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Usable Science for Managing Animals and Rangeland Sustainability

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On the Ground:

- Animals are critical components of rangeland ecosystems, and domestic livestock provide an extremely important management tool on rangelands.
- Decades of research have yielded much valuable information to support sustainable and effective grazing management, but increased complexity resulting in part from expanding environmental, economic, and societal pressures demands future investments in usable science focused on rangeland animals.
- Three priorities for usable science are recommended:
  - Proactive drought planning
  - Better matching livestock production systems to rangeland resources
  - Comprehensive synthesis of and effective communication concerning environmental impacts (positive, negative, and neutral) of livestock on rangelands.

Keywords: research priorities, applied, large ungulates.

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Rangeland animal agriculture has long been a part of the human experience. Nomadic pastoral societies such as the Maasai, Bedouins, and Mongols have existed for centuries. For these people, livestock are not a quaint curiosity or a lifestyle choice; their animals are their life. Similarly, in North America, groups such as the Seminole and Navajo adopted herding after European introduction of livestock. Today, the culture and heritage of the American west largely revolve around livestock production.[1] Although cowgirls and cowboys, shepherds, and herders are often romanticized in music, movies, and literature, not everyone thinks livestock production is an appropriate use of rangelands. For instance, the Center for Biological Diversity's Grazing webpage states:

The ecological costs of livestock grazing exceed that of any other western land use. In the arid Southwest, livestock grazing is the most widespread cause of species endangerment. By destroying vegetation, damaging wildlife habitats and disrupting natural processes, livestock grazing wreaks ecological havoc on riparian areas, rivers, deserts, grasslands and forests alike—causing significant harm to species and the ecosystems on which they depend.[2]

Contrast the preceding quote with the following excerpt from the Environmental Protection Agency's Ag 101 webpage:

Beef cattle production is a strong animal industry within the United States and throughout the world. Since beef cattle can graze forages in the open range and pasturelands, they serve a unique role in providing high quality protein for human consumption from byproducts and forage sources that humans and non-ruminant animals do not consume. Considerable land in the U.S. and the world that will not support intensive crop production, can often times sustain grasses and forages that provide conservation of the land, and produce feeds that cattle can utilize.[3]

Importance of Animals on and to Rangelands

The fact that there is such a dichotomy of perception, opinion, and information on the importance of animals on and to rangelands simply reinforces the need for objective "usable science" to inform rangeland animal production and management. Large wild and domestic ungulate herbivores are so important and closely linked to rangelands that the definition of rangeland accepted jointly by the International Rangeland Congress and the International Grassland Congress specifies lands that "are grazed or have the potential to be grazed," and are "a natural ecosystem for the production of grazing livestock and wildlife."[4] In fact, for many people, it is through animals that any awareness or understanding of rangelands exists. These lands are where the buffalo roam, where the deer and the antelope play.

In addition to providing food, water, cover, and space for wild and domestic herbivores, these unique and diverse lands provide a wide variety of ecosystem goods and services. Rangelands are extensively managed lands that cover approximately half of the land area on the planet[5,6] and are dominated by plants and plant communities that provide food and cover for many animals, including wild and domestic herbivores. Rangeland herbivores, especially ruminants, are ideally suited to rangeland habitats owing to their unique ability to convert plant biomass to animal biomass and to at least survive on a relatively low-quality diet.[7] This important fact is one, but not the only, reason that herbivores are important to humans. They are able to convert plant biomass that is inedible to humans into food and fiber that is at least usable by, and perhaps essential to, humans[8]: For example, vitamins and minerals from red meat can help improve cognitive abilities and stave off immune-deficiency.[9] Although often maligned for methane production, overgrazing, and water consumption,[10] domestic livestock also provide essential environmental contributions, products, and economic opportunities. Livestock provide meat, milk, fiber, and a variety of byproducts. In some cases livestock provide fuel, building materials, traction, and transportation. Livestock are the only source of property for the underprivileged in some cultures and may serve as the "rural bank."[11] Domestication provides opportunities to manage tractable herbivores of different body sizes to maintain desired rangeland conditions or improve them where necessary.

It is widely recognized that poorly managed livestock grazing can cause ecosystem degradation. But it is important to remember words of wisdom from Aldo Leopold, who stated that the same forces that cause ecosystem degradation—the cow, plow, ax, match, and gun—can be used to restore them. The keys to this approach, as applied to how livestock grazing management affects rangelands, are 1) a thorough appreciation for the limitless number of ways livestock grazing can be managed, 2) an improved understanding of how different approaches to livestock grazing management affect the structure and function of rangelands, and 3) a comprehensive understanding of how management affects the well-being and performance of rangeland livestock and wildlife.

Unfortunately, livestock grazing is often viewed as an "on/off switch." Examples of this gross oversimplification of a very complex ecological process include simple comparisons of grazed vs. ungrazed areas. Furthermore, and partially driven by the importance of detecting differences between or among treatments in order to publish research results, grazed areas used in many studies often do not represent what most would consider well-managed livestock grazing. Rather, exclosures or areas left ungrazed for some period of time are often compared to improperly managed livestock grazing, and the differences detected are discussed as the "effects of grazing." Knowing the history of the exclosure/ungrazed area is also crucial to understanding their comparison to the "grazed" treatments. For example, it is not uncommon for livestock exclosures to represent conditions expected after some period of protection from earlier poorly managed livestock grazing. Other livestock exclosures might represent protection from a long period of well-managed livestock grazing, and still others might represent areas that have never been grazed by livestock. These provide very different interpretations when compared with whatever livestock grazing management is being practiced outside of the exclosure. These and other shortcomings make it no surprise that it is difficult (at best) to find reliable generalizations about the "effects of grazing" in the literature. For example, the effects of heavy livestock grazing on plant species richness can be anywhere from slightly positive to negligible or distinctly negative[12] for a variety of reasons.[13–16]

The Need for Usable Science

Rangelands are increasingly being conceptualized as coupled social-ecological systems,[17] and it is widely recognized that more and better information is needed to inform grazing management. Although much is known about the effects of herbivory on plants and plant communities,[18] Reid et al.[17] provide many great examples of how our understanding of rangelands is evolving and indicate that many assumptions about how grazing affects vegetation still linger. To better inform grazing management, it seems quite clear that adaptive management and some combination of case studies and experimental research is necessary.[18–20] Another way of thinking about these research needs is conceptualizing them as usable science, which incorporates the needs of the users throughout the process. Worldwide, much arable land is being converted to nonagricultural uses, open space is declining, and the population is expected to reach 9 billion by 2050. We need usable science focused on animals and rangelands to enable more effective and more efficient management of rangeland resources and the animals they support. In fact, because of the tractability of domestic livestock along with the many and varied interactions among large ungulate herbivores and rangelands, domestic livestock provide an extremely important management tool for rangelands, particularly in the face of climate change.[21]

From an animal production standpoint, what exactly is usable science? The following examples complement the definition offered earlier.

Louis Pasteur and George Washington Carver conducted usable science that uncovered new uses of animal products and ways to use by-products from other agricultural or industrial processes in the care and feeding of animals. The following excerpt from Louis Pasteur's biography on Encyclopedia.com is particularly interesting:

> *"To an extent, Pasteur's interest in practical problems evolved naturally from his basic research, especially that on fermentation, for the biological theory of fermentation contained obvious implications for industry."*[22]

Carver is often noted for developing many uses for agricultural products such as peanuts and sweet potatoes. Both of these individuals put knowledge into the hands of people; this is the essence of usable science. Similarly, many

researchers are focusing on producing more efficient animals, reducing methane, and using less water. Livestock are one of the many tools needed to achieve stewardship and sustainability of rangelands, especially as rangeland and animal managers adapt to changing climates.[21] Usable science can address practical issues concerning the interaction of rangeland and animal management, and good examples of usable science exist. For instance, targeted livestock grazing reduces the risk of catastrophic wildfire and provides improved opportunities to manage cheatgrass.[23,24] Future usable science could further develop these ideas or pursue the role of targeted grazing to help reduce fuel for wildfires along the wildland–urban interface or to help manage other unwanted or invasive plant species. Crawford et al.[25] reviewed studies that demonstrated how livestock grazing could be managed to improve the quality and accessibility of forbs for species such as sage grouse, and this approach could be expanded for other wildlife. Well-managed livestock grazing is compatible with maintaining properly functioning riparian conditions, improving riparian conditions where necessary,[26] and supporting biodiversity.[27] In addition to better understanding the effect of livestock on targeted ecosystems, studies informing animal handling and management within the societal perceptions of these practices will be equally useful.

The idea of conducting rangeland animal experiments to improve management is not a new development. As early as 1902, Bentley[28] conducted collaborative rangeland grazing experiments in central Texas designed to "invite attention to the methods pursued and the actual results attained that all interested may take advantage of the experience acquired in the work" as a response to overgrazing and drought conditions at the time. If it was important to create knowledge that informs management of natural resources and grazing animal agriculture on rangelands over 100 years ago, how much more important is that now?

What Was Done

The Process

The animal working group was composed of the authors of this paper. As described in detail by Maczko et al. (*this issue*), the animal working group was part of a larger group of rangeland professionals that met as part of the Workshop on Future Directions for Usable Science for Rangeland Sustainability to develop a broad research agenda intended to address the need for usable science pertaining to rangelands. After hearing perspectives from constituent groups such as producers, nongovernmental organizations, and funding agencies, the large group broke into smaller working groups. The first assigned task was to brainstorm a list of issues that each working group felt were most important issues in their subject area. The animal working group's 36 issues were combined with those of the other groups, for a total of 142 issues to be evaluated and ranked by all participants in the meeting. The top three animal issues emerging from this process were: 1) proactive drought planning (No. 2 priority of 142), 2) better matching production systems to the resource base (No. 15 priority of 142), and 3) comprehensive synthesis and effective communication of livestock impacts on rangelands (No. 55 priority of 142). The animal working group then reconvened to discuss the prioritized issues in more detail and identify research questions. After presentation of these ideas, the entire group had an opportunity to comment and provide feedback. The outcomes of our process are described below.

Outcomes

Issue 1: proactive drought planning

The selection of drought as a priority issue was no surprise. Drought, weather, or climate were common themes directly or indirectly in many of the issues articulated. In fact, the top-rated issue by all participants was "understanding and managing for variability (climate, drought, fire)," submitted by the socio-economic working group. The animal group felt that proactive planning was important for rangeland animal producers/managers in order to facilitate science-based collaborative decision making, improve preparedness and flexibility, and ensure both economic and ecological sustainability. This topic has broad applicability and is important to livestock producers, land managers, rural communities, and, ultimately, consumers.

At a scale larger than the agricultural enterprise, this process should be inclusive, involving livestock producers, natural resource managers, extension agents, suppliers/retailers, policy makers, and local governments. Policy makers and local governments (counties and conservation districts) are particularly important to fully support the managers making decisions on the ground. All involved would benefit from this process. It is likely that in addition to land and livestock owners and managers, state, regional, and local technical advisors; producer organizations; natural resource user and interest groups; government agencies; and local communities would all support and advocate for usable science to support proactive drought planning. User-friendly and easily accessible tools and knowledge to develop site specific drought management plans are needed. The kinds of research activities that might best address the issue of proactive drought planning include efforts that facilitate improved drought prediction at scales that are more site specific than those currently available. Case studies that demonstrate successful management efforts and include economics and collection and analysis of qualitative data and information would also be useful.

Research question: What are the appropriate rangeland management decisions that make land more drought resistant and what are reliable drought and weather variation indicators, effective triggers, and management actions before, during, and after drought that will help optimize management of sustainable working lands?

Research projects to address this question could include long-term case studies of successful operations in drought-prone areas. Observation of within-year phenology and its correlation to the amount, timing, and distribution of

precipitation, or meta-analyses of plant–animal–soil responses to management practices (e.g., those being conducted in the USDA Natural Resource Conservation Service's Conservation Effects Assessment Program[i]) might also be included.

Issue 2: matching production and management systems to the resource

Optimization of livestock production is likely more important than maximization. Sustainable use of water, land, and animals is important to all stakeholders, private and public. The words that come to mind here are stewardship and common sense. Browsing animals such as goats may be better suited to steep, sloped shrublands than cattle. Cattle may be a better match than sheep on grasslands with a significant predator population. Sheep may be the best option for targeted grazing along a wildland–urban interface. Breeds or classes with high maintenance requirements might not be well suited for extensive arid environments. Livestock that have genotypes with high growth potential will likely make better use of productive environments with abundant and high quality forages than genotypes with low growth potential. In less productive and arid environments, livestock with lower growth potential may be better adapted and more efficient than animals with genotypes selected for rapid growth.

Research questions:

1) What are the major resource characteristics that drive production system options?
2) How can producers properly match animals (species, breed, class, and nutrition) and production systems to the resource base?
3) What are the benefits of incorporating stocking rate flexibility into grazing management; how is this best implemented, and how are the benefits most effectively demonstrated?
4) How can producers best exploit existing and expanding knowledge of animal behavior, distribution, and stockmanship to achieve rangeland management and production goals?

Addressing these questions will likely require a combination of controlled manipulative experiments, descriptive studies, geospatial meta-analyses, quality controlled database analyses, and case studies/descriptions. Furthermore, our group agreed that it is extremely important that the information obtained from pursuing the preceding questions be made widely available through a clearing house or portal for successful approaches by region and characteristics of the grazing land resource. Trade magazines, social media, and user–user communications would be very effective for increasing awareness of the information obtained to answer these questions and the clearing houses where people can find the information.

[i] To learn more about the USDA Natural Resources Conservation Service Conservation Effects Assessment Program see http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/.

Worldwide, livestock production is recognized as an essential industry, but also one that can have negative impacts on the environment,[29] although the most commonly cited contributions of the livestock industry to greenhouse gas production have been called into serious question.[30] Still, and as might be expected, one significant opportunity to help mitigate the effects of climate change is through improved grazing management.[29] There are tremendous opportunities to improve grazing management through efforts that better match livestock production systems to the land resources being used.

Matching animals to the resource is only part of this priority and has received more attention than other aspects of production systems. Most textbooks on rangeland management include important information about animal selection (e.g., see Heitschmidt and Taylor[31] and Holechek et al.[32]), but there are opportunities to expand this knowledge base with further study of kinds, classes, and breeds of livestock and their interactions with the environment. Also, information about and appreciation for how animal behavior relates to grazing management has expanded,[20,33,34] and there are countless opportunities to further develop knowledge about how animal behavior influences the selection and management of animals for a particular location and operation.

Beyond matching the animal to the resource, there are opportunities to further develop flexibility in other aspects of production systems. One component of production systems that has received some attention is calving date. Various calving dates have been evaluated with respect to their effects on feed costs,[35] cow and calf performance,[36] and profitability.[37] There are likely many other considerations regarding calving dates and how well production systems match the resource. For example, might calving date influence terrain use by cows? Further research on calving dates is warranted as is research on many other aspects of production systems.

Issue 3: comprehensive synthesis of and effective communication concerning environmental impacts of livestock on rangelands

The effects of livestock grazing on rangelands may be positive, negative, or neutral, depending on a great many factors. However, these impacts are often expressed as gross generalities, and most agree that in a general sense, the effects of livestock grazing on various components of rangelands and pasturelands are understood fairly well.[38,39] At the same time, and almost without fail, such statements are followed by recommendations for future research to improve our understanding of the complex ecological process known as herbivory. Perhaps the broad generalizations that came from past research are no longer sufficient and managers now require more detailed and more specific information. Reid et al.[17] recently suggested that our understanding of rangelands continues to evolve and there are still assumptions regarding the effects of herbivory that need to be addressed. Other indications that more detailed and site-specific information is important for livestock grazing management include recommendations to incorporate adaptive management,[19,20] and the importance of moving beyond more traditional

approaches.[20] Although there is clearly a need for additional research on how livestock grazing affects rangelands, the animal working group discussion identified an intriguing opportunity to search for and synthesize potentially valuable data and information that may not have found its way to the peer reviewed literature.

Society's view of domestic livestock grazing seems to be almost entirely driven by information and data about its negative impacts. There is a very good chance that at some level this has resulted from a widespread awareness of historically unmanaged or poorly managed livestock grazing that occurred in the late 1800s and early 1900s, especially in the western United States. In addition to this, some members of the animal working group suggested that studies that failed to detect statistically significant effects of livestock grazing may not be published in scientific journals and so are "lost" or not accessible. The same may be true for studies that documented positive effects of livestock grazing, although probably to a lesser degree than studies finding no effect. This issue is important to land and livestock managers because studies that were designed and implemented well, yet detected "no effect" of livestock grazing on various components of rangeland systems, may provide valuable information to managers. Despite the potential value of such contributions, it is far more difficult to publish papers describing studies that found "no difference" or "no treatment effect(s)" than those that report differences between or among treatments. So it makes sense that many of these results have not made it into the mainstream scientific literature. This may also influence researchers to plan and conduct studies on livestock grazing treatments that are most likely to produce differences (i.e., ungrazed vs. heavily grazed). Well-designed and carefully implemented studies that found no effects of livestock grazing, perhaps by including or focusing on well-managed, livestock grazing can provide important information about how to maintain existing desired conditions or how livestock grazing might be compatible with other land uses and managing for other ecosystem services. This is especially important given that rangeland conditions in the U.S. are better now than they have been since the late 19th century and are improving.[40]

Livestock producers, industry organizations, agencies, and conservation organizations are expected to advocate for a comprehensive synthesis of the positive, neutral, and negative effects of livestock grazing on rangelands. There is a need to better understand what research has been done to document the full spectrum of impacts and fully understand how to prevent negative impacts and promote positive or neutral impacts. This type of synthesis would also identify gaps in knowledge and future research opportunities.

Research Question: Is the full range of livestock effects on rangelands and associated natural resources (positive, negative, and neutral) adequately represented in the primary, peer-reviewed literature and communicated to society?

This question would first involve a thorough review of the primary literature on the effects of livestock grazing on rangelands. In addition, an effort should be made to thoroughly review government reports, theses, dissertations, and "gray literature." Meta-analyses would likely also be useful at this stage. Information obtained from the "gray literature" and meta-analyses should be evaluated, vetted through a panel of experts, and then compared to the review of the primary literature. Finally, a synthesis of the findings should be produced and shared with organizations and institutions interested in communicating them to individuals and groups who are, or should be, interested.

What Next?

Our intent in this article is to generate support for usable science focused on animals and sustainable rangelands. The rangeland animal working group was dominated by people who are considered "end users" of information generated through research, which is arguably the most important component of usable science. In the short term, members of the group plan to pursue funding to begin addressing certain components of the research questions presented in this article. Over the longer term, consideration and further discussion of priority issues and needs for usable science (those presented here and additional ones) are strongly encouraged, with the ultimate desired outcome being funding to support needed research.

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