

## Reducing Uncertainty in Ecological Risk Assessment

By Timothy J. Ward, Ph.D.

### Introduction

Since the purpose of an ecological risk assessment is to assist risk managers with environmental decision making, its value is critically linked to maximizing the accuracy and minimizing the uncertainty of a risk prediction. The goal of an assessment is to evaluate risks to environmental values (assessment endpoints, such as the protection of valuable game fish and their spawning grounds, that are generally too complex to measure directly) using data from laboratory and field studies (measurement endpoints, such as the concentration of metals in the sediment, that can be measured). Uncertainty occurs because the identification and evaluation of all important effects on the structure and function of a complex ecosystem are beyond the scope of most assessments (i.e. measurement and assessment endpoints are dissimilar). The role of an ecological risk assessor is to choose the tests that are appropriate for the site under investigation, and then use professional experience and judgment to bridge the gap between the measurement and assessment endpoints. In addition, when an assessment leads to a conclusion that remediation is required, the risk assessor's judgment is instrumental in interpreting the results in relation to cleanup decisions and remediation goals.

Ecological risk assessment requires an understanding of ecology, ecotoxicology, and environmental chemistry, and a steady increase in knowledge in these fields means that risk assessment techniques evolve continuously. Several recent documents provide information designed to reduce uncertainty. Massachusetts Contingency Plan (MCP) Technical Updates [Assessing Risk of Harm to Benthic Invertebrates](#) and [Freshwater Sediment Toxicity Tests](#) recommend assigning a greater weight to the results of benthic invertebrate toxicity tests. These sediment toxicity tests are certainly not new, but experience has acknowledged their increased value relative to the other two

*Subjective judgment inherent in an investigation as complex as the evaluation of ecological risk can be reduced if appropriate data and models are used to improve the credibility, consistency, accessibility, and reproducibility of the assessment (Suter et al., 1993). New information offers the potential for a reduction of uncertainty.*

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branches of the traditional sediment triad: the comparison of sediment concentrations to benchmark values and surveys of the benthic community at the site under investigation.

An EPA white paper [Assessing Risks to Populations at Superfund and RCRA Sites](#) (Munns & Mitro, 2006) discusses the gap between measurement and assessment endpoints. The authors remind us that data generated by any one of the triad tests (measurement) may not provide enough information to accurately predict important community and ecosystem-level effects (assessment). The white paper further points out that existing measurements simply characterize the conditions present at the time and place of sampling, and do not, therefore, allow us to consider important long-term patterns such as extinction probability and recovery potential at a site. The purpose of these three documents is to improve the ability of risk assessors to distinguish ecologically significant responses from those that are not (i.e. what constitutes an acceptable ecological risk?).

## Weight of Evidence

Natural variability can be the monkey wrench of risk assessment, adding unwelcome complexity and uncertainty to the process. In some cases, an additional expenditure associated with increased data collection can shrink the wrench, reducing the potential for a remediation that does not adequately protect the ecosystem or one that is more complex and costly than needed. Each of the individual triad tests has advantages and shortcomings, and for some sites, especially those that are uncontaminated or severely contaminated, the use of one test alone may be sufficient to accurately determine risk/no risk. For sites with slight to moderate contamination or those with critical ecological components, the triad, with its higher costs, may actually present a better value if it reduces the scope of remediation.

The first triad test - sediment chemistry analyses and comparisons of results to established benchmark values—forms the familiar screening level ecological risk assessment. This test, which is relatively simple and inexpensive, is an appropriate choice if the purpose of the assessment is to verify that a site is

uncontaminated. In order to serve as a stand-alone evaluation of ecological risk, the test was designed to be very conservative, possibly leading to a remedy that is not cost effective. This test can be useful in pinpointing the chemical(s) that may be responsible for contamination. Increasingly we are gaining an understanding of the mechanisms that control the bioaccumulation of chemicals from sediment by organisms. These insights have helped to explain why some sediments with chemical concentrations above benchmark values do not cause toxic effects in the field. One example of this increased understanding is a bioavailability model that uses measured concentrations of acid volatile sulfides and simultaneously extracted metals (AVS/SEM) to determine whether metals in the sediment are in a form that can readily move into organisms or if instead they are likely to be bound to sulfides present in the sediments and unable to move to the organisms. Other models exist or are being developed that will continue to improve risk measurement methods.

The second triad test – the benthic survey – has the advantage of allowing direct observation of conditions at the site, eliminating the need to extrapolate from data produced in a laboratory. The advantage of field surveys is that they incorporate all the factors that affect bioavailability of contaminants and include the effect and interaction of all contaminants. The usefulness of benthic surveys is limited by natural biological variability, which often makes it difficult to identify an effect, and by the need for a suitable reference site so that conditions in the absence of contamination can be characterized. Additionally, observed effects at the site can not be linked to concentrations of specific chemical contaminants.

The third triad test – a sediment toxicity test conducted in the laboratory – is now given increased weight under the MCP based on several considerations. Most importantly, studies have shown that the results of these tests, especially chronic tests that measure survival, growth, and reproduction of organisms placed in the sediment during the laboratory test, are generally aligned with ecological effects (or the lack of effects) observed in the field (Kuhn et al., 2002). Sediment toxicity tests are site

specific, allowing significant, sensitive effects to be measured directly. This means that the factors at the site that influence the bioavailability of contaminants are included in the evaluation, as are the interactions of all contaminants that are present. In addition, natural stresses that are unrelated to contamination at the site are eliminated (e.g., predation, temperature fluctuations). A shortcoming of this test is the potential sensitivity difference between the species used in the laboratory test and those at the site. Additionally, if sediment is toxic, the specific responsible chemical(s) can not be identified without a follow-up toxicity identification evaluation.

While the interpretation of the results of toxicity tests and benthic surveys may be more complicated than chemical analyses/benchmark comparisons, risk predictions may be scientifically strengthened by their use. Predictions may also be improved by using more than one type of test or by utilizing different weights for each piece of evidence. Identifying an effect in any one of the three triad tests, such as the occurrence of a chemical in sediment at a concentration above a reportedly “safe” concentration, mortality of a portion of exposed organisms during a toxicity test, or decreased abundance of a species at the site, does not necessarily mean that the sediments are hazardous to the ecosystem at the site, but rather suggests that there is the potential for risk. Taken together, however, the three tests significantly increase the weight of evidence and the strength of a risk/no risk prediction, especially if bioavailability is considered during chemical analyses.

### **Levels of Ecological Complexity**

Sediment toxicity alone is inadequate for differentiating hazard from risk. Risk assessment needs to extrapolate from effects on individual organisms to predict risk to complex populations, communities, and ecosystems at the site (Table 1). Many factors other than toxicity are known to influence the long term health of natural ecosystems, but toxicity during laboratory tests with sediment-dwelling organisms have generally been shown to be accompanied by changes in diversity and abundance of resident

organism populations at the site (Long et al., 2001). Of course, no two ecosystems are the same, and some are more able to resist and recover from stress than others.

The EPA white paper (Munns & Mitro, 2006) suggests that available population models can be useful for extrapolating from a measurement endpoint to an assessment endpoint. For example, they may allow a better prediction of long-term effects, such as growth or decline of the natural populations, based on effects on individuals during toxicity tests. Models can be designed to include the sort of random catastrophic events that occur in nature, incorporate the spatial and temporal scales of the site, and even consider the probability of each possible outcome. The type of demographic data (survival, growth, reproduction) available from chronic sediment toxicity tests can be used to model population growth rates, allowing a prediction of the risk of long-term extinction or recovery of populations at a contaminated site. The ultimate test of the ability of a measurement endpoint or model to accurately characterize risk at a site is the correlation of the prediction with actual observations at the site, and this confirmatory analysis and model validation is essential to reduce uncertainty.

Because no two sites, and therefore no two risk assessments, are identical, expert opinion will continue to play an important role. Suter et al. (1993) point out that the subjective judgment inherent in an investigation as complex as the evaluation of ecological risk can be reduced if appropriate data and models are used to improve the credibility, consistency, accessibility, and reproducibility of the assessment. Continuing scientific research offers the potential for future improvement of risk assessment methods and a reduction of uncertainty.

**Table 1** – Responses to Stress at Different Levels of Biological Organization that can be Useful for Ecological Risk Assessment

Level of Organization	Responses to Stress
Individual Organisms	Reduced Lifespan
	Reduced Growth or Growth Rate
	Altered Development
	Reduced Reproductive Success
Populations of Organisms	Reduced Abundance
	Altered Distribution
	Changed Age Structure
	Altered Gene Pool (adaptation)
Ecosystem: Structure	Population Extinction
	Changed Community Composition
	Changed Species Diversity
	Reduced Abundance or Biomass
Function	Reduced Organic Decomposition
	Reduced Nutrient Conservation
	Reduced Primary Productivity
	Reduced Ecosystem Production
	Altered Food Web (predator-prey changes)

Adapted from Sheehan, PJ and Loucks, OL. 1994. "Issue Paper on Effects Characterization". In: Ecological Risk Assessment Issue Papers. Risk Assessment Forum, US EPA, Washington, DC. EPA/630/R-94/009.

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## About the Author

Tim Ward is an environmental toxicologist with over 25 years of experience conducting and supervising ecological fate and effect studies, and evaluating ecological risk. Before joining Gradient, he was the President and Co-Founder of T.R. Wilbury Laboratories, Inc. and he has managed laboratories at the EnviroSystems Division of Resource Analysts, Inc. and ENSECO, Inc.