On Ecological Risk Management

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1. What is ecological risk management?

Risk management is the process of setting rules or operating procedures for minimizing damage when there is uncertainty about relationships and outcomes. Risk management is important in many aspects of human life. Risk management is applied to public health, highway safety, finance, engineering, construction, and environmental protection. Risk management requires *risk analysis*, or *risk assessment*.

Ecological risk management is the process of setting rules or operating procedures for minimizing damage to ecosystems and/or components of ecosystems, such as water, soil, vegetation, and animal populations. Ecosystems components are natural resources available for human use, and ecosystem processes, such as nutrient recycling, provide important services such as water purification and production of harvestable biomass.

2. What is the first step in risk management?

Risk management begins with identification of something of value that requires protection. In the case of public health, it is obvious that our goal is to reduce mortality, injury, infection, and ailments such as heart and liver disease. Factors shown to influence these negative health outcomes are candidates for risk management. For example, since smoking has been shown to increase the incidence of cancer, we would want to establish guidelines and thresholds to limit smoking effects on people. Given our knowledge that high speeds increase the likelihood of a car crash as well as damage during crashes, the need for risk analysis and management are obvious. Because heavy metals (for example, elemental Hg, Cd, and Pb) in the environment have been documented as a threat to human health, risk management is used to limit heavy metal deposition to the environment and human exposure.

3. What is the first step in ecological risk management?

Ecological risk management aims to limit damage to various aspects or components of ecosystems, including natural resources such as wildlife, forests, or landscapes with high recreational or aesthetic values. Valuable ecosystem services include water cleansing and nutrient recycling, and fisheries production. In the U.S. and most other democratic countries, identification of the ecosystem aspects or components worthy of protection is decided by society based on a process such as executive or legislative actions or direct citizen voting. For example, the Texas Legislature passed Senate Bills 2 and 3, both of which call for *identification of environmental flows required to protect a sound ecological environment.*

4. What if knowledge is incomplete regarding relationships and outcomes?

This will virtually always be the case for risk management. If all relationships were well understood and outcomes could be predicted with great precision and accuracy, there would be no need for risk analysis and risk management would be a trivial problem. Risk implies that there is uncertainty. We are forced to make important decisions "based on the odds". Everybody is familiar with the following desperate question: "What are my chances for surviving this doctor?" The doctor never answers: "Your chance of survival is precisely 43.597 to 1." The patient probably wouldn't want to give up simply because his/her assessment for survival was given as a value less than 50/50. *Risk analysis and management are the means to make optimal decisions in the face of uncertainty.*

5. How does one select a level or value to provide enough protection?

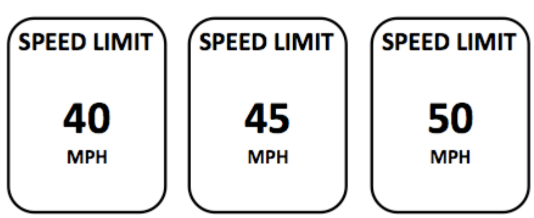
Given that risk analysis seeks to optimize decisions in the face of uncertainty, an important directive is the *precautionary principle*. The precautionary principle states that if uncertainty is large and the stakes are high, the margin for error should be skewed towards the end of the scale that enhances protection. For example, if you know that a chemical is extremely toxic (arsenic), one would want to limit its consumption to an extremely low level. A less toxic, yet potentially harmful substance (nicotine) might be permitted in larger doses.

Obviously, a variety of factors influence application of precautionary principle. The relative value of interrelated components and potential tradeoffs are assessed. How damaging is the negative outcome? (Heart attacks kill people.) What are the broader opportunity costs in terms of other benefits of setting the protection higher or lower? (I will be little safer on the highway, but how much longer will it take me to get places?) Are there other potential negative outcomes strongly or weakly correlated with the outcome we are trying to manage? (If I eat healthier food, my risk of a heart attack will be lower, and my risk of diabetes will be lower also.)

6. How do you know when the protection level you have selected is the correct value?

By definition, in risk management one never knows this with 100% certainty. The process of risk assessment involves empirical research with statistical analyses to derive probabilities (e.g., drug dose responses, epidemiological statistics, etc.) and modeling to estimate probabilities. Once the probabilities have been derived or estimated, the precautionary principle takes effect. A sub-directive of the precautionary principle is to avoid damage that is difficult or impossible to reverse. If setting a threshold higher incurs little opportunity cost and provides for lower risk, and setting the same threshold lower incurs no opportunity cost but high risk of irreversible damage, then the logical choice is the second option.

Let us consider again the example of traffic safety. What is the correct value for limiting speed on a given stretch of highway? We have three options, what is formula for choosing the correct speed limit? There is no formula for this, and likely never could be one. Should we try to set a speed limit with greater numerical precision to reduce risk? Perhaps instead of 45 mph, the better value is 47.65 mph.



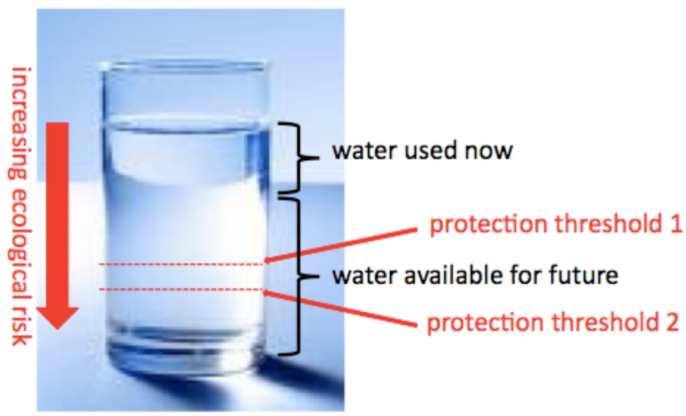
One could image a scenario in which 50 mph is selected for a stretch of highway. After two years of implementation, assessment reveals that there were 85 crashes including 6 fatalities on this stretch of highway. As a consequence, the speed limit is adjusted down to 40 mph. This is adaptive management. This scenario also represents risk management performed without benefit of the precautionary principle, and considerable harm was done as a result.

7. How would this work in ecological risk assessment?

Consider two examples involving human appropriation of surface water resources. The first scenario (essentially a worst-case scenario) has already happened. With the growth of Miami and nearby metropolitan areas along the southeastern Florida coast, water projects increasingly diverted water from the Kissimmee River/Lake Okeechobee drainage, which reduced the overland flow of water through the Everglades and Florida Bay. Great quantities of water were diverted through a canal system for urban and agricultural uses. This infrastructure was built up over several decades, but at some point people became concerned that the Everglades ecosystem was being damaged because of lack of water. These concerns increased until a point was reached in which society valued the Everglades and Florida Bay resources more than the agricultural interests. In the past two decades, massive investments have been made for restoration of the Everglades and Florida Bay. Millions, if not billions, of dollars have been invested in research and restoration activities. Clearly, risk was not managed well in this system, and restoration is much more expensive than conservation.

The second scenario is happening every day in river basins all over the world. Imagine that a local community is assessing the costs and benefits of surface water allocations to meet human needs in the future. It is easier to estimate the amount of surface water that is available at present and in the future than it is to estimate the complete set of ecological values (ecological components and processes) and risks associated with each of them. The ecological risks associated with water diversion likely are quite large. If there is great uncertainty associated with ecological protection thresholds, the precautionary principle of risk management dictates protections that minimize damage to the ecological values. If the set of anticipated new water rights do not need to be allocated immediately, there is little or no opportunity cost associated with conservative ecological protection thresholds that minimize the probability of doing serious irreversible damage (*sensu* the Everglades).

We can illustrate this logic using a glass of water. If we have a fixed amount of water available for allocation to the ecosystem and society, and if we have two options for a protection threshold, and if there is uncertainty inherent in this decision, then it is illogical to select the lower protection threshold (threshold #2). This is because there remains time to conduct further risk analyses, perhaps with new methods and better conceptual models, and to learn from adaptive management (i.e., essentially trial and error with monitoring and evaluation). It would make no sense to select the lower threshold, because the risk of damage is great and the benefit of doing so at the present time would be nil.



This last example is exactly the scenario we face in many river basins and sub-basins in Texas. According to the tenets of risk management, there is no need to set risk thresholds at levels yielding no immediate benefits in the near term, and at the same time create great potential to incur large and irreparable damage to ecosystems and the natural resources and values they embody. The precautionary principle always applies to risk management. Given that some time is available for further risk analysis, the precautionary principle increases the likelihood that costly or irreparable damage can be minimized.

To Learn More About Ecological Risk Assessment

EPA's Guidelines for Ecological Risk Assessment. Published on May 14, 1998, Federal Register 63(93):26846-26924.

Suter II, G.W. 1993. *Ecological Risk Assessment*. Lewis Publishers, Boca Raton, FL.