CHAPTER 12

Validation of Indicators

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ASSESSING the health of any ecosystem requires the measurement of a number of indicators. For an assessment of ecosystem health to have real value, it must not only address status, but also evaluate the risk of that status changing to a less healthy state. Although numerous indicators of ecosystem health have been proposed (Rapport et al 1985; National Research Council 1993), few have been tested to date. Such testing must incorporate evaluation of the indicator's sensitivity so as to provide unambiguous and reliable values for the assessment of ecosystem status. Indicator sensitivity must also be known so as to enable an evaluation of the risk of change in the health status of the ecosystem.

Analogous to indicators of human health, indicators of ecosystem health must change in predictable, repeatable ways when ecosystems shift to a less healthy condition. Sensitivity testing of these indicators must be the first step in evaluating analyzing indicators intended for assessment or monitoring purposes. Sensitivity testing is a necessary calibration step that must be carried out before potential indicators become incorporated into an assessment or monitoring system. The sensitivity of human health indicators (for example, blood tests, X rays, body temperature, heart sounds, pulse, and blood pressure) has been determined by recording many thousands of measurements of healthy and sick patients in order to identify the average values and range of values for healthy humans. Obviously, this approach cannot be used in ecosystem health—we cannot afford to lose ecosystems that are unhealthy and do not have the luxury of beginning to make measurements now in order to demonstrate how sensitive an indicator will be in a century or two. Ecosystem health assessments require sensitive indicators immediately.

Indicators of ecosystem health are classified into one of two categories: ecosystem process measurements or ecosystem property measurements. Measurement of ecosystems processes, such as primary production (rates of energy fixation), energy flow (rates of transfer of energy between trophic levels), and rates of nutrient cycling, requires expensive, complex, and time-consuming analyses.

As a consequence, indicators of the health of ecosystem processes frequently encompass properties that are clearly linked to the ecosystem process. These properties can be measured by point-in-time measurements. Such measurements can generally be made without expensive instrumentation and in a short period of time.

BENCHMARK SITES

Calibration and sensitivity testing of ecosystem health indicators can be performed by substituting space for time. The space (sites where measurements are made) is selected on the basis of available historical records. Places with documented histories of degradation or change in state can be compared with other places with documented histories of little or no degradation or change in state. In many cases, gradients of change may exist—from large change to imperceptible; such sites are very valuable for testing the sensitivity of indicators (deSoyza et al 1997). We obtain values for indicator sensitivity by measuring the responses of indicator variables across a series of sites with documented levels of exposure to environmental stress or with documentation of a variety of ecosystem changes over time that, in total, have resulted in ecosystem degradation.

For indicators of ecosystem health, the timing of measurements may be as critical as the actual measurement. For example, measurements of vegetation parameters that are related to primary productivity are best made at the end or peak of the growing season. Measurements made too early or too late could give erroneous results.

FIELD MEASUREMENTS

When assessing or monitoring the health of ecosystems, the field measurements must be rapid, repeatable, and not subject to observer bias. Such measurements should provide data about the health of both abiotic and biotic parts of the ecosystem. In addition, field measurements that can be used to calculate more than one indicator metric are especially desirable. For example, when assessing or monitoring rangeland health, the species composition and cover (percentage of surface covered by a species) can be used to calculate indicator metrics that relate to ecosystem properties such as productivity, biodiversity, resistance to wind and water erosion, and economic potential. In an aquatic ecosystem, density and species composition of benthos, dissolved oxygen, chlorophyll content, and species composition of the fish community are properties that could be used to calculate several indicator metrics that are related to ecosystem function (Fore and Karr 1996; Small et al 1996).

COMPUTING INDICATOR METRICS

Raw measurements from the field or simple average values may not be the best indicator metrics for assessing or monitoring ecosystem health, however. A more effective tactic may be to examine the statistical properties of certain measurements to determine whether the statistical properties are better metrics than are the mean values. In some cases, variance changes may prove more informative or more sensitive than changes in the mean.

In one example of how the statistical properties of a measurement are used in ecosystem health assessment, the size of unvegetated patches has been determined in desert rangeland ecosystems (deSoyza et al 1997). Their size, which was measured by length of patch intercepted by a line (a percentage of the total length of line), proved to be related to a number of ecosystem processes, such as wind and water erosion, productivity, biodiversity of the soil flora and fauna, water infiltration, and soil nutrient distribution. When this measurement was made on a series of benchmark sites that provided a gradient from completely degraded (unhealthy) to completely functioning (healthy), however, mean bare patch size did not vary with the gradient. The frequency distribution of bare patch size offered a somewhat better metric; when tested against the benchmark gradient, however, it did not provide an interpretable pattern. When the frequency data were log-transformed and used to calculate a skewness value, a pattern emerged with respect to the gradient. The divergence from a normal distribution was indicative of system degradation and could be quantified by the skewness statistic. An early manifestation of disturbance in these desert rangeland ecosystems is a small increase in size of bare patch but a larger increase in the number of large bare patches, which is expressed as skewness to the right. As the ecosystem degrades, larger bare patches become abundant and small bare patches appear only rarely, which skews the frequency to the left (Figure 12.1). An even better correlation between bare patch size and degradation gradient was obtained by multiplying the skewness statistic by the mean bare patch size to obtain a weighted skewness (Figure 12.2).

Indicator metrics need not only involve single measurements. Frequently, combined measurements or ratios emerge as the most sensitive indicators when tested against an unhealthy–healthy benchmark gradient. The selection

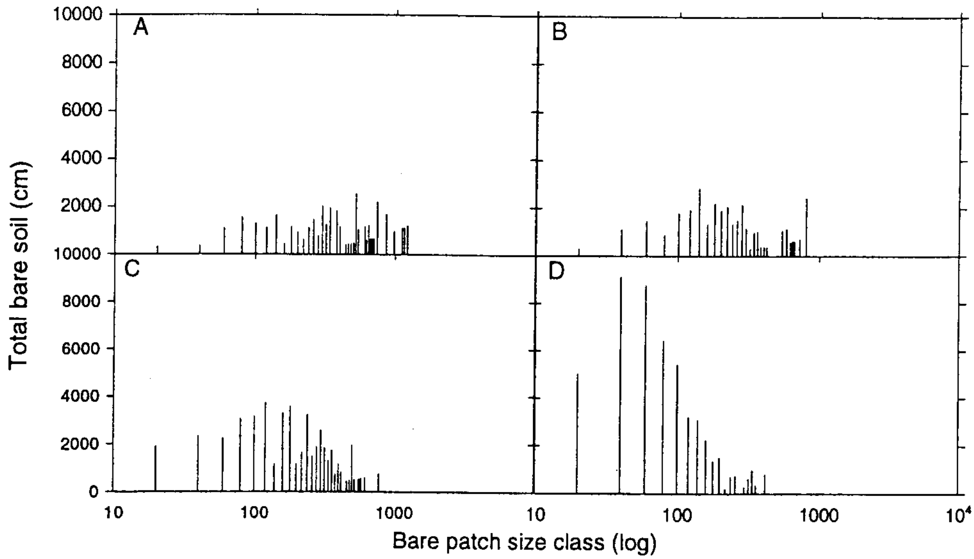

FIGURE 12.1. *Frequency distributions for bare soil patches at Camp Well. A = distribution at CWO, 50 m; B = distribution at CW1, 200 m; C = distribution at CW2, 400 m; D = distribution at CW3, 1050 m. The x-axis is log scale.*

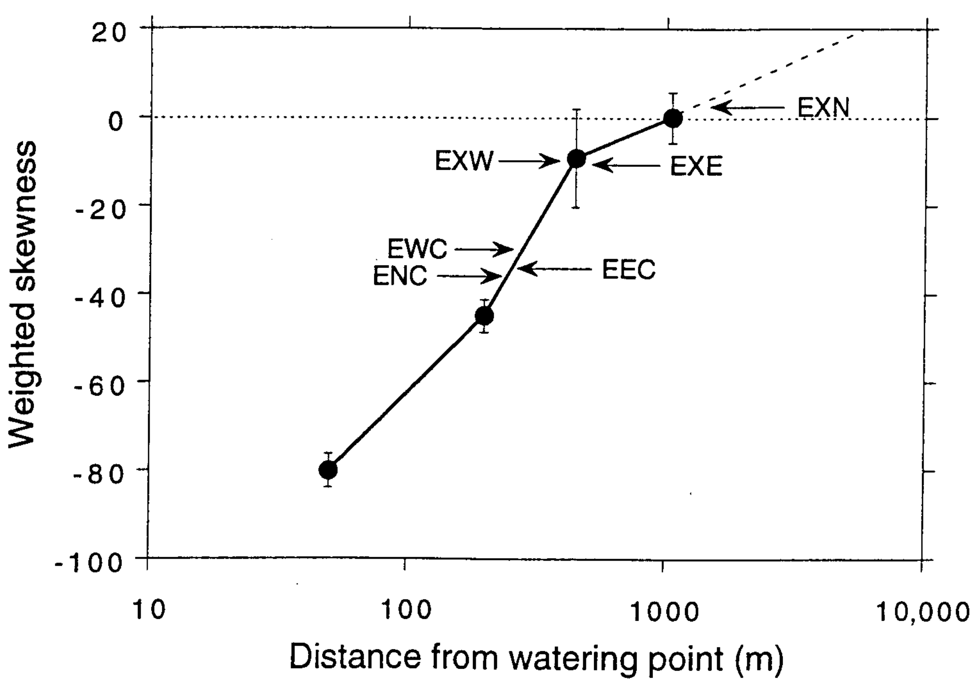

FIGURE 12.2. *Weighted skewness for log-transformed data (skewness statistics × mean bare soil patch size) plotted as the mean for the three disturbance gradients. Also shown (arrows) are the relative positions of bare patch weighted skewness for the ungrazed enclosures and the adjacent grazed pastures. Error bars indicate standard error. ENC = north grazed pasture; EEC = east grazed pasture; EWC = west grazed pasture; EXN = north enclosure; EXE = east enclosure; EXW = west enclosure.*

of metrics and their interpretation with respect to ecosystem function remains dependent upon the type of ecosystem under study. The most important step in the calibration or sensitivity testing of indicators is the selection of as wide a gradient of unhealthy to healthy benchmark ecosystems as possible. The selection of appropriate benchmark ecosystems may depend in part upon the kinds of stressors to which the ecosystem is exposed, but the availability of documentation of the system's degradation history is the most important criterion for selecting benchmark systems.

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