Components of Managed Grazing and Complexity of Conducting Grazing Studies

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James Bartolome's presentation emphasized methods for developing reliable knowledge about how rangeland and other systems work. To accomplish this he provided several examples of models utilized to develop reliable knowledge about range systems: descriptive models, ecosystem models, and predictive models. The world is very complex and developing reliable scientific knowledge is difficult, but critical. We can construct a hierarchy of reliability of knowledge about the world that proceeds from first description of things, then to understanding, then the ability to predict the consequences of actions, and finally an ability to control actions in order to produce favorable consequences. The progression of reliable knowledge from description, to understanding, to prediction, and finally control is very important for scientists and land managers who ideally are able to control things in a predictable manner. James cited the example of climate change to demonstrate how knowledge becomes progressively more complex and less reliable as it proceeds through the four levels with control being the ultimate test of understanding and reliability of knowledge.

There are two basic avenues for developing reliable scientific knowledge, experiments and observations. Experiments are problematic in that they need to be performed in a controlled environment utilizing simplified treatments. These circumstances do not reflect the complexity of the real world; experiments are also very difficult to replicate in order to gain the statistical credibility important in the scientific community, especially when researching complex ecosystems. Observational studies can be advantageous in that researchers are not required to control and isolate variables, but instead look at the big picture and take natural variation into account and analyze patterns that these complex systems demonstrate. However, observation has the disadvantage that, although the research can be replicated, researchers cannot easily control and predict the effects of all the important variables.

The first model that James presented was a descriptive model. Descriptive models constitute a way to simplify ecosystems and their changes over time in a way that can be very powerful and useful. Descriptive models can help guide the management of non-equilibrium type ecosystems in which there is a high degree of uncertainty regarding the consequences of management actions. James used hypothetical states and transitions in California valley grasslands as a good example of a descriptive ecosystem model pertinent to rangeland ecosystems. This model is comprised of three states and three transitions. State 1 is characterized by native perennial dominated pristine grassland that was then altered by Transition 1; the introduction of livestock beginning in 1769 and of exotic annuals, which changed the ecosystem to State 2 characterized by mixed perennials and exotic annuals, this State 2 ecosystem then underwent further change as a result of Transition 2; characterized by the elimination of native perennials due to cultivation, competition with exotic annuals, and overgrazing. State 3 resulted, an ecosystem dominated by exotic annuals. Transition 3 can reverse Transition 2 through better grazing management, however there as yet is no known reversal for Transition 1 that would return the ecosystem to its pristine state-one condition, therefore Transition 4 remains undefined. Descriptive models such as this are very useful because they describe a variety of complex ecosystem processes in a simplified manner. However, it is disappointing that, although descriptive models can be very powerful tools for testing and predicting ecosystem behavior, they have mainly been used as different ways to repeatedly describe the same old ecosystem condition models, thereby stopping short of realizing their full potential and not progressing beyond description to develop more powerful tools to predict ecosystem behavior. The bottom line that Dr. Bartolome emphasized was that describing the same things over and over in essentially the same way is not productive, and although description is fundamental to understanding these systems, researchers cannot simply stop there.

Ecosystem models both describe how a system works and represent an understanding of function within a system. One simple grassland ecosystem model consists of four functional groups: primary producers (grasses), primary consumers (herbivores), secondary consumers (carnivores), and decomposers (detritivores). The ecosystem model demonstrates that there are relationships among these functional groups, for example the transfer of energy and nutrients through processes such as herbivory. These processes have resulted in important evolutionary interactions over time such as the efficient transfer of energy from primary producers to primary consumers and eventually to secondary consumers. These processes and interactions are fundamental to ecosystem function and are the processes that range managers manage, whether to encourage biodiversity or to produce livestock.

Dr. Bartolome's example looks at two aspects of herbivory in an ecosystem model; components of grazing management and plant response to grazing. The process of herbivory is a dominant feature of grassland ecosystems whether managed or under natural conditions. The most important components of herbivory include: intensity, timing, frequency, distribution, and kind and class of animal. Selective grazing by livestock in conjunction with managing the components of herbivory should theoretically affect plant abundance. The grazing process is complex and has different interacting factors, however the effect on the system can be determined by examining plants and plant responses to grazing. For example, if the goal is to restore native perennials into California grassland systems utilizing herbivory as a tool, researchers must examine the potential natives and the problem exotic species and their differential responses to grazing. Dr. Bartolome explained that this methodology can be utilized to both encourage desirable species such as the native purple needlegrass (*Nassella pulchra*) and to discourage undesirable species such the exotic barbed goatgrass (*Aegilops triuncialis)*. The impact of grazing on grasslands from the plants' point of view can be understood by examining the characteristics of the species under consideration, the components of prescribed herbivory, and its effects on and relationship to each species. Dr. Bartolome cited examples of data collected pertaining to the relationship of components of grazing management to plant response to a particular grazing regiment for both desirable and undesirable species; these relationships and grazing effects are evident but have not been proven experimentally.

Predictive models pertaining to non-equilibrium systems represent the next level of reliable knowledge. State and transition models were devised because scientists realized that the older linear and equilibrium-based Clementian models for range condition did not always reliably predict management outcomes. Equilibrium systems are defined as systems in which undisturbed stable systems predominate. Equilibrium system structure is determined by biotic interactions such as competition, and populations are limited by the availability of resources. These systems also demonstrate density dependence in that as a particular species becomes more abundant its numbers tend to be regulated. Processes in equilibrium systems are primarily shaped by biotic interactions such as plant to plant and plant to animal. In contrast, non-equilibrium systems are characterized by biotic decoupling, in which organisms tend to behave independently of one another and are structured and influenced primarily by abiotic factors and limitations. Non-equilibrium systems demonstrate density independence as observed in the case of invasive species. Processes in these systems are dominated by environmental factors like weather. However, Dr. Bartolome emphasized that the real world reflects a continuum and that equilibrium and non-equilibrium processes are not mutually exclusive, for example non-equilibrium system characteristics can predominate at some scales and equilibrium system characteristics at others. Dr. Bartolome cited a publication titled “A state-transition approach to understanding nonequilibrium plant community dynamics of California grasslands” as a good example of utilizing state and transition models to understand community structure and its controls.

To develop a predictive non-equilibrium system model data gathered from a study initiated by H.F. Heady were utilized. The study consisted of nine sites with experimentally manipulated residual dry matter levels simulating heavy to moderate grazing intensity to examine the effect on community production and structure. The experiment included the vital attributes of control, replication, and good geographical distribution. Grazing is obviously more complicated than mulch management and this experiment was designed as a compromise to overcome experimental difficulties associated with utilizing livestock. To develop a predictive State-and-Transition model the results of this five-year experiment were utilized to determine which factors were most influential in controlling community structure. Traditional state and transition models have been designed based on prior knowledge of what the system looks like and how it should behave. However, Dr. Bartolome and his colleagues Randy Jackson and Barbara Allen-Diaz have taken a different view, that the models should instead be data-based and let the data dictate what the states and transitions in the model actually look like. The project yielded a very complicated model consisting of three distinct rangeland types with numerous states and transitions that reflect the complex nature of these range systems.

The results from the ST model development and Correlation and Regresssion Tree (CART) analysis demonstrated that site was the most important factor separating states. For example, native perennials increased with higher average rainfall; indicating that physical factors strongly influence states. Abiotic factors such as inter-annual variations in rainfall and temperature explained most transitions among states. Surprisingly, weather variables did not produce the anticipated “grass, legume, filaree” years or control changes in biomass, a disturbing result considering how annual grasslands are currently managed. Residual dry matter levels only explained a small number of the observed transitions, and then only at the driest sites. The results indicated that only 6-20% of the total variation in the system could be explained by the major treatment (RDM level) and the rest was attributed to abiotic factors. The data driven model created a series of questions that are hard to answer, but the bottom line is that system dynamics exhibit a strong site and time dependency at multiple scales and demonstrate many characteristics of non-equilibrium systems.

As previously discussed, the ability to effectively control and monitor system response is the ultimate test of the reliability of our knowledge. One good method for determining the reliability of our knowledge is to perform a meta-analysis of existing literature on a particular subject. Dr. Bartolome cited a review of 45 studies that examined the effects of fire and grazing on native plant species composition and showed highly variable results that were strongly influenced by site and annual weather. Therefore, weather had much more of an effect on native perennial grasses than did fire or grazing. A conclusion is that management effects are poorly predicted by the existing literature and therefore our ability to control systems based on the existing literature appears to be poor.

In conclusion, most rangelands are non-equilibrium type systems with limited response to biotic interactions including grazing. This does not mean that grazing is not important, but that it needs to be kept in context; the effects of grazing are constrained by physical characteristics. Rangeland systems exhibit small-scale spatial variability which, coupled with a site-time dependency, make predictions about system response to the environment and management very unpredictable under current levels of knowledge. Our ability to predict and control these systems is not particularly good at the present. Also, there are severe and largely intractable limitations on current experimental and observational approaches for predicting rangeland response to grazing management. Effective grazing management requires understanding of the components of herbivory and an ability to deal with complex interactions at multiple spatial and temporal scales. More experimental work on grazing effects and plant responses would be helpful, but the dominance of abiotic factors means that the crucial key for the manager is tracking responses with monitoring. Efficient methods for objectively evaluating and measuring grazing impacts on resources need more development; there is a prime need for better methods of monitoring grazing and management effects on these complex systems.