



Using Structural Equation Modeling to Link Human Activities to Wetland Ecological Integrity at Rocky Mountain National Park



Past Disturbance and Wetland Condition

Wetlands in Rocky Mountain National Park are threatened by a complex history of anthropogenic disturbance, including altered hydrologic regimes, the loss of elk, wolves, grizzly bears, and beaver, and the reintroduction of elk (absent their primary predators) (Figure 1). More recently, nonnative moose were introduced to the region and have expanded into the park. Monitoring data suggest that up to half of the park's wetlands are not in a reference, or healthy, condition.

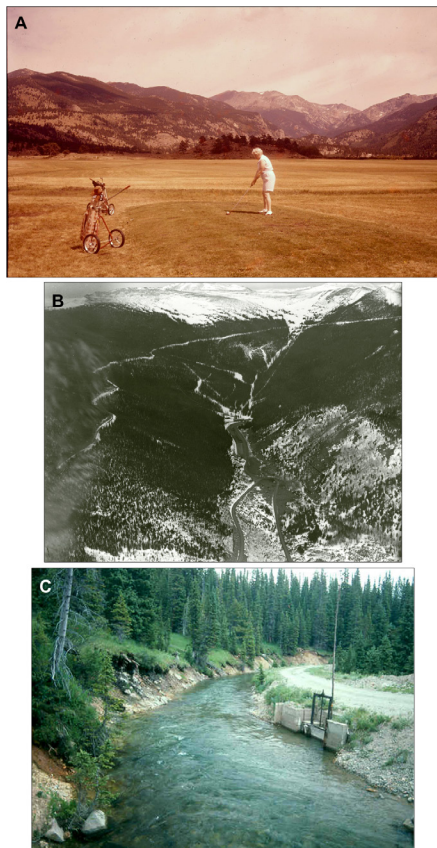


Figure 1. Examples of historical and current small and large scale human disturbances in Rocky Mountain National Park: (A) Moraine Park golf course, circa 1955; (B) Hidden Valley ski area in 1973 showing ski runs, parking areas, an associated blow down, and Trail Ridge Road; (C) the Grand Ditch with its supporting road and a headset in 2014. Images in A and B courtesy of Rocky Mountain National Park. Image in C by D. Cooper.

Understanding Complex Systems

Wetland ecosystem processes are often thought to be controlled by linear trophic cascades, such as wolf > elk > riparian. But other factors, such as the influence of beaver and human disturbances also contribute to wetland integrity. Rocky Mountain Network (ROMN) scientists developed a general hypothesis about how human alterations influence wetland integrity (Figure 2) and evaluated it using Structural Equation Modeling (SEM) at Rocky Mountain National Park wetlands. This type of modeling allows responses to be treated as drivers in linked structural or causal chains. Because this approximates the “complexity of nature,” it may provide more realistic tools for the management of natural resources.

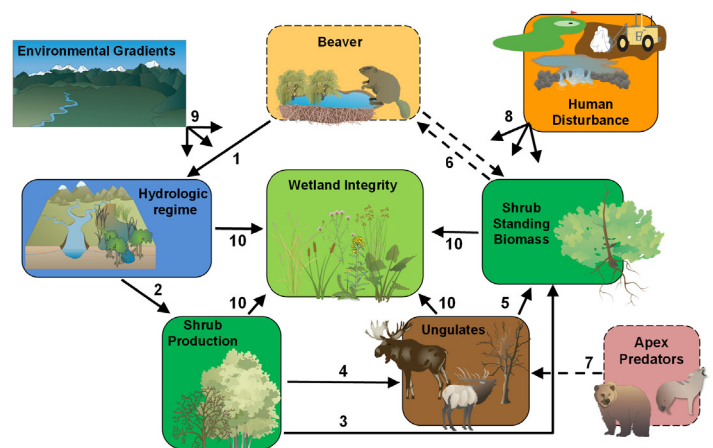


Figure 2. Meta-model representing a general hypothesis of the key inter-relationships driving wetland integrity responses to human activities. Dotted arrows and borders indicate historical relationships or model elements no longer functionally present but included in the model to capture important historical patterns and demonstrate possible restoration avenues. Graphics are courtesy of Integration and Application Network, University of Maryland Center for Environmental Science.

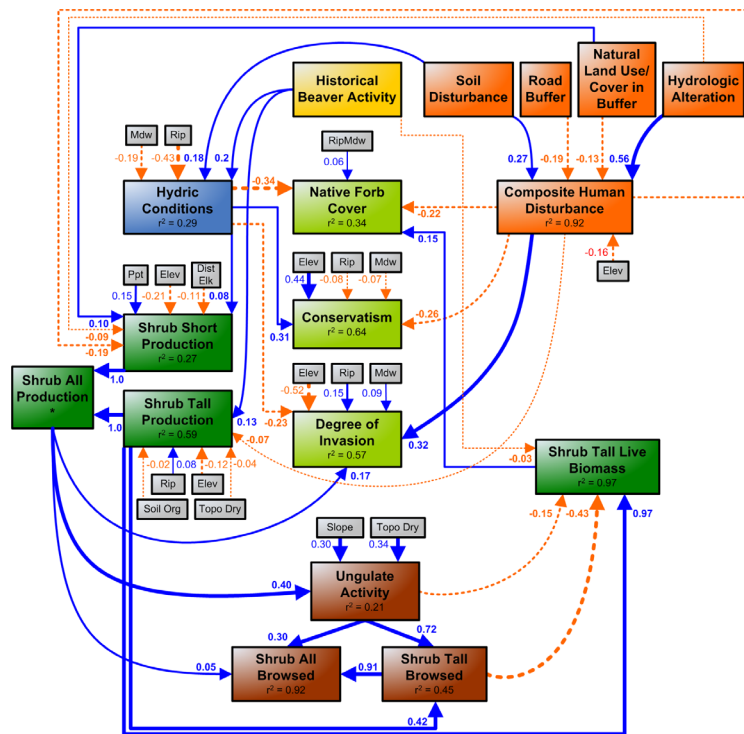


Figure 3. Graphical illustration of a structural equation model for the network of relationships driving wetland condition at Rocky Mountain National Park. The model is the focus of an article by ROMN and other scientists in an upcoming special issue of *Ecosphere* (see full reference below in More Information).

The Model

Based on long-term monitoring data from 124 wetlands in the park, the model identified three metrics that were highly sensitive to human disturbance: native forb cover, conservatism (the degree to which species are obligate to high quality natural areas), and degree of invasion (average invasiveness score of plant species in the wetland) (Figure 3). SEM analyses suggested several ways human activities have impacted wetland integrity and the landscape of the park. First, degradation is highest where the combined effects of all types of direct human disturbance have been the greatest (i.e., there is a general, overall effect). Second, specific human disturbances appear to create a “mixed-bag” of complex indirect effects, including reduced invasion and increased conservatism, but also reduced native forb cover. Some of these effects are associated with alterations to hydrologic regimes, while others are associated with altered shrub production. Third, landscape features created by historical beaver activity continue to influence wetland integrity years after beavers have abandoned sites via persistent landforms and reduced biomass of tall shrubs.

More Information

Schweiger, E. W., J. B. Grace, D. Cooper, B. Bobowski, and M. Britten. 2016. Using structural equation modeling to link human activities to wetland ecological integrity. *Ecosphere* 7(11):e01548. doi:10.1002/ecs2.1548.

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Sites with (A) high and (B) low wetland ecological integrity based on wetland monitoring data from Rocky Mountain National Park.

Discussion and Management Implications

Overall, it appears that the “how” behind the loss of integrity in Rocky Mountain National Park’s wetlands is largely a historical human disturbance story, overlain by the variance in the abundance of elk and moose, causing the loss of beaver and nearly eliminating once dominant tall willow communities. Low elevation portions of the park are surprisingly disturbed hydrologically for a large protected wilderness. Most of the remote, small wetlands in the park remain intact and are well protected by current park resource management strategies.

Protected landscapes, in general, can harbor important residual human disturbances that interact with ongoing natural processes in controlling ecosystem response. Thus, while many parks are more intact than surrounding landscapes, they are not by default in a “reference state.” This is even more likely given rapidly changing climate regimes. Moreover, in landscapes with strong historical and ongoing human disturbance gradients and no restored apex predators, this study suggests that wetland condition is not controlled by simple trophic cascades, but rather by multiple factors interacting in nonlinear ways. A more accurate model may be: wolf + hydrology (beaver) + human disturbance > elk > wetlands.

By exploring connections between human disturbance and wetland condition, ROMN scientists hope to increase understanding of wetlands in the park and to illustrate that monitoring data are often underutilized. Conventional approaches to statistical analysis are characteristically reductionist, seeking to isolate individual effects and/or describe net effects. However, the needs of science and society call for a move to more complex modeling of cause and effect. They also call for a capacity to drill down to place-based ecology. Long-term ecological monitoring, such as the work conducted by the Rocky Mountain Network, can inform place-based ecology by exploring the structure of systems in more detail. Structural equation modeling illustrates an approach to these aspirations that may have wide applicability in natural resource management.

About ROMN

The Rocky Mountain Network is one of 32 vital signs monitoring networks across the National Park Service. It monitors status and trends in upland vegetation and soils, wetlands, streams, alpine vegetation, and other systems at six parks throughout Montana and Colorado.