Case Studies in Developing Rangeland Sustainability Indicators: Scale Matters

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Introduction Several new monitoring systems that rely on ecosystem sustainability indicators" are being developed and used in California . Indicators ideally are ecosystem attributes that can be measured over time to determine whether specific management goals and objectives are being achieved . We argue that attempting to apply one set of indicators to all cases repeats a long history of inappropriate generalization of ecological science . Instead , a tool box of broadly accepted indicators from which managers can select to meet specific needs better recognizes diverse ecological , social , and political contexts (Harris and Hobbs 2001) . To be practical , indicators must fit the situation--in particular local capacity for consistent application , address the important questions (Ford and Huntsinger 2007) , and provide meaningful data . Indicators should be based on what we know about how systems work , and should be dynamic as more data is collected and interpreted and understanding of system structure and function increases . One of the primary purposes of indicators is to challenge assumptions and identify knowledge gaps , replacing them with more reliable , data-driven information .

Goals for indicator monitoring systems often include terms such as sustainability , productivity , integrity , and health . These inter-related terms should be defined (sensu Battles (pers .comm) and Harris and Hobbs 2001) as demonstrations or tests of rangeland ecosystem :

- productive capacity
- desired biological community composition and structure
- ability to recover from stress (chronic and cumulative in its effect , e .g . heavy grazing) and from disturbance (sudden and often severe effect)
- production of economic , social , and aesthetic benefits to the owner , manager , and local communities , in order to maintain economic and social viability .

Methods We use case study analysis of three indicator development projects to discuss how indicators , to be effective , need to be scale-sensitive , temporally as well as spatially .

Results and discussion The first case study is a grassroots effort by ranchers on California's central coast to develop an indicator system with currency among the ranching community , ecological scientists , agency managers , and the public . A second case is California's statewide assessment of rangeland conditions and sustainability , conducted at the level of the state government and for the state legislature . A final case is the well-known Montreal Process , and the five criteria and 28 indicators developed as part of that process . For each of these initiatives , we examine the indicators in the light of their applicability at particular scales , their commonalities and differences , and issues of application and implementation . We will discuss criteria for appropriate selection of indicators for particular situations , and issues of application and relevance .

Conclusions We return to the underlying foundation of our understanding of basic factors driving rangeland ecosystems , and the link to sustainability indicators . Models of ecosystem function , for example , should be evaluated for their repeatability over time and space to determine whether they are generalizable or idiosyncratic , and based on experimentation should be explicitly linked to spatial and temporal scales and the identification and potential revision of indicators . Indicators , therefore , to be useful , must be explicitly tied to a spatial scale . A critical consideration is that processes that occur at one level of a system may not be indicative of dynamics at higher or lower levels (Allen and Starr 1982) .

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