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Synthesis

Interpreting and Correcting Cross-scale Mismatches in Resilience Analysis: a Procedure and Examples from Australia's Rangelands

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ABSTRACT. Many rangelands around the globe are degraded because of mismatches between the goals and actions of managers operating at different spatial scales. In this paper, we focus on identifying, interpreting, and correcting cross-scale mismatches in rangeland management by building on an existing four-step resilience analysis procedure. Resilience analysis is an evaluation of the capacity of a system to persist in the face of disturbances. We provide three examples of cross-scale resilience analysis using a rangeland system located in northern Australia. The system was summarized in a diagram showing key interactions between three attributes (water quality, regional biodiversity, and beef quality), which can be used to indicate the degree of resilience of the system, and other components that affect these attributes at different scales. The strengths of cross-scale interactions were rated as strong or weak, and the likely causes of mismatches in strength were interpreted. Possible actions to correct cross-scale mismatches were suggested and evaluated. We found this four-step, cross-scale resilience analysis procedure very helpful because it reduced a complex problem down to manageable parts without losing sight of the larger-scale whole. To build rangeland resilience, many such cross-scale mismatches in management will need to be corrected, especially as the global use of rangelands increases over the coming decades.

Key Words: *Cross-scale interactions; land management; landscape processes; scale effects.*

INTRODUCTION

Human-controlled disturbances can cause loss of natural resources and reduced productivity. Land management practices need to focus on minimizing these undesirable outcomes. A testable principle is that, if a system, such as a rangeland, is well managed at all appropriate scales, it will have lower economic and social costs in the long term than if it is poorly managed at one or more spatial scales (Fernandez et al. 2002). This is especially true if the system is affected by both strong and weak management actions that mismatch across scales (e. g., Olsson et al. 2004). The principle, including cross-scale mismatches in management actions, can be explored using the construct of system resilience (Gunderson 2000) and by extending the procedures of resilience analysis (Walker et al. 2002).

The resilience of a system has been defined as its capacity to persist in the face of disturbances (Anderies et al. 2002). For example, a resilient rangeland, when disturbed, maintains and reorganizes its key attributes, including essential landscape structure (e.g., vegetation patchiness), processes (e.g., nutrient cycling), and functions (e. g., productivity). Resilience needs to be measured relative to a specific system attribute and scale, and to a specific disturbance (a natural event or management action), that is, the resilience "of what to what" (Carpenter et al. 2001). An example is a rangeland manager's goal to maintain profitable cattle production on a property ("of what") in the face of a natural event such as drought and a management action, such as destocking ("to what"). Thus, the problem becomes one of defining and measuring the key attributes of a system's resilience relative to a given purpose and spatial scale, and analyzing the effect disturbance has on these

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attributes at this scale, and across other scales (Gunderson and Holling 2002, Walker et al. 2004).

A four-step resilience analysis procedure has already been devised in which a system, such as a rangeland, and its key attributes (of what) and issues (to what) are defined, measured, and critically analyzed (Walker et al. 2002). The applicability of the four-step procedure was explored by these authors using a few generalized examples, but specific cross-scale resilience effects and mismatches were not analyzed or interpreted. Investigation of the cross-scale transfer of resilience effects is a new and crucial research area (Carpenter et al. 2001). Identifying and analyzing cross-scale links and interactions is core to understanding the resilience of a system (Fernandez et al. 2002), and coordinating actions across scales has already been shown to improve management in other kinds of agricultural systems (e.g., Peterson et al. 2003, Olsson et al. 2004).

In this paper, we propose a procedure for interpreting and correcting mismatches in the strength of cross-scale management actions that affect a system's resilience. We expand an existing four-step resilience analysis procedure (Walker et al. 2002) by focusing it on cross-scale interactions and effects (hereafter, cross-scale resilience analysis). We extend the question posed by Carpenter et al. (2001) to resilience "of what to what, across what scale?" Cross-scale resilience analysis incorporates possible ways of improving the resilience of a system by establishing a more even balance in the strengths of those cross-scale management actions affecting each key attribute under consideration. We use three examples from a rangeland region in northern Australia to illustrate an application of the cross-scale resilience analysis procedure.

THE FOUR-STEP PROCEDURE WITH CROSS-SCALE EFFECTS ADDED

In the extended procedure, summarized in Fig. 1, groups of stakeholders work through the following four steps (paraphrased from Walker et al. (2002); our modifications are shown in bold text):

1. Describe the system as a box-and-arrow diagram, identifying key components, drivers, processes, and issues operating at different scales, **and use arrow width to illustrate the relative strength of interactions between components that cut across spatial scales**;

2. Describe long-term visions for the system, giving three to five plausible scenarios for achieving these visions, **and focus on any management actions within scenarios that mismatch in strength across scales**;

3. Work with collaborating scientists to explore the scenarios for uncertainties in possible future outcomes, **and interpret any likely effects on outcomes due to cross-scale mismatches in the strength of management actions**; and

4. Evaluate the implications of taking different approaches **to correct cross-scale mismatches in the strength of management actions.**

Typically this four-step, cross-scale resilience analysis procedure would be applied in facilitated workshops using a highly participatory process involving stakeholders, scientists, policy makers, and others concerned with a particular system (e.g., Walker and Abel 2002, Peterson et al. 2003, Olsson et al. 2004). However, for the purposes of this paper, we simply illustrate how the cross-scale resilience analysis procedure is applied using published information for a rangeland system located in the Victoria River District (VRD) of northern Australia, where we have considerable experience (e.g., Ludwig et al. 1999, 2004, Kraatz 2000, Stafford Smith et al. 2000, 2003, Ash and Stafford Smith 2003, Bastin et al. 2003).

APPLYING THE EXTENDED PROCEDURE: EXAMPLES FROM AUSTRALIA'S RANGELANDS

The VRD is primarily used as rangeland, producing beef cattle for live-export markets, but it also serves as a home for Indigenous communities and outback settlements, and as an area for recreation, tourism, and military training. Historically, the VRD has undergone major changes in land use (App.). The current occupants include people managing land at the local scale (i.e., pastoralists, park rangers, military personnel, and Aborigines and European settlers living in stations, communities, and towns).

At a broader regional scale, people living in more distant, larger towns (e.g., Katherine) provide services for those living within the VRD (e.g., trucking firms haul cattle, fuel, and other supplies). At the State/Territory scale, others provide social, economic, and infrastructure support, often from distant cities (e.g., Alice Springs, Darwin). Stakeholders in the VRD have identified key system components, drivers, and issues. These include climate and market variability, economic viability, social adjustment to land-use changes, and natural resource issues such as effective management of fire, grazing, feral animals, and exotic weeds (Kraatz 2000).

In the following three examples illustrating the cross-scale resilience analysis procedure, we have identified and labeled key links between VRD rangeland attributes and management actions (Fig. 2). We focused on those interactions that cut across the scales at which different management groups operate. We simply rated the strength of interactions as strong or weak, based on our understanding of this system. For brevity, we have not attempted to include all components and links in this rangeland system.

Example 1: Landscape Repair

In this example, the key rangeland attribute measured to indicate resilience is water quality (the resilience "of what" in Fig. 1, Step 1]). By mapping interactions across scales as arrows (Fig. 2), we identified strong links between the quality of water flowing from the region (the "across what scale" in Fig. 1, Step 1) and pasture and livestock management practices. Cattle grazing (the "to what" in Fig. 1, Step 2) can strongly influence the condition of local patches of vegetation that function to retain vital resources within pastures (Tongway and Ludwig 1997) (Fig. 2, interaction [1a]). During the 1880–1960 period of frontier settlement in the VRD (App.), extensive patches of vegetation were damaged. This led to increased runoff and soil erosion (Condon 1986). Paddock erosion strongly affects downstream water quality (Fig. 2, interaction [1b]), but monitoring to detect water pollution is limited [1c]. Although water quality standards and regulations exist [1d], imposing these constraints on managers of pastoral enterprises is fraught with legal and political difficulties, largely because identifying and documenting numerous and diffuse sources of soil erosion and water pollution is costly. Even if most enterprise managers are highly effective in controlling cattle in their pastures [1e] pollution can still result from the actions of the few who are not. The contrasting strengths of these interactions identify cross-scale mismatches (e.g., [1b] vs. [1c]). In Step 3, the effects of these mismatches were interpreted (e.g., feedbacks from regional water quality monitoring are inadequate to promote actions that prevent or repair damage to vegetation patches). From this analysis, it can be seen that improving the strength and timeliness of the feedback link from regional water pollution monitoring to the pasture management level is one way to improve overall water quality in the VRD. Working through Step 4 suggested that correction of cross-scale mismatches, such as the above, are likely to be welcomed by people involved in managing rangelands in the VRD. For example, awareness of the importance of monitoring soil erosion and preventing, or repairing, rangeland damage is growing (Karfs et al. 2000, Sullivan and Kraatz 2001). People in the VRD are active in community groups such as LandCare, a formal body supported, in part, by the Australian government.

Example 2: Biodiversity Conservation

The key attribute measured to indicate resilience here is the richness of biodiversity at the regional scale. This is a serious concern for Australia's rangelands because significant losses in biodiversity have already occurred (Woinarski and Fisher 2003). Areas well away from artificial cattle watering points are critical refugia for some plants and animals sensitive to grazing (Fig. 2, interaction [2a]) (James et al. 2000). Rangeland condition is actively monitored in Australia (Ludwig et al. 2004), but the emphasis of monitoring has been on vegetation cover, not biodiversity [2b]. Even though many cattle enterprises have the capacity to incorporate retention of refugia into their pasture and stock management strategies [2d] (James et al. 2000), few do so because government incentives that encourage conservation of biodiversity are weak [2c]. Mapping this issue (Fig. 1, Step 1) revealed these mismatches in the strength of cross-scale interactions (Step 2). When interpreting the mismatches (Step 3), we found that, for economic reasons, some cattle enterprises in the VRD have added fences and increased the number of cattle watering points. This reduces the size of paddocks and enhances water availability. Grazing is then spread more uniformly across the pasture, and cattle numbers and production can be increased. However, this also means there are fewer, or no, areas distant from water, so refugia are reduced or lost. If many adjoining properties in the VRD are intensively fenced and watered in this way, a further loss of biodiversity at the regional scale is likely to occur. One way to correct the cross-scale mismatch between government regulations and policies and rangeland management (Step 4) would be to improve conservation incentives so that people in State/Territory governments, regional communities, and local enterprises share a strong and common goal: to conserve biodiversity while maintaining productive landscapes (James et al. 2000, Woinarski and Fisher 2003). The existence of the Victoria River District Conservation Association, which is a formal community-based organization, suggests that such collaboration could work.

Example 3: Premium Cattle

In this example, the key attribute to measure to indicate resilience is the quality (value) of beef produced from VRD rangelands. Following the same four steps again, we found that producing premium quality beef strongly depends on how well cattle are handled (Fig. 2, interaction [3a]) and, of course, on pasture quantity and quality. The marketing of agricultural goods is changing across the globe, increasingly targeting the sensitivity of consumers about how animals are treated [3b]. However, market premiums for beef produced in a caring way are still relatively small [3c]. If premiums for this quality beef were higher, the economics of beef-producing enterprises would benefit, potentially leading to animal and pasture improvements to continue the cycle [3d]. However, the effect of the cross-scale mismatch between consumer requirements and current premiums would need to be corrected. There are positive signs that this is occurring. The Australian beef industry has responded by developing “CattleCare,” a national-scale accreditation scheme aimed at developing animal-sensitive management practices. The scheme focuses on promoting high quality animal husbandry and careful handling, combined with minimal use of chemicals. State and Territory agencies and regional community groups, including those in the VRD, are changing their mindsets to proactively evaluate the positive benefits that can result from producing and promoting premium cattle (Hunt 2003).

CONCLUDING REMARKS

These three examples highlight the importance of identifying and addressing cross-scale mismatches in management at all relevant scales when looking for ways to improve rangeland resilience. We propose that a cross-scale resilience analysis procedure provides a useful tool to facilitate this process. In an actual situation, correcting mismatches would be arrived at after prolonged consultation between stakeholders at all levels, and the steps we have simply outlined here would be far more complex. Each attribute and its issues would ultimately be incorporated into the decision-making process as a whole and not considered in isolation. The potential value of cross-scale resilience analysis is that it breaks a complex task into more manageable parts that can then be integrated to form a realistic and informative picture on which to base management decisions at multiple scales.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol10/iss2/art20/responses/

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APPENDIX
A brief historical profile of land use in the Victoria River District

This profile is largely based on events described by Duncan (1967), Rose (1991) and Makin (1993). The time-line divisions are arbitrary, but each period is characterized by events that have shaped this rangeland region (a more detailed description and historical profile for the VRD is available from the authors).

- *Pre-1880.* Traditional Aboriginal use of country, such as fishing, hunting, gathering, and cultural ceremonies prevails (Rose 1991). Indigenous family and clan groups managed the country for its natural resources at local scales.

- *1880–1960.* Frontier European settlers start using this country as rangeland. Settlers managed free-range cattle and land at pasture and property scales. Aborigines serve as stockmen (Makin 1993).

- *1960–1990.* Modern use of country by cattle production enterprises, using fencing and artificial watering points, becomes established (Stockwell and Andison 1996). Most enterprises were still managed at pasture-property scales, but often under direction from corporate bodies and under lease agreements with government land management agencies based in distant cities.

- *1990–2005.* National and international nature conservation groups based in cities (e.g., Australian Conservation Foundation and World Wildlife Fund) influence the use and repair of damaged country (Sullivan and Kraatz 2001). Pastoral properties remain locally managed, but now managers use land conservation practices, often through participation in regional community groups.