes that an agency can find out what the public wants in terms of ecosystem management and protection and then deliver that "product." There are difficulties in defining the public, but TQM has been successful in some business applications. Its usefulness in managing and protecting public natural resources is open to question, however. In a pluralistic society, it is unlikely that there will be a common public goal for ecological resources that will allow the principles of TQM to be used effectively.

Risk assessment and management, the final management paradigm reviewed here, has been used as a tool in some of the previous paradigms or as a stand-alone approach. Strongly advocated by some, the approach has generally been used for assessing the role of chemicals in ecosystems or components of ecosystems. The basic idea of risk assessment and risk management is that there are many risks to the environment, ecosystems, and human health. These risks ought to be identified, quantified, and managed.

4. AVAILABLE TOOLS

There is a widely used set of tools and techniques to generate data for a risk assessment. Initially, the question of who assumes the "burden of proof" needs to be addressed. Do risk assessors assume that current ecological conditions are the norm and any proposed deviation from the status quo must be justified? Or do they assume some pristine ecological state as the norm? Or do they assume that the person or organization proposing the action must justify it? One of the reasons that the Endangered Species Act and Section 404 of the Clean Water Act are so potentially powerful is that they effectively shift the burden of proof to those who would change a defined condition (e.g., species must not go extinct or wetlands must not be altered unless there is explicit government approval). ***The practitioners of ecological risk assessment often overlook values, ethics, and burden of proof in defining the problem and operate instead on a purely technical level. To continue with the salmon example, why do we assume that the physical alterations of salmon rivers, such as the Columbia, are irrevocable? Is it not an option to demand that the organizations responsible for dams demonstrate that the dams are not adversely affecting salmon populations or alter their operations (including removal) so as not to adversely affect salmon? Why should the burden rest with those trying to protect or restore salmon?***

Bioassays are the most commonly used tools in producing the basic data for ecological risk assessment dealing with exposure to chemicals. There are many permutations of the basic bioassay, and the literature is extensive. Bioassays work well for certain types of ecological problems and especially for the "command and control" regulatory approach. Severe limitations, however, occur in assessing multiple, concurrent stresses, assessing effects on ecosystems or regions or assessing effects that are not chemically driven (e.g., land-use alterations). It is easy to lose sight of the fact that bioassays are simplifications of the ecosystems and regions with which risk assessors are concerned and are merely surrogates for the realistic tests or experiments that cannot be performed. On an administrative level, the use of bioassays has become institutionalized, and the public may now view such tests as more relevant to protecting the environment than is warranted.

Environmental impact analysis and monitoring are additional tools often used in risk assessment. Such analyses are relevant to real-world problems and are often targeted directly at public choice issues; there is an extensive literature on their many approaches and procedures. Because problems are "relevant," they are often complex scientifically, and, therefore, the resulting predictions lack the

scientific rigor typically seen in scientific journals. As a result, users often lack confidence in the reliability of the predictions. Moreover, the process of developing an environmental impact statement may be more important than the actual document produced.

Modeling and computer simulation are tools that have proved to be very popular in ecological risk assessment. These tools have many desirable features, such as the ability to deal with complex problems, the ability to evaluate alternative hypotheses quickly, and the ability to organize data and relationships into a defined whole. However, modelers often fall into the trap of substituting analytical rigor for intellectual rigor. Very simplistic (and incorrect) ideas can be masked by mathematical complexity. ***Even some of the most widely accepted and applied models in ecology illustrate the problem of developing and applying models to actual management issues. Further, the ease and beauty of tools such as computer-assisted geographic analysis can also cause the analyst to lose sight of intellectual rigor and common sense.***

Because most ecological risk assessment problems are complex and do not lend themselves entirely to laboratory experiments, field experiments, or modeling, the use of expert judgement and opinion is desirable and necessary. Expert opinion is useful, but is not without problems. For example, when experts have dramatically different opinions, how does a risk assessor handle this analytically? History is filled with examples of experts being completely in error. On the other hand, risk assessors trust that experts are less wrong on topics of their expertise than are nonexperts, and the use of experts and formal expert systems will continue to increase. There is the particularly insidious problem, when relying on the opinions of technical experts, of separating their personal and organizational values from their technical opinions.

Risk assessment, at least in the problem formulation stage, must include an explicit determination of what the customer wants. This is not as easy as it sounds. The customer is usually the public or a subset of the public (or an institutional surrogate such as a law or a court determination). Typical information from the public is that people want to "protect the environment," "protect endangered species," or "maintain a sustainable environment." The same people may also say that they want to "protect family-wage jobs," "maintain economic opportunities for our children," and "protect the sanctity of personal property." It is very difficult to move beyond such platitudes and obtain information that is really useful in risk assessment. On the other hand, individuals or elements of society with a direct and vested interest will have very specific preferences. Those less directly affected tend to have more general preferences. For example, studies show various elements of the public possessing at least nine different concepts of sustainability for forests, many of which are mutually exclusive (Gale and Cordray 1994).

5. APPLICATION

The first step in conducting any analysis of ecological risk is to clearly define the "problem." Unfortunately, this step is often overlooked or resolved simplistically. In many cases, agreeing on the problem is impossible because that is in itself the political impasse. There is also tension between analysts who want to simplify the problem so that it is technically tractable and politicians (who work in the real world) who must keep problem definition as realistic (which means technically complicated to analysts) as possible. Defining the problem is a political process requiring technical input, but it is based on values and priorities.

Considering the specific example of the Pacific salmon helps clarify the issues. An analyst must explicitly resolve whether the focus is on preserving some or all stocks (distinct populations) from extirpation or maintaining some or all stocks at "fishable" (high) levels. These are largely mutually exclusive alternatives. They are also not scientific decisions. Further, defining which species, communities, or ecosystems are to be evaluated in risk assessment is value based and not solely a scientific determination. Does the analyst consider the "baseline" condition to be 10,000 years ago; 200 years ago; or for the Columbia Basin, preimpoundment construction (basically before the Second World War)? Analysts should not decide these questions, society should. Depending on the baseline selected, the results of a risk assessment will differ.

Most practioners argue that, to be more useful, risk assessment (estimating risk) must be separated from risk management (making choices) both in practice and in appearance (Ruckelshaus 1985, Sutter 1993). There are counterarguments against separating assessment from management. Usually, the arguments recognize that it is impossible to separate a person's values from his/her technical (risk assessment) activities, and, therefore, the separation is illusionary. Separating the two activities (management and assessment) is not as easy as it might appear. Many scientists have strong personal opinions on public choice issues that concern ecological resources. It is difficult for anyone to separate purely technical opinions from personal value judgements. Even more difficult is convincing all elements of the public (all stakeholders) that the assessment is being conducted without a bias on the part of scientists.

The best scientists and most credible scientific information must be used in risk assessment. Besides being independent, the assessors must not advocate their organization's political position or their own personal agenda. If the risk assessment is not perceived to be independent, the results will be suspect. Further, the research and assessment function within an organization should be separated from the management and regulatory function. Credibility and impartiality are difficult to maintain, especially in the public eye.

Risk analysis will result in a number of options to "manage" the risk. These may range from drastic, expensive options to those that maintain the status quo, which may also be expensive. Options must be presented as clear alternatives with statements of ecological benefits and costs, and measures of uncertainty, for each. There is not a lot of rationality in most decision making, but there should be in decision analysis (Douglas and Wildavsky 1982). For example, risk analysts (and scientists) deal with estimates of ecological "change," while risk managers (and politicians) deal with ecological "degradation" and ecological "improvement." Such value-based statements move the scientist out of the scientific realm and into the political, value-driven realm. It may well be true that ecological conditions are better or worse from the *policy* perspective, but they are not better or worse from a *scientific* perspective.

My recommendations are (1) not to conduct a risk assessment unless there is a high likelihood that it will be used in decision making. If expectations are raised, and if no decision is made, the public senses that government institutions are not working. (2) Recognize that risk analysis of any significant ecological problem will result in options that create big winners and big losers. It serves no productive purpose to try to convince losers that they are really winners. ***If someone's property will be effectively expropriated for some larger societal good, that action should be clearly stated in the assessment. Conversely, if an owner is permitted to alter his property for short-term gain, but at huge expense to society at large or to future generations, that also should be clearly stated.***

6. SOME PROPOSED CHANGES

First, ecological risk assessment needs to be modified to create a paradigm of ecological *consequence* analysis. The concept of risk applied to natural resources will only work for a narrow set of problems where there is a clear public (and legal) consensus and on issues where there is an agreed-upon time frame of interest (are benefits and risks defined over 10 years or 10 centuries?). With all ecological "risks," a probability (of cause and effect or of ecological change) is neither good nor bad, it is only a probability. The resolution of many ecological problems is not limited by lack of scientific information or technical tools, but by conflict created by fundamentally different values and social priorities (e.g., for the salmon example. cheap food via irrigation water use vs. fishing; cheap power vs. free-flowing rivers; personal freedom vs. land-use zoning). If we are dealing with an ecological problem that is at an impasse because some of the stakeholders do not accept the utilitarian model, we should not be surprised when risk assessment and management do not resolve the issue. We need to do ecological consequence analysis, and let the political process select the desired option.

Second, the concept of ecological "health" needs to be better defined and understood by politicians and the public. The fundamental problem is not lack of technical information, but what is meant by health. Is a wilderness condition defined as the base, or preferred level, of ecological health? Is the degree of perturbation by human activity the measure of ecological health? The concept of ecological "degradation" is human value driven; the concept of ecological "alteration" is scientific. If the consequences of chaotic events in ecosystems are considered, what is "natural"? There are scientific answers for some of these questions, but political (social) answers to many others.

Third, risk assessors need better ways to use expert opinion. Most of the policy-relevant problems in ecology are too complex for easy scientific experimentation or analysis. An old rule in policy analysis is that if something can be measured, it is probably irrelevant to public choice. If problems are simplified to the point of making them scientifically tractable, then the result may lack policy relevance. Expert opinion must be used. Computer-generated maps and computer-assisted models may be elegant, but for really important decisions, the political process demands expert opinion.

Fourth, better ways need to be developed to evaluate and measure public preference and priorities in framing ecological issues. Public opinion polls always show that the public is very supportive of the environment, as it is with peace, freedom, and economic opportunity. The public is similarly supportive of preserving biological diversity, ecosystem management, and sustainable natural resource management. Unfortunately, this type of information is of limited use in helping make difficult environmental decisions. The public is not a monolith; it encompasses many divergent views, and individuals vary greatly in the intensity of their opinions. Individuals may argue forcefully for the industrial economic paradigm or for the natural economic paradigm, but practical political options are not framed in this context.

The fifth critical need is to develop better ways to present options and consequences to the public, to policy analysts, and to decision makers. Society is not well served by statements such as "it is a complicated problem and you need to have an advanced degree in ecology to understand it," or "you can select this option without significant cost to society" when there will be costs to some people. The main take-home message in risk assessment must be that there are no free lunches in environmental protection and that policy alternatives and the consequences of each must be explained in ways that the users of the assessments understand.

7. CONCLUSION

Biological and social science must be linked if public decision making is to be improved. Too often, forestry, fisheries, and wildlife problems are viewed as biological challenges. It is society that should define problems and set priorities, but the public speaks with not one, but many voices. Many of the stated public demands are mutually exclusive. Ecological "health," for example, is a social value defined in ecological terms. But, incorporating public input into risk assessment and management may be carried to the extreme (e.g., democratization).

Scientists must maintain a real and perceived position of providing credible ecological information — information that is not slanted by personal value judgements. Those involved in risk assessment cannot become advocates for any political position or choice, lest their credibility suffer. Such a position may be painful at times because no one can completely separate personal views from professional opinions. Risk assessors must be clear to the public (and political officials) on what scientific and technical information can and cannot do in resolving public choice issues.

We should not assume that complex ecological problems, such as the decline of the Pacific salmon, have only technological and rational solutions. Although tools such as risk assessment might help at the margins of the political process, they are not going to resolve the key policy questions. Nonrational ideas are extremely important in all significant public choice issues. Scientists and risk assessors should guard against technical hubris, a false sense of confidence in technology, technological solutions, and rational analysis, including risk assessment.

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QUESTIONS

1. What is the definition of ecological risk assessment? How does risk *assessment* differ from risk *management*?
2. Compare and contrast the application of risk assessment to ecological issues and human health issues.
3. What are the most important reasons offered for using risk assessment to help solve ecological problems? What are the major objections to the use of risk assessment to help solve ecological problems?
4. Compare and contrast the role of values, ethics, and science in formulating the "problem" in ecological risk assessment.
5. What are the commonly used alternatives to ecological risk assessment? What are their advantages and disadvantages?
6. Should the process of risk *management* be linked to risk *assessment*? What are the major benefits and dangers with the alternatives?
7. How is *adverse* determined in ecological risk assessment? Who decides what is adverse?
8. What role should scientists play in risk assessment and in risk management?

About the Author:

Dr. Bob Lackey is professor of fisheries science at Oregon State University. In 2008 he retired from 27 years with the Environmental Protection Agency's national research laboratory in Corvallis where he served as Deputy Director among other senior science and management jobs. Since his very first fisheries job mucking out raceways in a California trout hatchery, he has worked on an assortment of natural resource issues from various positions in government and academia. His professional assignments involved diverse aspects of natural resource management, but mostly he has operated at the interface between science and policy. He has published over 100 articles in scientific journals. Dr. Lackey has long been an educator, having taught at five North American universities and continues to teach a graduate course in ecological policy. Canadian by birth, he is now a U.S.-Canadian dual-citizen living in Corvallis, Oregon.