SOCIAL AND ECOLOGICAL CHALLENGES WITHIN THE REALM OF ENVIRONMENTAL SECURITY

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Abstract: Here we provide a brief discussion of the key principles of ecology and risk required to successfully manage natural resources and maintain environmental security. These ecological principles represent the context within which all economies function; the set of rules that—even if violated in the short-term—over the long haul will define the boundaries of our actions. The risk assessment framework offers a way of organizing information, which then allows us to pose critical questions and find the answers needed to effectively manage our pursuit of triple-bottom-line sustainability.

1. Introduction

As governments and societies evolve their understanding of prospective acts of terror, environmental security has come to the fore as a prominent topic. This public discourse has led to a broader appreciation of the deep connection between societal well being and ecological systems. On one level, we know sustained economic prosperity links directly to "surplus" ecological resources; that is, goods and services acquired by society from ecological systems. Surplus resources are those that are regenerated within some reasonable period through conversion of solar energy into food, fiber, or some other humanly accessible commodity, such as timber, or service, such as the assimilation of human-generated nutrients by wetlands. Thoughtful extraction of minerals and fossil fuels also can be managed to provide sustainable social structures and minimize impacts to ecological systems.

On another level, there exists only a poor recognition by societies of how ecological systems function, even those functions tightly woven into the global economy. Confrontations over energy supplies and clean water dominate contemporary news. Managers responsible for supply of these resources are acutely aware of the vulnerability of energy supply routes, surface waters, and aquifers to intentional acts of aggression, mischief, or accidents.

Here we provide a brief discussion of the key principles of ecology and risk required to successfully manage natural resources and maintain environmental security. These ecological principles represent the context within which all economies function; the set of rules that—even if violated in the short-term—over the long haul will define the boundaries of our actions. The risk assessment framework offers a way of organizing information, which then allows us to pose critical questions and find the answers needed to effectively manage our pursuit of triple-bottom-line sustainability.

2. Ecological Imperatives

Ecology, like other sciences, is value neutral [8]. Perceptions of utility, aesthetics, and worth emerge from our sense of place, cultural legacy, and contemporary traditions. Influenced by life experiences and new knowledge, perceptions change. This dynamism of perception leads to differences in values among different peoples, uncompleted reflections of our varied cultural, ethnic, class, gender, and age-related experiences. Implicit in this understanding is the sobering realization that ecological systems will function at some level with or without humans. The recognized societal value of a mangrove swamp, coastal salt marsh, king salmon, or any other ecological entity is just that: a societal value. If a mangrove swamp is eliminated, some other vegetative cover type, with a different suite of plant and animal associates, will occupy that space. The altered landscape will have different properties, different rates of productivity, and different quantities of surplus materials that we might exploit, but there will be a functional ecological system.

Economies, whether explicitly acknowledged by society or not, are based on the flow of ecological goods and services. The relationships between economic and cultural prosperity and ecological systems become clear when catastrophic events such as droughts, floods, unseasonal cold snaps, excessive heat, and other events disrupt food production. More subtle disturbances also occur, often with great economic consequences, such as the spread of disease or the introduction of exotic species [9].

Insights that emerged following discoveries of May [14] and others (as cited by Gleick [6]) provide the foundation for understanding ecological systems as chaotic entities that demand new ways of thinking about predictions of ecological conditions. We now know that ecological systems are self-organizing, complex, multidimensional, nonlinear, and dynamic entities. Equilibrium is never attained; one part of a system may appear to be in stasis, but other parts of the system are not. Historical events determine current and future structures and past conditions cannot be repeated. Collectively, these conditions render the forecasting of future system states tenuous at best [13].

Several aspects of ecological systems confound our ability to make predictions. A key factor relates to the rate at which ecological processes play out. The ebb and flow of populations and species assemblages across a landscape are tempered by multiple internal and external factors including climate, weather, predation, disease, and competition for limited resources. Collectively, these dynamic responses can give a sense of direction to the resource, such as progression to a long-lived forest type from the time of the last disturbance. However, short-term trajectories (in an ecological sense) may give false indications of long-term trends (predictions desired by an economic society). Coincidental "fortuitous environmental changes" that align nicely with a particular policy hypothesis also can be misleading.

Predictions also are made difficult due to actions of multiple stressors. In any environmental setting, multiple parameters influence organisms, populations, and ecosystems. For example, there can be several metal and organic substances, biotic interactions, and physical conditions present at any given time. Across a landscape, exposure to these parameters varies from locale to locale and over time.

Arguably, no organism resides at the optimum position for all of its niche parameters. In other words "stress" is a constant. However, physiological mechanisms provide organisms with the means of finessing the effects of specific stressors through the adjustment or realignment of baseline optimal conditions. For example, as the weather changes from spring through fall, plants effectively shift their response to temperature, gradually adjusting to warmer conditions in spring and then reversing this trend in the fall. In northern temperate climates, temperatures readily tolerated by plants in April or May can be fatal when they occur in July or August. Anticipation [18] and acclimation are important survival mechanisms for organisms. In addition, the cumulative effects of stressors confound predictions of their effects.

Complex stressors are those that cause different effects under different circumstances [4]. Examples of this include differential responses to essential nutrients across the range of concentrations from deficiency through sufficiency and finally to toxicity. With essential nutrients, there are differential responses to a given nutrient depending on the co-occurrence of paired nutrients (e.g., copper and molybdenum). Similarly, response to a stressor depends on the degree to which the exposed organisms are acclimated or adapted to the particular stressor. Most interesting are the situations in which the sequence of exposure to different stressors results in different ecosystem-level responses [5].

The implications of responses to a set of complex stressors in ecological risk assessment can be quite profound. Though some of the better studied relationships (such as elemental pairs copper:molybdenum or zinc:cadmium, as well as pH:ammonium) are often considered, responses to complex stressors, if acknowledged at all, are seldom incorporated into risk assessments. When monitoring an ecological system as a means of evaluating the predicted consequences of a release, complex stressor interactions could be highly significant.

Slight variations in initial conditions of a population, community, or ecological system and the magnitude of a stressor can have profound consequences. In other words, responses are not proportional to the magnitude of stress across the full range of possibilities. Most of us are aware of common examples that illustrate this point—a 5°C temperature change (say from 25°C to 20°C) on a given day would not be terribly disruptive to us, but a shift from +1°C to −4°C would have much larger importance to organisms unaccustomed to freezing conditions, such as citrus trees. Similarly, we can observe major changes with over-harvest of timber, excess harvest of fish, diversion of water from estuaries, and many other scenarios. The concept of a tipping point [2] applies to societies and to ecology; societies after all are subcomponents of ecological systems. We should anticipate that terrorist activities, as well as the presumably benign actions of others, can have profound consequences to ecological systems, especially when the actions occur near a tipping point.

A common concern of environmental management and the focus of ecological risk assessments is the establishment of a reference baseline condition that can be used to evaluate pre- and post-conditions for specified endpoints. The rationale for establishing a reference baseline carries some intriguing philosophical baggage [10, 11, 20]. Implicit in the pursuit of the baseline is an assumption that a stable ecological condition would exist, but for the actions of humans. With or without humans acting on the landscape, climate-driven ecological succession has been occurring; in the Northern Hemisphere the most recent episode is being shaped by changes since the last glacial epoch waned some 10–15,000 years ago.

Humans have a philosophical penchant for embracing constancy [17] even when compelling data to the contrary exist. The search for a reference baseline reflects this penchant, but need not be crippling. Though the search for this elusive ecological baseline is difficult, we can describe a snapshot view, a fixed point in time, in which we characterize static conditions [12]. After selecting some desired prior landscape condition, ecologists, it would seem, have an obligation to clearly describe those conditions that are possible and those that are unattainable. Even so, there remain many challenges in monitoring the changing status of those conditions, and many other confounding factors need to be acknowledged [7].

The linkage of economy to ecology relies on the rates of change of critical resources and ecosystem functions [15, 19]. As a change in availability of a resource occurs, there must be corresponding changes in the economy (such as price changes or restraints on demand). If the ecological changes are rapid, there are likely to be disruptions within the economic system before society develops a means of coping with the new realities. In this sense, one aspect of environmental security is the alignment of economics with the anticipated flow of ecological goods and services—including preparedness for the range of scenarios that entail the need for rapid response (for example after an act of terrorism or a natural disaster) and more deliberate responses (such as those associated with climate change or invasive species).

3. Risk Assessment

Risk assessment is one of the most powerful tools available to manage environmental security. An assessment begins with problem formulation, a phase of work that explicitly acknowledges the management goals and decisions that are to be made [21]. Diverse stakeholder input is central to developing a good risk assessment and this should begin with the earliest stages of work.

Tools are available to guide the elicitation of stakeholder values as well as to engage stakeholders in the decision process [1]. The degree of success in reaching consensus is directly related to the timing of communications and clarity of each stakeholder's role. If the goal genuinely is to obtain meaningful input from stakeholders, it is critical to engage in dialogue before decisions have been made; *telling* is much less successful than *asking*. In the arena of environmental security, emotions are already high, so efforts to conduct dialogues calmly become most important.

The steps of problem formulation normally articulate the boundary conditions of a risk assessment through unambiguous statements regarding the values to be protected, also known as assessment endpoints. The assessment endpoints guide the selection of measurements (measurement endpoints) and models that are used to characterize the risks. Typically, pictorial and narrative descriptions are organized into one or more conceptual models that depict the functional relationships between pressures or stressors and the values to be protected. Iterative passes through the conceptual model are needed to refine it and hone in on the assessment and measurement endpoints. Determination of the information needed to complete a valid risk assessment provides the foundation for defining data quality objectives, producing a sampling and analysis plan, and proceeding through the analysis and characterization stages of the assessment. A crucial aspect of problem formulation is the understanding of the ecological setting or context that the analysis is to address; here the ecological imperatives described previously are paramount.

The risk assessment approach has particular application for environmental security. Risk, in the final analysis, is about evaluating scenarios. The outcome of a risk assessment is an estimate of the probability of different scenarios occurring. Input to the analysis of scenarios can be an admixture of quantitative and qualitative observations and direct measurements or modeled projections. The output can be organized to feed these data into multicriteria decision analysis programs. In the end, by varying different input parameters of the scenarios, the sensitivity of the various inputs can be evaluated.

In the interplay of policy and regulatory actions, varying degrees of tension inevitably arise due to differences in stakeholders' tolerance or acceptance of environmental risk. These tensions often are created as a direct consequence of the processes followed in reaching decisions, but there is much more. Explorations from nearly two decades ago into risk perception have provided powerful insights into the way people handle multiple forms of information as they make decisions (Table 1). In general, we can conclude that scientific or technical descriptions of a risk event or activity form only a small part of the body of information that people process as they consider accepting or rejecting the risk. Those science-based or technological features are largely limited to understanding the mechanisms and characterization of uncertainty. From the regulatory side, the most critical feature influencing public acceptance of decisions is trust in the responsible institution. Many of the remaining features relate in one form or another to communications and the degree of control that the public feels it can exercise, either directly or indirectly. Historically, public notice and public hearings and comment periods have been the primary means for public input into the environmental management regulatory process. As the regulatory process evolves to meet current challenges, there are opportunities to achieve the goals of public input in ways that are more satisfying to all stakeholders and simultaneously streamline the process so that efforts can be focused on issues in proportion to the importance of the issues. One approach that is effective in gaining trust and transferring an appropriate level of control to public groups is the Consensus Based Environmental Decision (CBED) procedure standardized recently by the American Society for Testing Materials International [1].

Within the regulatory arena, many well intentioned policies and laws are operational. Unfortunately, most, if not all, policies and laws were crafted without consideration of contemporary ecological insights. As such, policies often have unintended consequences. In some instances, rigidity of prescriptive measures stifles innovation or at least provides the foil for inaction.

As we move into the next generation of environmental management, we ought to embrace the insights of contemporary ecology and related socioeconomic advances. In her delightful commentary on the Hierarchy of Influences, Meadows [16] describes the 12 touch points or nodes where people can attempt

TABLE 1. Factors Important in Risk Perception and Evaluation [3].

Factor	Conditions associated with increased public concern	Conditions associated with decreased public concern
Catastrophic potential	Fatalities and injuries grouped in time and space	Fatalities and injuries scattered and random
Familiarity	Unfamiliar	Familiar
Understanding	Mechanisms or process not understood	Mechanisms or process understood
Uncertainty	Risks scientifically unknown or uncertain	Risks known to science
Controllability (personal)	Uncontrollable	Controllable
Voluntariness of exposure	Involuntary	Voluntary
Effects on children	Children specifically at risk	Children not specifically at risk
Effects manifestation	Delayed effects	Immediate effects
Effects on future generations	Risk to future generations	No risk to future generations
Victim identity	Identifiable victims	Statistical victims
Dread	Effects dreaded	Effects not dreaded
Trust in institutions	Lack of trust in responsible institutions	Trust in responsible institutions
Media attention	Much media attention	Little media attention
Accident history	Major and sometimes minor accidents	No major or minor accidents
Equity (also related to environmental justice)	Inequitable distribution of risks and benefits	Equitable distribution of risks and benefits
Benefits	Unclear benefits	Clear benefits
Reversibility	Effects irreversible	Effects reversible
Origin	Caused by human actions or failures	Caused by acts of nature or God

to manage systems (Figure 1). She points out that, ironically, people tend to focus first on the nodes of lesser importance (i.e., 12, then 11, and so on), to the overall drivers of the system, probably because they are easier.

The current paradigm of energy security is "protect the source at all costs," and the only source considered is fossil sun. Energy security becomes national security, and national security has morphed to include environmental security. The current atmosphere in which we discuss environmental security focuses much on numbers (attacks, cells, immigrants), stocks (monetary, energy), on down to the rules of the (current) system. The perceived risks of direct attacks on our supporting ecological systems bind tightly to those numbers and rules. Meadows' key point, and the reason that the power to transcend paradigms comes first in the hierarchy, refers to the unspoken certainty that the current paradigm of environmental security thinking is the only paradigm. Letting go of that certainty and opening up to the idea of

12. Constants, parameters, numbers
11. The sizes of buffers and other stabilizing stocks, relative to their flows
10. The structure of material stocks and flows and nodes of intersection
9. The lengths of delays, relative to the rate of system changes
8. The strength of negative feedback loops, relative to the impacts they are trying to correct against
7. The gain around driving positive feedback loops
6. The structure of information flows
5. The rules of the system
4. The power to add, change, evolve, or self-organize system structure
3. The goals of the system
2. The mindset or paradigm out of which the system arises
1. The power to transcend paradigms

Figure 1. Hierarchy of Influences [16].

multiple, interlinked ways of dealing with our interactions with local ecologies and global ideologies reveals where the power of paradigm resides.

Surfacing our assumptions about the ruling paradigm allows for the depiction of an even greater set of possible system transformations. The strategies used by systems ecologists in framing complex socioecological interactions mesh cleanly with the formalisms of integrated risk management. Managing for environmental security presents many challenges. To be successful, it is essential that the ecological context of different scenarios be understood and that a diverse range of affected stakeholders is engaged. An integrated risk assessment approach can provide the framework for exploring various scenarios.

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