2 Other Types of Assessments

While risk assessment is broadly applicable to environmental decision making, other sorts of assessments and decision tools are more appropriate or more commonly employed in certain situations. Some apparent alternatives are actually complementary to risk assessment. The relationships of some of these alternatives to ecological risk assessment are discussed in this chapter. Assessments based on ecological epidemiology are discussed in Chapter 4.

2.1 MONITORING STATUS AND TRENDS

Concerns about the state of the environment have led to the development of programs to monitor status and trends in physical, chemical, and biological attributes. In particular, the expenditure of large sums of money for environmental regulation, treatment, remediation, and restoration has led to questions of efficacy: Are we achieving benefits that are commensurate with the expenditures? Is environmental degradation occurring that is not being addressed by existing programs? Hence, there is a need for environmental monitoring to quantify the state of the environment and generate environmental report cards. These programs may, like the US EPA's Environmental Monitoring and Assessment Program (EMAP) (Jones et al. 1997; Jackson et al. 2000) or the National Oceanic and Atmospheric Administration's National Status and Trends Program, generate their own data or, like the H. John Heinz III Center for Science Economics and the Environment (2002), analyze the existing data.

Monitoring to determine the environmental status and trends is conceptually distinct from monitoring for risk assessment. Such programs are concerned with broad patterns of common conditions, as indicated by results of random sampling, rather than the specific adverse effects that are of concern to risk assessors (Suter 2001). They are not concerned with the causal relationships that are the heart of risk assessment. Similarly, they monitor indicators, many of which are indices, rather than actual valued attributes of ecological entities (Jackson et al. 2000). Finally, they are not concerned with informing particular management decisions. The assessments generated by EMAP and similar programs are descriptive rather than predictive and serve as environmental report cards for regions, states, or nations (Jones et al. 1997; Office of Research and Development 1998; Jackson et al. 2000).

Although these progams are not designed for risk assessment, they can potentially provide relevant information. They may reveal conditions that should be addressed by follow-on assessments, which address the causes of conditions and the risks and benefits of corrective actions (Chapter 4). If they are continued over time, they may reveal trends that confirm the broad benefits of environmental regulation and management or reveal their failings. However, environmental monitoring programs in the United States have seldom achieved these goals (H. John Heinz III Center for Science Economics and the Environment 2002).

2.2 SETTING STANDARDS

Environmental standards are concentrations of contaminants in the environmental media that are legally enforced thresholds for acceptability. For the dynamic media, water and air, standards must also include an averaging period and a recurrence frequency. For example, US acute ambient water quality criteria are defined as 1 hour average concentrations that are not to be exceeded more than once in every 3 years (Stephan et al. 1985). The enforcement of standards is an alternative to estimate site-specific or case-specific risks. Standards are set by a variety of methods (Chapter 29).

Standards may be risk-based, but most often they are set so as to simply constitute reasonable and enforceable levels that do not correspond to defined ecological endpoints or defined levels of protection. In the latter case, risk assessments must treat a set of standards as effectively an endpoint in themselves, and risk assessments are limited to estimating the risk of exceeding a standard. However, standards that are set at levels that are estimated to constitute a defined risk to defined endpoints can be used in full risk assessments. For example, the maximum permissible concentrations in the Netherlands are intended to protect all species in the ecosystem from toxic effects (Sijm et al. 2002). In that case, once the term "toxic effects" is defined, one can estimate the risks and monitor for success.

Standards of enforcement and risk assessment may be combined in a common decision framework. For example, the Canadian Council of Ministers of the Environment integrates standards- and risk-based approaches into their framework for remediation of contaminated sites (CCME 1999). Remedial objectives for a site are normally set to the national guidelines, but the guidelines may be adapted to the site, or a site-specific risk assessment may be performed. Site-specific assessments are required if unusual or sensitive receptors, site conditions, or exposure conditions are identified, significant knowledge gaps exist, or guidelines are not applicable, because they do not exist or the contaminants constitute a complex mixture.

2.3 LIFE CYCLE ASSESSMENT

Life cycle assessment provides an integrative assessment of a product or industry by considering the potential environmental and health effects from the extraction of raw materials, through manufacturing, transport, use, and recycling to ultimate disposal. Like risk assessment, it has multiple uses. It can be used to determine the alternative products or processes to be used. Examples include paper vs. plastic bags, disposable vs. laundered diapers, or coal vs. nuclear power. Alternatively, it may be used by an industry as part of its due diligence to determine the environmental consequences of its activities and the potentially associated liabilities. Much of life cycle assessment has been devoted to inventorying materials and energy uses, and waste stream releases of manufacturing processes. Comparisons have been largely qualitative, employing ranking and scoring techniques, because of the difficulty of comparisons involved. For example, there is no obvious commonality to the environmental effects of extracting oil for a plastic bag vs. harvesting trees for a paper bag. However, life cycle assessments are becoming increasingly sophisticated, including analysis of uncertainty in parameters, scenarios, and models (Huijbegts et al. 2003). This trend could result in the convergence of life cycle assessment and comparative risk assessment (Sonnemann et al. 2004).

2.4 PROHIBITIONS

One alternative to risk-based decision making is the use of prohibitions against certain classes of agents or actions. For example, the 2001 Stockholm Convention on Persistent Organic Pollutants (POPs) commits signatories to eliminate or reduce production of, or trade in, chemicals that have the properties of being organic and relatively persistent. This commitment is based on the concern that, even if a chemical has little toxicity and extremely low concentrations, it may prove to have unexpected toxic properties or may accumulate in unexpected ways.

A clearly problematical example of this alternative to risk-based decision making is the prohibition on ocean disposal of sewage sludge (Weis 1996). Sewage sludge, the solid matter generated by the treatment of sewage, contains organic matter, nutrients, microbes, and household and industrial chemicals. Sludge may be dumped at sea, incinerated, buried, or incorporated into surface soil. The disposal of sewage sludge at an open ocean site (106 miles offshore) by the City of New York was permitted on the basis of studies, assessments, and reviews indicating that there were no significant ecological or health risks from the practice. However, sewage sludge and all other ocean dumping were banned by an act of Congress. The reason was public outrage over beach pollution in New Jersey and misinformation blaming New York sludge rather than the true sources (combined sewer overflow and a runoff from a landfill). This political decision has compelled the onshore disposal of sewage sludge without any consideration of the relative risks. Incineration and other land-based alternatives have also proven to be controversial, but have not led to reconsideration of the prohibition on ocean disposal.

Prohibitions of categories of chemicals or actions, in the absence of evidence of significant risks or of analysis of alternatives, may have unanticipated and undesired consequences. Persistent pesticides are replaced by more toxic pesticides, and sludge gets spread on land rather than deep ocean sediments. Because prohibitions are usually in the form of laws or treaties, they inhibit the choice of optimum decisions in individual cases. However, when formal analysis of individual decisions is difficult or unlikely, blanket prohibitions may result in net benefits to the environment.

2.5 TECHNOLOGY-BASED RULES

An alternative to risk-based regulatory decisions is to specify a particular technology or a set of approved technologies for treatment or remediation. This approach is less popular than it was formerly, because it tends to stifle technological innovation, which could reduce costs or improve performance. It also tends to preclude fitting the solution to the site-specific problem. However, when monitoring of performance is not feasible, requiring a particular technology is a relatively simple way to achieve a minimum level of protection.

2.6 BEST PRACTICES, RULES, OR GUIDANCE

A more flexible alternative to the use of a technology is to tell the engineers or managers to do the best they can. This is reflected in phrases such as "best management practices," "best available control technology," "as low as reasonably achievable," or "best practicable technology." These sorts of rules have been applied when a hazard has been identified, but could not be quantitatively assessed when the costs of achieving low risks were judged to be prohibitive relative to the benefits of the product or technology, or when risks were already low but public concern required regulatory action. Best practices and rules have become less popular as the utility of risk assessment has increased. In addition, ethical and practical considerations have intervened. Ethically, it is difficult to justify exposing one group to a higher risk than another simply because of the availability or cost of control technologies. This equity concern is reinforced by the observation that, when industries are required to achieve risk-based standards, new technologies are developed and costs of existing control technologies decline. On the other hand, strict interpretations of best practices and rules can result in treatment or remediation to levels of agents that pose minuscule risks or below-background levels of metals, radiation, or other naturally occurring agents. However, it has been argued that best available technology mandates are more effective than risk assessment and other science-based approaches, because they avoid conflicts and uncertainties concerning good science and are not delayed by data collection and analysis (Houck 2004).

Best practices and guidance are also a practical means of improving environmental quality when conventional regulatory approaches are impractical. For example, it is difficult to quantify and write emission permits for runoff of sediment and nutrients from tilled agricultural fields, but best practices such as buffer strips along streams can be encouraged or imposed (Cestti et al. 2003).

Trade or industry groups may define good practices in the form of codes of conduct. These codes allow members to take responsible actions without being disadvantaged by less responsible competitors and may forestall demands for regulation.

2.7 PRECAUTIONARY PRINCIPLE

The precautionary principle is sometimes presented as an alternative to risk assessment. However, like most environmental principles and slogans, it has many definitions and uses. There are at least 14 different versions of the principle (Foster et al. 2000). Some of them are alternatives to risk-based decision making and others are supplementary.

The most extreme versions require definitive proof of safety before allowing new technologies or actions (Foster et al. 2000). This would stop all new activities, including the introduction of greener technologies, because the criterion is impossible.

More commonly, as in the 1998 Wingspread Statement on the Precautionary Principle, actions should be regulated or existing contamination mitigated if they raise threats of harm to human health or the environment, even if the hypothesized causality is "not fully established scientifically" (Raffensperger and Tickner 1999). Similarly, the 1992 Rio Declaration on Environment and Development declares: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." Hence, the emphasis is on precautionary actions in the absence of strong evidence. The trick is to distinguish credible threats from those that are incredible or even smoke-screens for protecting existing industries or practices from new industries or practices. This requires some sort of risk assessment.

Another definition of the precautionary principle is that the burden of proof should be placed on those who propose an action. This definition is usually vague, but in some cases it is a reaction to the use of conventional hypothesis testing in environmental assessments (Weis 1996). Such tests give priority to the null hypothesis (nothing is happening or will happen as a result of the action), and require that it be disproved with 95% confidence. A precautionary alternative would be to require proof of no significant effect, rather than of a significant effect. This would require specifying an effect, a magnitude of change, and a maximum acceptable probability of type II error. This formulation of the assessment process in terms of placing a burden of proof on any stakeholder is inconsistent with the idea of performing an unbiased assessment of the probability of effects. Ideally, risk assessments should estimate uncertainty rather than using it to force a particular decision.

Another class of definitions of the precautionary principle simply calls for a bias toward protection when making a decision. One particularly clear version states that the least hazardous alternative should be selected (Kreibel et al. 2001). This decision criterion implies the need for comparative risk assessment.

The case for a precautionary approach to environmental management is made in a European Environmental Agency review of 14 cases in which effects resulted when early warnings did not prompt precautionary actions (Harremoes et al. 2001). The lessons that they draw from the case studies amount to a call for more complete risk assessments that incorporate all uncertainties including gaps in scientific knowledge, consider alternatives, and carefully scrutinize claimed benefits as well as risks from products and technologies. This would result in better-informed decisions, which could reduce cases of both inadequate precaution and excessive precaution.

2.8 ADAPTIVE MANAGEMENT

Often, because of the complexity of ecosystems and their interactions with human activities, it is not possible to predict the consequences of an action with confidence. The precautionary approach in such situations would be to avoid action, but that is usually not possible. An alternative response is to try something and see if it works. That approach is problematical because the success or failure of a management action may result from the effects of uncontrolled variables such as the weather or population cycles. Adaptive management provides a more rigorous version of the "try it and see if it works" concept (Walters 1986). In adaptive management, the alternative actions are treated as experimental treatments. Ideally, the treatments are randomly assigned to replicate systems that may be replicated in space (e.g., lakes within a region) or in time (e.g., years for an annually breeding species). The results are then used to design or select an optimum management plan. The concept of adaptive management was developed for resource management where typical experiments have consisted of reducing harvesting fish or waterfowl in some years to determine the relationship between harvesting and recruitment. Other examples include applying alternative timber harvesting techniques to different forest watersheds or different farming practices to agricultural watersheds to determine the effects on water quality or stream habitat quality.

Adaptive management has obvious appeal in terms of realism of the assessment and defensibility of the resulting decision. However, it has seldom been applied. This is in part because of the difficulty of designing and carrying out the experiments. Like any other poorly designed experiment, an adaptive management experiment that does not have replication of treatments and systems or random assignment is subject to confounding, bias, or random effects that can cause misleading results. However, even unreplicated experiments may improve the quality of decisions, particularly if they are well monitored to minimize the potential for unrecognized confounding variables and if they monitor mechanistic parameters to confirm the plausibility of the assessment models. An example is the experimental release of water from the Glen Canyon Dam to the Grand Canyon reach of the Colorado River. The experiment was intended to determine whether simulated spring floods could restore habitat for rare species and improve recreation. While careful and extensive monitoring of the experiment gave apparently clear results, it has been recommended that the experiment be replicated (NRC 1999).

Another reason that adaptive management may fail is that the experiment is not based on an explicit model of exposure and response in the system. Such assessment models can (a) focus on the experimental design of critical system attributes, (b) suggest types and levels of treatments for the experiments, and (c) provide a means to extrapolate the experimental results so that managers know how to adjust management practices under current conditions or how to change them in future conditions (Holling 1978; Walters 1986).

Finally, adaptive management may not be used because risk managers and assessors are reluctant to admit that they do not know which alternative action is best (Walters 1986). Admission of uncertainty is particularly difficult when the costs are high or social disruption may occur. On the other hand, adaptive management experiments may be a means to defer a difficult decision.

Adaptive management can fit well with the ecological risk assessment framework. The emphasis of risk assessment on uncertainty and causal models provides a basis for determining when adaptive management is needed and what treatment levels are needed to distinguish among alternative assessment models. The clearly defined assessment endpoints provide the response parameters to be measured during the experiment. The alternative actions should be based on alternative risk models or parameterizations, so that the experiments could also be designed to elucidate the functional relationships and parameter values. The results could then be used to develop and refine assessment models for future applications. This approach has been applied to the assessment of risks to the largemouth bass population of Coralville Reservoir, Iowa, from agricultural use of dieldrin (Mauriello and Park 2002). The assessment model showed that recovery would occur if dieldrin were completely eliminated, and therefore it should be readily detected.

A trial-and-error approach may be useful, even when there is no explicit adaptive management. Many laws and regulations require that effluent permits be renewed or that products be reregistered. This provides an opportunity to examine the environmental results of the initial registration or permit, and to use the observed effects as a basis to revise the original decision. For example, a reassessment of the use of granular carbofuran considered bird kills as a basis for prohibiting previously permitted uses (OPP 1989). This process may be facilitated by monitoring of environmental effects of a permitted use.

2.9 ANALOGY

Prediction is inherently difficult, particularly when complex ecological systems are involved. Some ecologists have concluded that rather than applying conventional data and models to predict the effects of a new project or agent, one should simply study the effects of a similar project or agent and assume that the effects will be analogous (Goodman 1976). For example, if we wish to know the risk that a eutrophic system will develop rapidly in a proposed reservoir, we should look at other reservoirs in the region rather than modeling the proposed system. If the most similar reservoir is eutrophic, the new one will be so as well. This approach fails if the combination of project or agent and receiving ecosystem is not sufficiently similar. It converges on risk assessment if the analogous systems are used to develop empirical models of exposure and empirical exposure–response relationships.

2.10 ECOSYSTEM MANAGEMENT

Some have argued that real ecosystems, exposed to multiple agents, are too complex for rigorous analysis of clearly defined endpoints, as implied by the ecological risk assessment concept (Lackey 1994). One suggested alternative approach is variously termed ecosystem management or watershed approach (Christensen 1996). In practice, these assessments tend to have broadly defined goals like ecological integrity, sustainability, or health, and to emphasize stakeholder involvement in the process rather than analysis (Lackey 1998; Committee on Environment and Natural Resources 1999). This approach avoids the difficulties of analyzing complex situations by focusing on reconciling the perceptions and desires of the inhabitants or users of a watershed or regional ecosystem. The assessments may be simply descriptive, because their purpose is to achieve a common understanding of the state of the system rather than to predict the outcomes of choices (Berish et al. 1999). Ecosystem management may be implemented by land and resource managers, regulatory agencies, consortia of nongovernmental organizations (NGOs) (e.g., the Friends of the Potomac) and special interests (e.g., the Northwest Power Planning Council), and quasi-governmental commissions (e.g., the Interstate Commission on the Potomac River Basin), with various combinations of mandate, authority, and public legitimacy (Loucks 2003).

The inherently political character of many ecosystem management programs is problematical. While it is valuable to achieve consensus, or at least acquiescence, of the stakeholders, such processes are not necessarily protective of the ecosystem or its resources and may not even be socially just. Stakeholder processes may be dominated by those with the greatest financial stake or even by those with the most effective representatives. On the other hand, this approach may be effective when conventional management processes are stalemated.

2.11 HEALTH RISK ASSESSMENT

Human health risk assessment has been considered an alternative to ecological risk assessment based on the assumption that if you protect humans, nonhuman receptors will be protected as well. Although this proposition is heard less often than formerly, it is still believed by many risk managers. For a variety of reasons, some nonhuman species are likely to be more exposed to environmental contaminants than humans, or are more sensitive (Box 2.1). This is even more true for nonchemical agents. While the destruction of ecosystems for highways, reservoirs, etc. has implications for human health, it is devastating to the nonhuman species and ecosystem functions involved. Similarly, introduced species such as kudzu, nutria, Asian carp, and chestnut blight in North America, various deer in New Zealand, or mink in Europe have severe ecological effects with few, if any, health implications. The fact that nature is declining while the human species is expanding proves that protecting humans has not served to protect nonhuman species. Hence, rather than an alternative to ecological risk assessment, health risk assessment should be a complement to it (Chapter 37).

2.12 ENVIRONMENTAL IMPACT ASSESSMENT

Environmental impact assessment (EIA) is not really an alternative to ERA. It is distinguished by the nature of its mandate rather than by a different way of analyzing or managing hazards to the environment. In the United States, EIAs are legally mandated by the National Environmental Policy Act of 1969. Similar legal mandates exist in Canada, Europe, Australia, and elsewhere. In contrast, risk assessment is a practice that has been developed by regulatory agencies to provide scientific input for decision making. Hence, EIAs are imposed by law on often reluctant agencies, while ERAs are performed voluntarily by agencies to assist in performing their mandates. According to a prominent EIA practitioner, the test of EIA compliance is the enforcement of the assessment mandate, while the test of risk management is the achievement of desired risk levels (Lawrence 2003). Hence, EIAs are more concerned with acceptable process. In addition, they tend to be concerned with development projects such as dam construction or resource management, and not with typical ERA topics such as new chemicals, effluents, or contaminated sites. However, only the historical exigencies of laws and regulations are behind this distinction. Calls for more scientific rigor and analysis of uncertainty push EIA toward risk assessment practices, while calls for legal and policy reviews and for more stakeholder and public participation push risk assessment toward EIA practices.

2.13 SUMMARY

Ecological risk assessors must be aware that their assessment approach is not the only option. Some options such as prohibitions, best practices, technology-based rules, or standard setting are genuine alternatives that are useful when ecological risk assessment is not practical.

BOX 2.1
Why Human Health Risk Assessment Is Insufficient

Risk assessments have emphasized risks to human health and have largely neglected ecological effects. This bias results in part from anthropocentrism and in part from the common but mistaken belief that protection of human health automatically protects nonhuman organisms. The assumption that health risk assessments will be universally protective is justified by the protection of humans from very small risks (one in a million risks of cancer) and the use of conservative assumptions in most health risk assessments. However, there are obvious counter-examples, such as the fact that some chemicals that commonly cause severe effects to aquatic organisms like chlorine, ammonia, and aluminum, pose no risk or negligible risks to humans in drinking water. Nonhuman organisms, populations, or ecosystems may be more sensitive than humans for any of the following reasons:

1. Some routes of nonhuman exposure are not credible for humans, including respiring water, drinking from waste sumps, oral cleaning of pelt or plumage, and root uptake.
2. Chemicals are likely to be more toxic to some nonhuman species than to humans simply because there are far more nonhuman species, and some of them are likely to have properties that make them more susceptible than humans. In some cases this sensitivity is due to mechanisms of toxicity that do not occur in humans, such as eggshell thinning by DDE, stomatal closure in plants by sulfur dioxide, and imposition of male sex in snails by tributyl tin. In other cases, the cause is unknown, as in the greater sensitivity of birds and some nonhuman mammals to chlorinated dibenzodioxins.
3. There are mechanisms of action at the ecosystem level, such as eutrophication by nutrient chemicals, aquatic anaerobiosis due to degradable organic chemicals, and blockage of light by suspended solids, that have no human analogs.
4. Nonhuman organisms may be exposed more intensely to chemicals, even when the routes of exposure are the same. Any case of environmental pollution is likely to result in much higher exposure to some nonhuman organisms than to humans. Humans (at least in affluent cultures) inhabit closed dwellings, obtain a variety of food from a variety of locations, tend to move among a variety of locations, and in general are not immersed in a particular ambient environment. For example, most humans eat at most a few meals a week that contain fish as one component, and the fish come from a variety of sources, while a heron or river otter eats only fish for nearly every meal and eats the whole fish and not just the relatively uncontaminated muscle.
5. Most birds and mammals have higher metabolic rates than humans, so they receive a larger dose per unit body mass because proportionately they consume more contaminated food, drink more contaminated water, and breath more contaminated air. High metabolism may also result in more rapid metabolism of organic chemicals, but many nonhuman species have fewer metabolic enzymes than humans.
6. Some chemicals are designed to kill "pests" or "weeds" and are released to the environment at levels that are lethal to nonhuman organisms by design. In such cases, "nontarget" organisms that are physiologically and ecologically similar to the pest are inevitably affected.
7. Nonhuman organisms are highly coupled to their environments, so that even when they are resistant to a chemical they may experience secondary effects, such as loss of food or physical habitat. In contrast, humans in industrialized countries have alternate sources of food and materials for shelter if a portion of their environment is damaged by chemicals.

These arguments are mitigated somewhat by the fact that we are concerned about extremely low risks of human mortality that cannot be detected (10^{-6}) and have no significant consequences

Continued

BOX 2.1 (Continued)

for nonhuman populations. They also do not apply to mutagenic effects. Mutations are unacceptable in humans, but natural selection inconspicuously weeds them out of all but the smallest nonhuman populations. However, even for the polychlorinated dibenzo-*p*-dioxins (PCDDs), which are much-feared and regulated carcinogens, environmental exposures have been associated with significant effects on nonhuman organisms without clear and significant human effects, despite careful human monitoring. While the prompt effects of the PCDD release on humans at Seveso, Italy, were limited to some cases of chloracne, rabbits and other herbivorous animals were killed (Wipf and Schmidt 1981). No human effects were established at the Love Canal dump site that included PCDDs, but field mouse populations have been devastated by sterility and early mortality (Rowley et al. 1983; Christian 1983). The PCDD-contaminated oil at Times Beach, Missouri, killed horses, cats, dogs, chickens, and hundreds of sparrows, but apparently no humans (Sun 1983).

Others such as adaptive management can be supplementary, while those like the precautionary principle may provide guidance to risk management. Finally, some approaches such as life cycle assessment and EIA are equivalent practices developed in other contexts that may share methods and data with ecological risk assessment.